The Concept of Levels of Organization in the Biological Sciences

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Dedicated in friendship to Jan and Magga

“He who has suffer'd you to impose on him knows you.”

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Chapter One: The Intuitive Appeal and Ubiquity of 'Levels of Organization'

1.1 Introduction

References to the scientific concept of *levels of organization*[1] are ubiquitous in both philosophy and the biological sciences. The image of the world that the concept evokes posits a vertically stratified structure in which the entities and processes of nature are connected together into a graduated continuity: The things found at one horizontal slice of reality somehow 'make up' or 'are continuous with' the things found at the next slice, and so on. This continuity is often depicted as extending from the basic elementary entities and processes of physics all the way through the biosphere. This image in its complete or abridged form is present in the vast majority textbooks of the biological sciences, introductory as well as advanced, and serves to summarize the basic construal of the natural world whose particular workings scientists seek to uncover by explanation (see also Lobo 2008). Philosophers in turn readily cite this image of the world as a self-evident observation in which to cast some of the biggest questions of our time. Questions concerning the reducibility of natural phenomena to lower-levels of organization (Wimsatt 1976; Burian and Stout 1995; Sarkar 1992; 1998, esp. 53-60; Craver 2007a, Ch. 7; Bechtel 2008, 143-48; Brigandt and Love 2010), whether 'emergent' phenomena exist (McLaughlin 1992; Emmeche et al. 1997; Kim 1999; Stephan 1999a; Korn 2005; Theurer 2014), and the nature of causation outside of physics (Malaterre 2011; Love 2012; Ellis 2012; Hoffmann-Kolss 2014; Franklin-Hall *forthcoming*) are three well-established areas of philosophical discussion that make heavy use of the concept of levels of organization.

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[1] In what follows, the term <levels of organization> refers to things (levels) posited by a certain claim, even if their existence is tentative or hypothetical. When the term <levels> appears without qualifier in the text (e.g., *of organization* or *of reality*), it will refer to <levels *of organization*> unless otherwise noted in the text. The term <'levels of organization'> (with scare quotes) refers to *the concept of* levels of organization as a theoretical notion discussed by philosophers and scientists.

Despite this ubiquity, the usage of the concept of levels of organization in science *and* philosophy is governed mostly by its intuitive appeal, whose justification is often taken as self-evident. As such, the term's precise character and significance is rarely developed in detail. The philosopher William Wimsatt, one of the pioneering scholars that has devoted serious effort to analyzing the concept of levels, observes this as well, saying: “The notion of a compositional level of organization is presupposed but left unanalyzed by virtually all extant analyses of inter-level reduction and emergence” (1994 [2007], 203). Talk of levels of organization in the philosophical literature is quickly replaced or used interchangeably with a range of other distinct ideas. For instance, 'levels' is used as a shorthand reference to, e.g., a systematic dependence between certain properties related by supervenience or realization (respectively, Kim 1998, 1999; Aizawa and Gillet 2009), an epistemic ordering of scientific knowledge or disciplines (Oppenheim and Putnam 1958; Waters 2010), as an ontological thesis about the structure of the world (Oppenheim and Putnam 1958; McLaughlin 1992, 50; Churchland and Sejnowski 1992, 9, 15; Wimsatt 1994[2007], 201-202), or as a combination of several uses (Oppenheim and Putnam 1958; Mayr 1982, 65; Craver 2007a, 170-171). The looseness with which ‘levels’ are used has already called for some to eliminate the term from science (Guttman 1976), and at least minimize its usage in philosophy (Potochnik and McGill 2012; Eronen 2013).

More problematically, philosophers who refer to levels of organization often claim to be simply importing the term as it is used in science (e.g., Kim 2002, 2; Rueger and McGill 2010, 379; Potochnik and McGill 2012, 120). However, the number of sustained analyses dedicated to analyzing how the concept of levels of organization is used in science (and particularly biology) is vanishingly small. Apart from a small number of survey articles detailing a number of issues arising from the usage of 'levels of organization' (Wimsatt 1994[2007]; Kim 2002; Craver 2007a, ch. 5), the concept itself has received almost no direct attention in this regard. This is beginning to change.[2] The philosopher Markus I. Eronen

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[2] Indeed, the speed at which this is changing continues to gain momentum. Since the submission of this dissertation in summer 2014, a number of articles have been published that address 'levels of organization' in a manner parallel to the analysis here. In particular, David M. Kaplan has published a recent (2015) paper that calls specific attention to the lack of scholarly analysis on the concept of levels *of organization* (rather than other cognates of the term 'levels'). Kaplan, however, also goes further than other mere calls for attention by providing a useful summary of the concept in a number of explanatory accounts in philosophy, including the Hempel and Oppenheim's D-N account, Oppenheim and Putnam's account of microreduction,

(2013; 2014) has recently published two insightful papers on the levels concept, and Alan Love (2012), along with Ingo Brigandt (Brigandt and Love 2012), also offer an interesting analysis of the scientific use of ‘levels’ in the context of questions about causation and pluralistic explanation, respectively. Other authors, including those mentioned above, mentioned above (Rueger and McGivern 2010; Potochnik and McGill 2012), also point out the lack of such sustained analysis of 'levels' as an impetus for their respective treatments of the concept. Nonetheless the character and significance of the levels concept remains largely an open question.

1.2 Analyzing 'Levels of Organization' in Biological Science

The task taken up in this dissertation will not be to take a position in any one of the particular debates in which levels play a role (e.g., reduction, emergence, and causation). Instead, this dissertation will analyze the concept of levels as it is used in the biological sciences. More specifically, this endeavor will entail explicating[3] the *character* and *significance* of the concept of 'levels of organization' for explanation in the biological sciences. By ‘character’ is meant, very roughly, *what* scientists take to the term ‘levels’ to mean. The two terms ‘character’ and ‘meaning’ are not interchangeable, however. ‘Meaning’ is a more specialized term in philosophy, and is traditionally used to express the semantic content of a word or

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mechanistic explanation, and even contrasting the levels concept with Marr's “levels of analysis” framework. Likewise, Carl Craver has in a new (2015) paper also revisited the levels concept, and builds on his (2007a, Ch.5) analysis of levels by clarifying further his 'defining questions' approach to understanding levels (ibid.; see Chapter 2 for more details), and contextualizing his own mechanistic conception of levels among the many cognates of the levels concept. These two papers come as a particular surprise, given the lack of such papers during the duration of this dissertation's writing, and indeed given the silence on the issue of the levels concept in philosophy generally. Another area of philosophy where the levels concept has continued to 'run rampant' since the submission of this dissertation is the discussion of issues pertaining to non-fundamental causation (particularly top-down causation, higher-level causation, and causation in biology generally). Here, two recent papers (i.e. Hoffmann-Kolss 2014; Franklin-Hall 2014) have thematized levels of organization, albeit indirectly, in their arguments against attempts to articulate higher-level causation (especially in biology). The contributions offered in the analysis of this dissertation is proving to be, if nothing else, a timely choice in topic.

[3] The term “explicate” here is not meant to evoke any commitment to certain technical uses of the word that are sometimes used in philosophy (such as in the sense developed by Rudolf Carnap (1950, 3). Rather, what is meant by the term here is closer to the normal English use of the word, i.e. to make the meaning of the concept clearer. What this precisely entails will be explained presently.

concept in relation to a thing to which that word or concept refers. Instead, by seeking to understanding the character of the levels concept, the analysis that will be offered here will strive to uncover specific features of semantic content attributed by scientists to the concept as a tool used to aid in explaining phenomena. Concurrently, by 'significance' is meant, roughly, *why* the concept of levels is used. The ‘significance’ of the levels concept encompasses the purposes that are attributed to the concept by scientists who use the term to apply certain ideas in working to explain biological phenomena.

The analysis here will show that the concept of ‘levels of organization’ in the biological exhibits a *fragmentary* character across different instances of scientific usage. This means that though the concept is capable of clarity precision in given instances, it displays a modest semantic incommensurability across these given instances, which needs to be addressed.[4] That is, there are differences in the characterizations of what levels are in given instances such that no singular, common standard is available to compare and contrast all instances of usage of the levels concept. Instead, the semantic content that comprises the character of the levels concept in given instances is determined in a *contextualized* way, i.e., from the perspective of the researcher using the levels concept (cf. McClamrock 1991). This perspective encompasses a point of view from within a scientific discipline in which that researcher has been trained or is making their particular claim involving the levels concept (see Section 1.2.2 and Chapter 4 for more details on how this is specified).

This contextualized approach to determining the content of a scientific concept stands in contrast to another attitude concerning how to understand the character of a concept, i.e. a *comprehensive* approach. A comprehensive approach entails searching for an exhaustive, singular conception of that concept (here ‘levels’) for all instances of its usage. This often manifests itself in the search for the *essence* of the concept in question. The ‘essence’ of a concept refers to a feature or set of features that are taken to fundamentally or necessarily designate what that concept is (Robertson and Atkins 2013). The distinction between

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[4] See Chapter 4 for a closer specification of what is meant by “incommensurability” between usages of the levels concept. Here 'incommensurability' will be understood in the more mundane sense of “local incommensurability” (Kuhn 1982, 670-71), rather than the stronger sense of the term that imply, e.g., mutual intranslatability of impossibility of ever comparing the content of respective claims.

contextualized and comprehensive approaches to conceptualizing levels (and particularly its character) will be important for the analysis offered here. In particular, two other philosophical accounts of ‘levels of organization’ in scientific usage, which will be central to developing the main theses of this dissertation, represent polarized positions on how to approach analyzing the character of the levels concept (see Chapter 2). One, the layer-cake account, posits a comprehensive conception of ‘levels’, and represents the classical manner in which philosophers typically explicate the levels concept. Another, the mechanistic account, posits a radically contextualized conception of ‘levels’ that rejects *any* general import for ‘levels’ can be extrapolated from single instances of usage. The contextualized (but not radically so) ‘fragmentary’ account that will be developed and defended here is someplace in between these two accounts.

At the same time, the analysis here will also show that the levels concept exhibits a minimally unified significance across the instances of its usage. More specifically, it will be argued that another feature of concept usage of science, that concept’s *epistemic goal*, allows for a more unified (but not comprehensively so) conception of levels to be developed. This aspect of importance attached to a concept's 'epistemic goal' has recently been developed by Ingo Brigandt (2010; 2012) specifically for the purpose of analyzing concepts in the biological sciences that appear to display unavoidable, modestly, i.e. “local” incommensurable variation in their semantic content (see especially Chapter 4). An epistemic goal comprises a set of epistemic values, which motivate the usage of the concept in question. Unlike other elements that comprise a concept’s character, an epistemic goal is not a component of a concept’s semantic *content*, but rather a feature of how a concept is *used* by scientists. The epistemic goal motivating the use of the levels concept is to *structure explanatory problems* that biologists engage in their research. Explanatory problems include issues that belong to constructing explanations for biological phenomenon. These issues may comprise questions concerning, e.g., what is required for an *adequate* explanation for the respective phenomenon, or more subtle issues regarding the basic characterization of the phenomenon as something for which an explanation is sought. The particular manner in which levels can aid in structuring these problems, and hence contribute to their solutions, is dependent on the specific way that ‘levels’ are used in that instance of usage. These instances of usage will be contextualized in claims involving levels, or ‘level claims’, which will be introduced in the next section, and discussed in depth in the later chapters of this dissertation.

1.2.1 Level Claims

Identifying the kinds of claims in which ‘levels’ appear is important, as they serve as a sort of token markers expressing a more overarching understanding of levels. There are two general types of claims in which levels typically appear, namely descriptive and hypothetical claims. Both of these types of claims are closely connected to the significance of the levels concept in biology, i.e. the epistemic goal motivating the use of the levels concept. First, ‘levels’ can be used as a descriptive term made in a *descriptive claim* about a particular system. In this capacity 'levels of organization' attributes organizational features to a system for the purpose of characterizing *what a particular system is*. These types of level-claims correspond to what William Wimsatt (1974[2007], ch. 9) calls k-decompositions. According to Wimsatt, using ‘levels’ is closely tied to dealing with the complexity that a biological phenomenon can exhibit, which can interfere with scientific attempts to successfully explain that phenomenon. The use of ‘levels’ is for this reason is often built into the way that scientists basically describe, and basically approach describing, that phenomenon (cf. Burian and Trout 1995). For instance, take the visual system of the fruit fly (see Figure 1.1). A number of distinct biological disciplines may be involved in detailing how the insect visual system works, e.g., (neuro-) physiology, (neuro-) anatomy, electrophysiology, and even evolutionary biology. These *level-bound disciplinary perspectives* many characterize any given biological system in a number of non-overlapping ways (cf. Winther 2011, particularly Winther's notion of “partitioning”). Furthermore, each of these disciplinary perspectives may even be interested in explaining the same phenomena, such as how sensory information is extracted from the external world by the nervous system, how different cells process specific types of information, and how the visual system mediates flight behavior of insects. However, each of these disciplines will possess very different sets of criteria for how to differentiate the system in question into a set of relevant structures believed to be relevant for explaining the respective phenomenon (Lewontin and Levins 2007, 151-2; Love 2008; Winther 2011, 401). Using these various list of criteria, different descriptions will be offered for any given biological system, like the insect visual system, each of which corresponds to one or another disciplinary perspective (cf. Lewontin et al. 1984, 276-7).

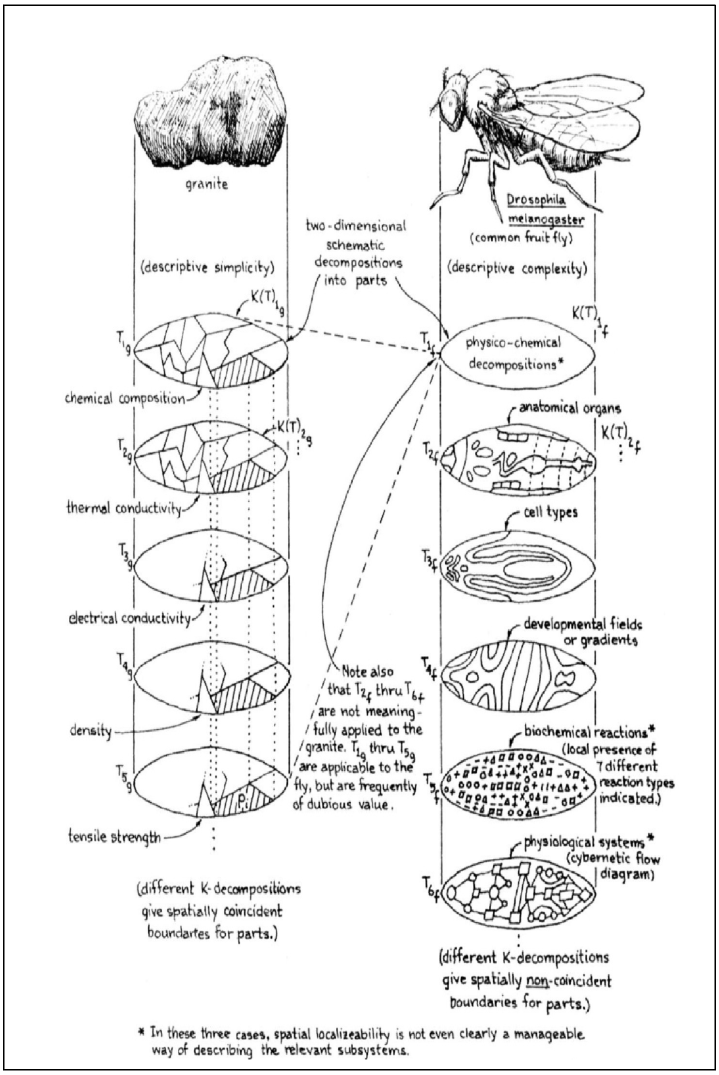

Figure 1.1 Different overlapping k-decompositions of a complex biological system. A number of disciplinary perspectives $(T)_n$ each view one and the same system (here the visual system of the fruit fly), and construct their own description of the system (k-decompositions, or $K(T)_n$), resulting in multiple ways of differentiating that system into parts relevant for the respective perspective. Figure taken from Wimsatt (1974[2007]).

Wimsatt characterizes this state of affairs in biology concerning such "descriptional complexity" as a "conceptual morass":

> "In biology, at least, the picture is further complicated by another factor – that different theoretical perspectives are not nearly as well individuated as in the physical sciences. Thus, anatomical, physiological, developmental, and biochemical criteria, not to mention paleontological information and inferences of phylogenetic relations and homologies, all interact with criteria of evolutionary significance in the analysis of organisms into functional systems and subsystems. This borrowing of criteria for individuation of parts from different and diverse theoretical perspectives is one of the factors which make functional organization in general and biology in particular such a conceptual morass at times" (Wimsatt 1974, 72).

Roughly, this means that applying the term 'levels of organization' will comprise a package of both epistemic and ontological information nested in a disciplinary perspective. What exactly belongs to this 'package' is determined in a contextual manner. This information results, firstly and most importantly, in a description of the system that differentiates that system into its partitioned units. However, since these claims are made from the perspective of a particular scientific discipline, the description that is offered is also accompanied, often implicitly, by both (1) a set of criteria that specifies why the system is differentiated in that way, and (2) a set of methods and techniques that directly inform the description of the system that is given. Multiple k-decompositions are often available for certain biological systems if they are investigated from different disciplinary perspectives. These different level-claims may or may not result in a similar rendering of the structure and significance of a system for a given case of explanation in science, and ascertaining the similarities and differences between these descriptions is often an issue of substantial discussion in historical biological research (see especially Chapter 5).

Second, 'levels' can be used as an operationalized term within a *hypothetical claim* that postulates a more effective means of searching for a solution to a given explanatory problem. The term 'levels' is operationalized in these cases by an implicit descriptive k-decomposition and by a normative prescription to direct research efforts towards the content of the k-decomposition, i.e. *how a system should be studied*. The "hypothetical" status of these claims captures the tentative nature of these kinds of level-claims as suggestions, rather than concretely explicative claim-statements, about a phenomenon for which an explanation is being sought. Another way to summarize this form of level claims is to consider these claims as *heuristic procedures* that designate reasoning patterns that scientists use to orient scientific investigation from one discipline to one another, and to nature as well. These types of level-claims correspond to what Lindley Darden (1991, 253) calls “strategies” in scientific reasoning.

> “If phenomena to be explained can be put into a hierarchy, a way of producing new ideas (in order to explain the phenomena) is to form hypotheses about the behavior of entities and processes at a different level of organization. If other fields have studied that level, then the interlevel relation may also be an interfield relation. Thus,...using interrelations...includes using interlevel relation[s] when a body of knowledge exists at the appropriate level. If no other appropriate level is known to exist, however, then the strategy “move to another level” is less like the interrelations strategy; the latter postulates a relation between *known* information. Phenomena may point to the existence of an as yet unexplored level, often at a lower level of organization” (ibid.).

In this capacity, 'levels of organization' fulfill two roles for scientific reasoning used to structure explanatory problems: (1) they represent sources of insight to which scientists are directed in their investigation of a particular problem (cf. ibid., 9), and (2) they offer an opportunity to change the change or modify the problem that is being asked. Understanding what these roles mean in a concrete case will depend on the way that levels are understood in that case, but both will exploit the “package deal” of epistemic and ontological information (described above) that the concept of levels offers. In this way, levels can offer insight into problems by postulating, e.g., new structures and investigative techniques with which to investigate a phenomenon. Similarly, by moving “up” or “down” a level, this can offer a straightforward means of generalizing or specializing the scope of the problem it treats, depending on what is deemed appropriate for that case (cf. ibid., 4.).

Both of these kinds of claims, and their importance for understanding the significance of the levels concept, will be discussed in depth in the final two chapters of this dissertation.

1.2.2 Wimsatt's Characterization of Levels

Grasping the character and significance of 'levels of organization' in science is a daunting task due to the wide variation it exhibits across its instances of usage (see especially Section 1.4; Chapter 4). One approach, pursued by Carl Craver, analyzes the levels concept by answering three "defining questions" that together articulate the basic meaning 'level' in a given instance (Craver 2007a, 171-172)[5]. The first defining question pertains to the types of things make up levels in the first place. The second defining question concerns specifying the inter-level relation by which things at putatively different levels are related to one another. The third defining question concerns specifying how a particular item is placed at the same level. Though Craver's defining questions are useful for clarifying the meaning of levels *in a particular instance*, it leaves completely open the question concerning what the character and significance of levels in science generally.[6]

A more faithful attempt to characterize 'levels of organization' as it appears in scientific usage is offered by Wimsatt (1974; 1976; 1994[2007]). The analysis offered in this dissertation is best seen as an attempt to offer a more in-depth analysis of Wimsatt's characterization of levels, which, though insightful and innovative in its own right, is not very clear. Though Wimsatt analyzes levels as a feature of the world, Wimsatt also emphasizes the significance of the concept for scientific efforts to construct explanation. He offers the following characterization for 'levels':

> "[L]evels of organization are a deep, non-arbitrary, and extremely important feature of the ontological architecture of our natural world, and almost certainly of any world that could produce, and be inhabited by, intelligent beings. (This gives levels an almost

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[5] See also Kaplan 2015 and Craver 2015, both of whom refer to the "defining questions" approach in their new survey articles to understanding levels.

[6] Indeed, this approach to grasping *the task of* analyzing the levels concept seems to favor a strongly contextualized perspective for conceptualizing levels, which is Craver endorses in his mechanistic conception of levels (see Section 2.3; cf. Craver 2015).

> Kantian flavor.) *Levels and other modes of organization cannot be taken for granted, but demand characterization and analysis*. If I am right, compositional levels of organization are the simplest general and large-scale structures for the organization of matter. They 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[2007], 203-4, emphasis modified)

This dense passage introduces a number of distinct characteristics of levels of organization. The second sentence of the passage is particularly noteworthy as it highlights ‘levels of organization’ as a proper subject of analysis, detached from an embedding debate. The levels concept, Wimsatt is saying, needs to be analyzed in terms of its inherent usefulness in science as communicating simultaneously several ideas about how the world is structured (i.e. detached from other philosophical debates), and how this structure of the world in turn influences the way that science is organized around it. Wimsatt continues this passage by expressing skepticism for the viability of traditional conceptual analysis in philosophy in capturing scientific usage of the levels concept, saying:

> “For anyone who still believes in 'necessary and sufficient conditions' style analyses, I note at least five qualifiers in this sentence – all apparently necessary – that would be difficult at best to deal with, and the referents of these qualifiers are also often disturbingly general, and correspondingly unclear. Note also, that I said that levels 'are constituted by,' not 'are defined in terms of.' *Definitional language is notoriously unhelpful in contexts like these. Broad-stroke characterizations, focused with qualifications and illuminated with examples, are more useful.*” (ibid. emphasis added)

This dissertation will take Wimsatt's idea here to heart: that a serious analysis of levels will have to be engaged by investigating the scientific contexts of usage in which the concept seems to play such a prominent role. In this spirit, instead of focusing on classical components of semantic content to gain insight into the concept of levels of organization, e.g. meaning and reference, this dissertation will seek to gain insight into other special features of semantic content that are more relevant to the scientific usage of ‘levels’, which belong to the character and significance of the levels concept. These features, which include e.g. the scope of level usage, definitional criteria, mode of presentation, and the epistemic goal of a concept, will be detailed below in Section 1.4 (see also Chapter 4).

1.3 Initial Distinctions

The term 'levels' without further qualifier is, on its own, “multiply ambiguous” (Craver 2007a, 163). What exactly does this mean? There are many terms and ideas that are related to, or even derivative of, the term 'levels of organization'. While some of these offer important insight into how scientists investigate and explain nature using the levels concept, others are only erroneously related to 'levels of organization' and therefore not useful for this analysis. This requires a few caveats regarding terminology in order to avoid confusion in what follows.

As mentioned above, the term 'levels of organization' as used in the biological sciences can encompass both ontological and epistemological connotations. These connotations are sometimes expressed using slightly different terminology, despite falling under the related umbrella term 'levels (of organization)'. Intuitively, a single 'level of organization' is taken to minimally refer to a set of structures and processes within a natural system that share similar features, such as their size, the types and magnitude of forces that govern their interactions, or a compositional relation to a common whole to which these things belong. Multiple organizational levels are hierarchical in the sense that the structures and processes found at one particular level are organized together as subordinate elements to the structures and processes found at higher levels, and in turn are superordinate to the more basic structures and processes organized together at lower levels (for more on hierarchical structures see section 1.5 below; cf. Simon 1962; Wimsatt 1976).

At least two further notions of 'levels' are also widely used in the literature, and will be implicitly considered here: 'levels of analysis'[7] and 'levels of explanation'. Both of these notions will be taken as epistemic cognates of 'levels of organization' because they rely in a non-trivial way on the hierarchical organization in their domains of inquiry postulated by the ontologically-leaning understanding of 'levels of organization'.[8] This is based on three observations. Firstly, areas of biological research are often demarcated in terms of the level of organization that they investigate, and correspondingly fall under a certain connotation of 'level'.[9] For instance, 'levels of analysis' are typified by a collection of investigative techniques and methods that are heavily associated with the structures and processes occurring at a particular altitude of the levels of organization that constitute a particular phenomenon (cf. Craver 2007a, Ch. 5, Sect. 2; Richardson and Stephan 2007). Neuroscience is a multidisciplinary field of biology that exhibits this quite well. Molecular neuroscience, for example, investigates phenomena like mechanisms of neurotransmitter-mediated signaling between synapses, or of biochemical cascades resulting from ion channel behavior. Research in this discipline hence focuses on stereotypical types of structures located a particular (or localized set) organizational level of the nervous system, i.e. synapses, receptors, axons, and other sub-neuronal structures. The investigations of these molecular researchers of the brain use specialized techniques such as gene knock-out studies and pharmacological interventions to analyze, e.g., the role of a specific protein within a biochemical cascade of interest. Such techniques are of little use in investigating phenomena involving structures and processes observed at a different level of organization, such as electrophysiological response properties of a single neuron, or interpreting the significance of an fMRI image study, which observes entire brain regions.

Relatedly, generalizations formulated by these levels of analysis that are used to *explain* biological phenomena also resemble the hierarchical structure postulated by the levels image of the world, if only via their association with the structures and processes that designate an altitude in the hierarchy of organizational levels, whose terms appear in said generalizations.

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[7] An important exception to what is meant by 'levels of analysis' is discussed in Section 1.2.1.

[8] McCauley's (1998) analysis of higher- and lower-level approaches to investigating models of cognition exemplifies this point as an implicit understanding of underlying the levels concept. See also McCauley and Bechtel 2001, who implement this further in their “heuristic identity theory”.

[9] The extent to which this kind of demarcation of disciplines holds is very shaky, and will be taken up several times in this dissertation. See especially Chapter 2 and Chapter 3.

Generalizations formulated using, e.g., single-cell electrophysiological recordings are procured to explain a phenomenon characterized at a corresponding level of organization, like direction-selective response properties of a particular neuron to a specific input stimulus that the organism encounters in an experimental setup. Such generalizations may simultaneously be utilized in the explanation of phenomena occurring at different organizational levels, such as whole-organism behavior, which is observed at the level of the whole organism. Generalizations originating from one altitude among organizational levels that constitute a system, especially in the construction of a multi-level explanation, that are nonetheless related to one another via offering insights into a phenomenon investigated at many levels represent "levels of explanation" (Brooks 2010; cf. Craver 2001; Potochnik 2010).

Levels of 'analysis' or 'explanation' are clearly epistemic in their import, with the former covering methodological or perspectival information about a particular phenomenon and the latter covering explanatory information about a particular phenomenon. Nonetheless, even these distinct meanings are made in relation to a set of natural items, which are postulated by the organizational variety of levels. For this reason, in what follows each of these particular terms will be taken as designating a different mode of application of an overarching concept – that of 'levels of organization'.

A consequence of this caveat is that the concept of levels is used to refer to several distinct (methodological, explanatory, ontological) aspects of a phenomenon, possibly simultaneously. Though probably unintentional, scientific usage of 'levels of organization' seems to exploit this openness of the levels concept (see Section 1.4; Chapter 4). As will be seen, the levels concept can be made clear in any specific circumstance, but there remains the question of whether the concept carries any overarching significance across the different instances of its usage.

1.3.1 Erroneous Concepts of Levels

Other uses of the term 'levels' are easily discarded as erroneous to any understanding of 'levels of organization', such as when referring to a degree or magnitude of something (level of calcium, level of activity, level of occurrences). Another unrelated 'levels' term is 'levels of processing', which refers to a set of usually processes that underlie a particular activity. This form of usage is frequently found in the neurosciences (see also Craver 2007a, Ch. 5, Sect. 3.2.1), and refers to a sequence of processes that tracks information dispersal between areas of the brain.

One particularly troublesome usage of the term 'level' in philosophical discussions conflates the term 'levels of organization' with David Marr's (1982[2010]) notion of “levels of analysis”, which is a key element to his “tri-level” program for computational neuroscience. This conflation deserves special comment due to the influence of Marr's program in the philosophy of mind, where this erroneous association is particularly rampant (see especially Kim 2002, 1-2; Pylyshyn 1984). Marr's program was meant as a unifying conceptual framework for cognitive neuroscience that advocated treating nervous systems as computational (that is, information-processing) devices. Within this program, three distinct “levels of analysis”[10] demarcate how any given cognitive function can be analyzed. These included the level of computation, level of algorithm, and level of implementation. The “computational level” refers to *what* and *why* a cognitive system does what it does, and is typically described in abstract, mathematical terms pertaining to information processing. This was considered by Marr to be of primary importance to explaining neural phenomena. The “algorithmic level” pertains to the implementation of the computation-theoretical in terms of a representational input-output model. The final “implementional level” concerns detailing how the former two “levels” are realized by the physical “hardware” of the system that houses them.

Two assumptions underlie Marr's framework, which make it clear that his notion of 'level' is completely different than the 'level of organization' variety. Firstly, each iteration of these

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[10] This sense of 'levels of analysis' is very different from the cognate sense of organizational levels discussed above. Though the syntax used to describe both of these senses of the term is identical, researchers who use them typically do not confuse their specific meaning. Marr, for instance, chose this designation and articulated its particular meaning without mentioning other possible meanings. Confusions between Marrian analytic “levels” and 'levels of organization' in the biological sciences are committed most frequently by philosophers of mind. Though analyzing the frequency, and impact, of this conflation would be interesting, it lies beyond the scope of this thesis.

"levels" each refer to one and the same system *as a whole*, which precludes the hierarchical ordering of natural systems and subsystems that comes along with references to levels *of organization* (particular levels of organization, though *related* into a whole, designate completely different structures and processes, which are contextualized *within* that whole). Marr's different analytical "levels", on the other hand, are simply three different (though complementary) ways of describing a given system *at a single level of organization*. Given this alone it seems more prudent to call these Marrian entities "dimensions of analysis" rather than "levels of analysis". Secondly, Marr's framework is strongly motivated by the claim that neural phenomena are best explained by abstracting away from their physical implementation. The physical "hardware" of the realizing system housing the computational programming is instead best characterized in a substrate-neutral fashion. Indeed, Marr envisioned his tri-level framework as replacing empirical-based, 'wet-biological' explanations in neuroscience:

> [G]one [are] any explanation[s] *in terms of* neurons – except as a way of implementing a method. And present is a clear understanding of what has to be computed, how it is done, the physical assumptions on which the method is based, and some kind of analysis of algorithms that are capable of carrying it out (Marr 1982, 18; emphasis modified).

This leads to what McClamrock (1991) refers to as the "de-contextualization" of a system from its natural setting (1991, 188). Abstracting away from the physical details, as Marr's framework does, is contrary to how scientific claims invoke 'levels of organization', which aim to do the exact opposite: to contextualize a phenomenon to a set of different structures and processes that constitute its workings in nature. This is best seen by looking at how scientists themselves depict levels.

1.4 Depictions of Levels in Biological Textbook*s*

In order to better grasp the subject of analysis of this dissertation, a short sketch of how levels are depicted in science is necessary. Probably the most familiar depictions of levels of organization in the biological sciences are found in the many textbooks available for the biological sciences.[11] This widespread use of the levels concept is a straightforward way of substantiating the ubiquity of the concept, given its presence in the large majority of textbooks of all degrees of specialization, whether for undergraduate introductory courses or for advanced graduate or postgraduate uses.[12] Moreover, looking at textbook depictions of levels offers a preliminary explanation for the ubiquity of the levels concept: Scientists take levels to be capable of expressing a wide range of important ideas concerning how phenomena are explained in biology.

Some examples of general textbooks for the biological sciences include Reece et al.'s *Campbell Biology*, and Sadava et al.'s *Life: The Science of Biology* (both now in their ninth editions), which are most often used in introductory undergraduate courses at universities. These textbooks utilize levels of organization as a fundamental motif, usually in its opening pages, to conceptualize both important features of the biological world *and* how to study it. Furthermore, they often portray the same number and identity of organizational levels. These include (in descending order): the biosphere, ecosystems, communities, populations, organisms, organs (and sometimes organ systems), tissues, cells, organelles, and molecules. For instance, Reece et al.'s series *Campbell Biology*, one of the principal introductory textbooks for college undergraduates, prominently features the hierarchical view of the world in the major themes of biology (see 1.4.2 below). Their depiction of, and comments about, the levels concept will be used to structure the rest of this section. Their depiction of levels is given in figure 1.2.

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[11] It first it may be asked: Why would textbooks be an important insight into scientific practice? They are, after all, 'merely' introductory in content and presentation, and hardly display the specialized, professional knowledge found in research articles. Textbooks are used to convey a basic and foundational understanding of what constitutes a particular branch of science. The information that is conveyed is a mixture of both theoretical and practical knowledge, and is instrumental in forming a researcher's initial contact with the body of knowledge attached to a particular branch of science or a specific discipline of that branch. For this reason, textbooks offer a special kind of insight into what science "is", or at least is taken to be, by students, aspiring scientists *and* established researchers. In this capacity, textbooks should be seen as scientific tools whose influence is present from the beginning a person's scientific education through one's specialization and accreditation as a researcher in their own right.

[12] Some may disagree with this observation (cf. Eronen 2014). Substantiating this observation in detail will not be pursued in this dissertation. A more in-depth substantiation of the presence of the levels concept in scientific literature nevertheless represents an important follow-up study to be carried out at a later time.

Exploring Levels of Biological Organization

1 The Biosphere

As soon as we are near enough to Earth to make out its continents and oceans, we begin to see signs of life—in the green mosaic of the planet's forests, for example. This is our first view of the biosphere, which consists of all life on Earth and all the places where life exists—most regions of land, most bodies of water, the atmosphere to an altitude of several kilometers, and even sediments far below the ocean floor and rocks many kilometers below Earth's surface.

2 Ecosystems

As we approach Earth's surface for an imaginary landing in Ontario, we can begin to make out a forest with an abundance of trees that lose their leaves in one season and grow new ones in another (deciduous trees). Such a deciduous forest is an example of an ecosystem. Grasslands, deserts, and the ocean's coral reefs are other types of ecosystems. An ecosystem consists of all the living things in a particular area, along with all the nonliving components of the environment with which life interacts, such as soil, water, atmospheric gases, and light. All of Earth's ecosystems combined make up the biosphere.

3 Communities

The entire array of organisms inhabiting a particular ecosystem is called a biological community. The community in our forest ecosystem includes many kinds of trees and other plants, a diversity of animals, various mushrooms and other fungi, and enormous numbers of diverse microorganisms, which are living forms, such as bacteria, that are too small to see without a microscope. Each of these forms of life is called a *species*.

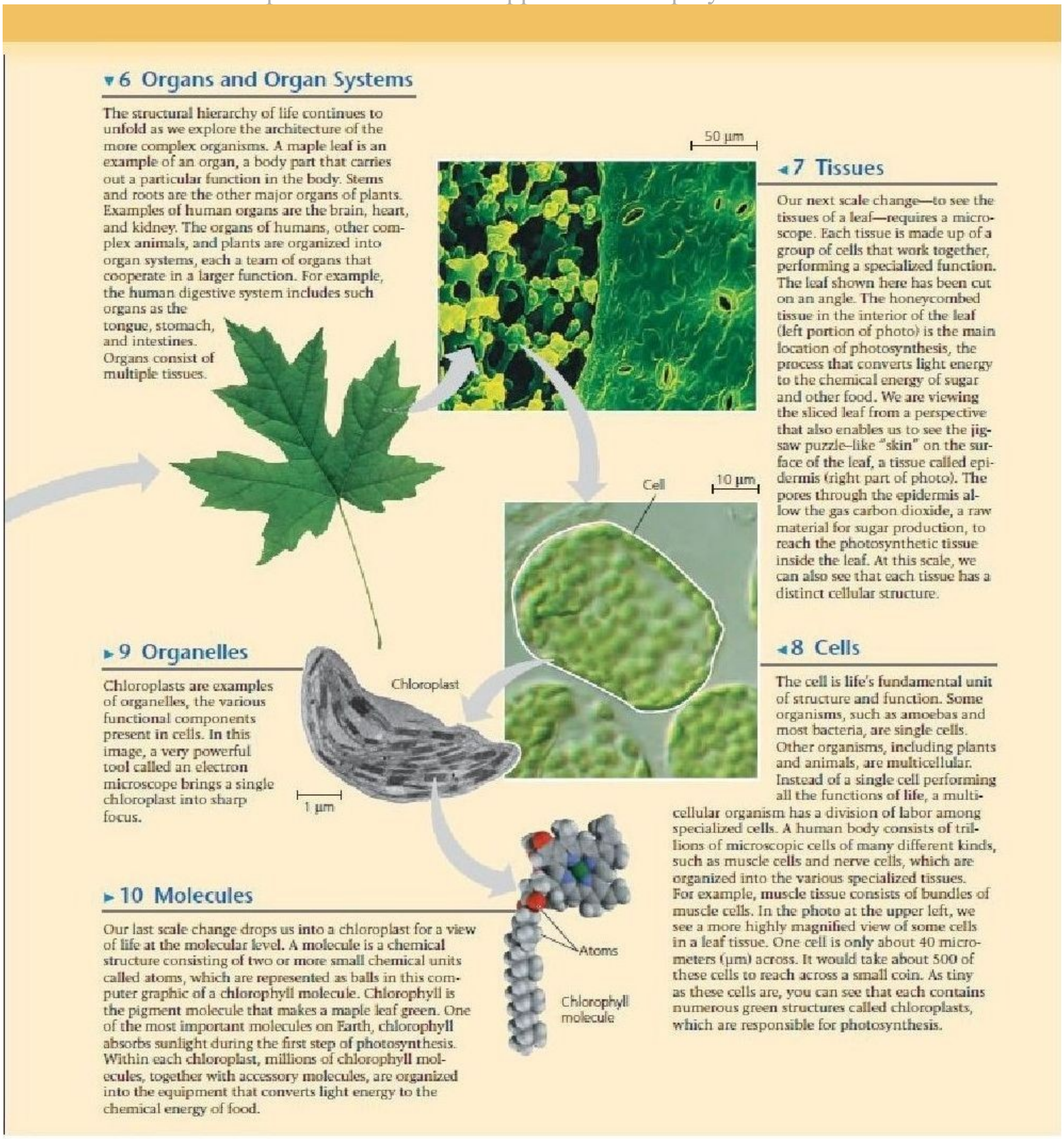
4 Populations

A population consists of all the individuals of a species living within the bounds of a specified area. For example, our Ontario forest includes a population of sugar maple trees and a population of white-tailed deer. We can now refine our definition of a community as the set of populations that inhabit a particular area.

5 Organisms

Individual living things are called organisms. Each of the maple trees and other plants in the forest is an organism, and so is each forest animal—whether deer, squirrel, frog, or beetle. The soil teems with microorganisms such as bacteria.

Figure 1.2 (a – above; b – below) Levels of organization as depicted in Reece et al. (2010). See text for details. Image taken from Reece et al 2010, 3).



▾6 Organs and Organ Systems

The structural hierarchy of life continues to unfold as we explore the architecture of the more complex organisms. A maple leaf is an example of an organ, a body part that carries out a particular function in the body. Stems and roots are the other major organs of plants. Examples of human organs are the brain, heart, and kidney. The organs of humans, other complex animals, and plants are organized into organ systems, each a team of organs that cooperate in a larger function. For example, the human digestive system includes such organs as the tongue, stomach, and intestines. Organs consist of multiple tissues.

◂7 Tissues

Our next scale change—to see the tissues of a leaf—requires a microscope. Each tissue is made up of a group of cells that work together, performing a specialized function. The leaf shown here has been cut on an angle. The honeycombed tissue in the interior of the leaf (left portion of photo) is the main location of photosynthesis, the process that converts light energy to the chemical energy of sugar and other food. We are viewing the sliced leaf from a perspective that also enables us to see the jigsaw puzzle–like "skin" on the surface of the leaf, a tissue called epidermis (right part of photo). The pores through the epidermis allow the gas carbon dioxide, a raw material for sugar production, to reach the photosynthetic tissue inside the leaf. At this scale, we can also see that each tissue has a distinct cellular structure.

▸9 Organelles

Chloroplasts are examples of organelles, the various functional components present in cells. In this image, a very powerful tool called an electron microscope brings a single chloroplast into sharp focus.

◂8 Cells

The cell is life's fundamental unit of structure and function. Some organisms, such as amoebas and most bacteria, are single cells. Other organisms, including plants and animals, are multicellular. Instead of a single cell performing all the functions of life, a multicellular organism has a division of labor among specialized cells. A human body consists of trillions of microscopic cells of many different kinds, such as muscle cells and nerve cells, which are organized into the various specialized tissues. For example, muscle tissue consists of bundles of muscle cells. In the photo at the upper left, we see a more highly magnified view of some cells in a leaf tissue. One cell is only about 40 micrometers (µm) across. It would take about 500 of these cells to reach across a small coin. As tiny as these cells are, you can see that each contains numerous green structures called chloroplasts, which are responsible for photosynthesis.

▸10 Molecules

Our last scale change drops us into a chloroplast for a view of life at the molecular level. A molecule is a chemical structure consisting of two or more small chemical units called atoms, which are represented as balls in this computer graphic of a chlorophyll molecule. Chlorophyll is the pigment molecule that makes a maple leaf green. One of the most important molecules on Earth, chlorophyll absorbs sunlight during the first step of photosynthesis. Within each chloroplast, millions of chlorophyll molecules, together with accessory molecules, are organized into the equipment that converts light energy to the chemical energy of food.

Reece et al.'s application of the levels concept, however, is decidedly open to interpretation. They introduce levels with the following passage:

> "The *study of life* extends from the microscopic *scale* of the molecules and cells that *make up* organisms to the global scale of the entire planet. We can divide this enormous range into different *levels of biological organization*" (Reece et al. 2010, 3; emphasis

added).

The highlighted terms and phrases in this passage reflect several features frequently attributed to the levels concept, which help to highlight what elements belong to the character of 'levels' in any given instance, and what kinds of things the levels concept is used for. What quickly becomes apparent is the number of distinct ways that levels are characterized in these depictions; i.e. there are different ways that the character of ‘levels’ can be specified. This openness in the way that levels are characterized in these textbooks shows that the levels concept represents the *package deal* of sorts mentioned above: That is, ‘levels can be taken as meaning several different things, sometimes simultaneously.

1.4.1 The Character of 'Levels' in Biological Science

The above passage from Reece et al. (2010) points to a number of elements that present themselves as comprising the character of the levels concept as given by various conceptions of the term. Three important elements include the scope of the conception, the definitional criteria used to identify levels, and the mode in which the concept is presented.

Scope of 'Levels'

The first notable element of the character of the levels concept mentioned in the above passage is the *scope* to which levels are applied in nature. ‘Levels’ typically extend to nature in either a *global* scope or a *local* scope. Global conceptions of levels are said to extend to the entirety of nature, and thereby encompass all natural phenomena. Reece et al.’s depiction of levels in Figure 1.2 is hence global, as it “extends from the microscopic scale of the molecules and cells that make up organisms to the global scale of the entire planet” (ibid.). Local conceptions of levels in contrast extend only to a limited part of nature, where this extension is determined in a contextualized manner. One clear example of local levels is found in the structure of proteins, which are composed of four well-defined levels of organization (primary, secondary, tertiary and quaternary). The locality of these levels is made clear by

Alan Love (2012) who discusses protein structure as an exemplary case of levels of organization:

> “The hierarchical representation of four structural layers of organization is applicable to proteins and nucleic acids. This categorization of hierarchical organization is extremely robust and well established empirically. But it quickly loses its significance when applied across the spectrum of biological macromolecules. In this sense, the 'levels of structural organization' are localized to a particular domain of inquiry (proteins and nucleic acids) and not reified into a nominalized designation (*the* tertiary structural level of biological macromolecules)” (Love 2012, 117).

Global and local conceptions of levels are often taken to be mutually exclusive of one another (see, e.g., Craver 2007a, 191; Potochnik and McGill 2012), though the extent to which this is justified will be taken up in later chapters.

Definitional Criteria

The passage from Reece et al. (2010) simultaneously refers to two distinct *definitional criteria* with which to identify levels and distinguish them from one another: *scale* and *composition*. Scale, i.e. size scale[13], is used at the beginning and the end of the passage to identify constituents that designate *three* distinct levels (molecules, cells, and the biosphere), while another level (organism) is clearly identified in terms of two compositional parts belonging to distinct levels (again, molecules and cells). These two different criteria are typically used to specify the interlevel relations in a hierarchical layout of levels. These are illustrated above in Figure 1.3. The first, composition (Figure 1.3a), specifies a particular element of a system (for instance, a muscle cell) as being *a part of* an embedding whole (such as a heart). This way of characterizing interlevel relations is central for the main philosophical accounts of levels, which will be discussed in Chapter 2.

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[13] The quality of size for the scale criterion here is directly implied by the terms “microscopic” and “global”. Size need not be the *only* quality designated by the scale criterion, and indeed could instead be an indicator for another quality, such as temporal scale, magnitudinal scale

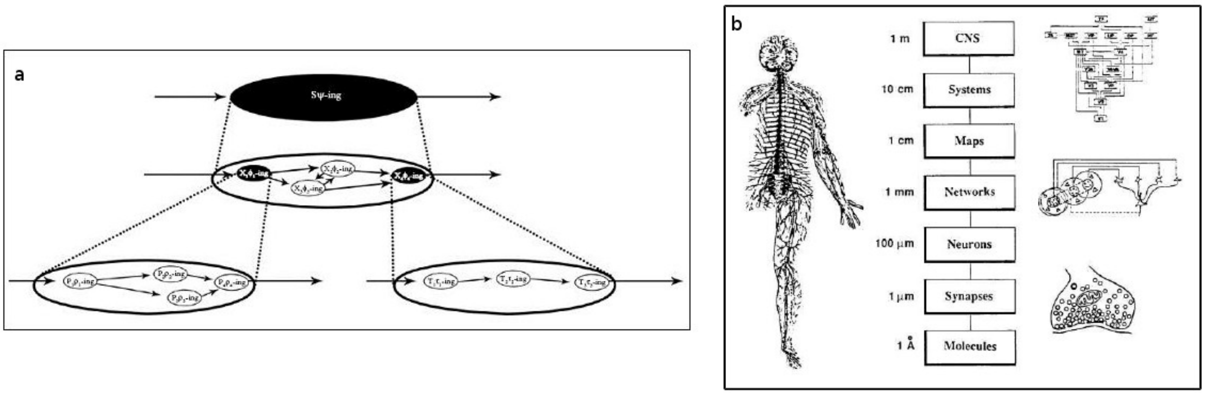

Figure 1.3 Two definitional criteria for levels. (a) A set of organizational levels demarcated by composition. In these types of representations, level identity, including the properties and entities that belong to a particular level, is defined in terms of a thing's parthood in an overall system. Figure taken from Craver 2007a, 194. (b) A set of levels (here, the levels of the nervous system) demarcated by scale. Figure taken from Churchland and Sejnowski 1992, 9.

The second criterion often used to define levels in scientific cases is scale, particularly size scale (Figure 1.3b). This way of demarcating levels offers an extremely accessible means of representing biological systems, which some of the several intuitive features of the hierarchical ordering that levels are often taken to express. For instance, it captures nicely the idea different organizational levels manifest different types of causal relations, and that these causal relations are exercised by typical kinds of entities.

Reece et al. shift between these two criteria in their descriptions of the major levels in biology depicted above in Figure 1.2. There, for instance, ecosystems "*consist of* all the living things in a particular area", but also designate the components of another (higher) level, as "[a]ll of Earth's ecosystems combined *make up* the biosphere. Likewise, organs are identified as "a body part *consisting of* two or more tissues" (Figure 1.2b), organelles comprise "the various functional components that *make up* cells", and the constituent of the bottommost organizational level in biology, molecules, are defined as a "chemical structure *consisting of* two or more small chemical units called atoms" (*ibid*; emphasis modified). In each of these instances the referenced levels (biosphere, ecosystems, organs, organelles, molecules) are identified in terms of their internal composition, or their role in their compositional relation to a (whole) object at another (higher) level. However, scale is also used, simultaneously with composition, to characterize different levels of organization. Regarding tissues, Reece et al. say that “our next *scale change* [downward from organs] to see a leaf's tissues requires a microscope...At this *scale*, we can also see that each tissue has a cellular structure”[14] (*ibid*. emphasis added). Molecules are similarly identified interchangeably with the scale criterion: “Our last *scale change* vaults us into a chloroplast for a view of life at the molecular level” (*ibid*; emphasis added).

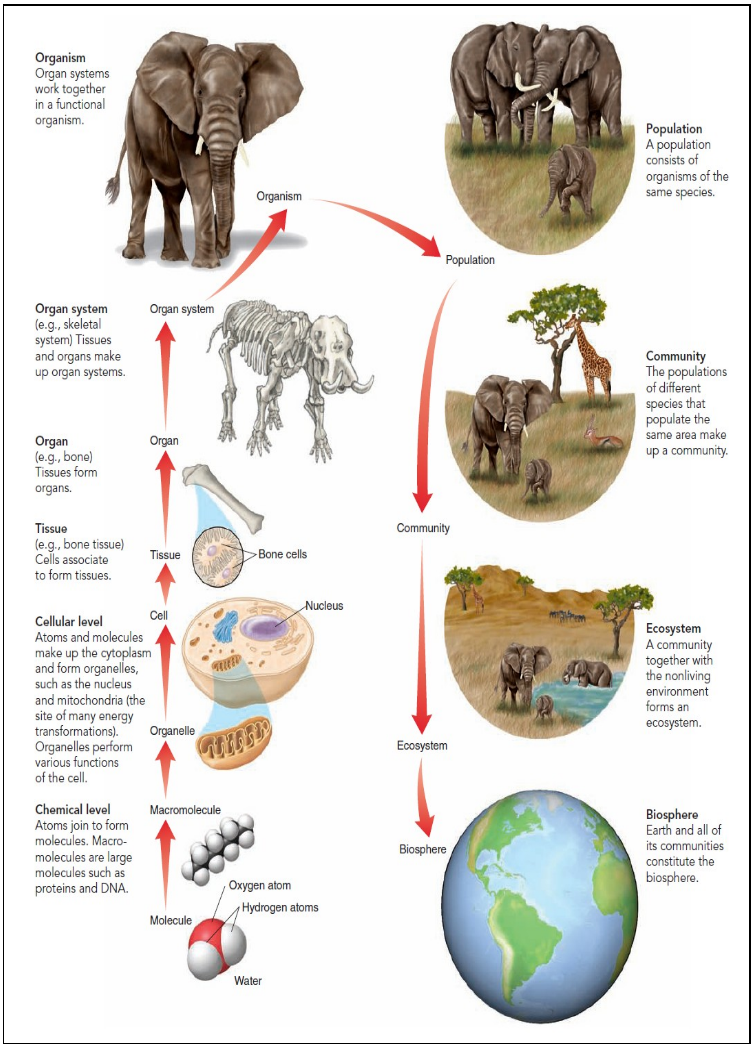

Figure 1.4 Levels of organization in Solomon et al. (2010). See Text for Details. Image taken from Solomon et al. 2010, 6.

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[14] This is also the first mention in Reece et al.'s depiction of levels that cites a particular scientific instrument in tandem with identifying and characterizing a discrete level of organization.

Solomon *et al.*'s (2011) *Biology*, one of the competitors to Reece et al.'s *Campbell* series in the introductory college textbook market, likewise introduce levels of organization as a basic motif of the biological world, saying that "[w]hether we study a single organism or the world of life as a whole, we can identify a *hierarchy of biological organization*" (2011, 6; emphasis added). Their depiction of levels is shown in figure 1.4.

Unlike Reece et al. (2010), Solomon et al. only mention a compositional interpretation of organizational levels. Each level is defined as either "being made up of" or "consisting of" things located at its lower adjacent level (Solomon et al. 2011, 6). Despite this appearance of offering a univocal, generalized definition of levels of organization, Solomon *et al.*'s series of textbooks backfires as an attempt to clarify the meaning of levels of organization. Choosing only one definitional criterion for identifying levels does not entail that the levels concept they articulate is any clearer than in other contexts that that utilize several criteria. For instance, there is no clarification for how the part-whole relation that holds between levels (in virtue of composition) could be specified in order to hold generally across all levels for all biological phenomena.

Mode of Presentation

Another element that makes up the character of the levels concept in biology is the *mode* in which the concept is presented, i.e. that which the concept is taken to express. Looking again at the emphasized phrases in the above passage, the text strongly implies both an *epistemic* and an *ontological* mode in which levels of organization are presented. Though the level-bound entities in the passage (cells, molecules, organisms, biosphere) are identified an undeniably ontological way (i.e. are posited as natural entities in the world), the "study of life", i.e. the *science* of biology, is strongly implied to emulate the hierarchical layout of the natural world in *some* way. This becomes clear by looking at how Reece et al. embed several implicatory claims into the passage that the disciplinary structure of biology *follows* the hierarchical structure of life. For them, "[t]he *study of life* extends from" the lowest levels of the living world to the highest ones" (Reece et al. 2010, 3). This seems to imply interdependence between the *study* of life and the "enormous range" of *natural phenomena* (molecules, cells up to the biosphere) divided into “levels of biological organization”. That is, the disciplinary structure of biology (epistemic) appears to mimic (ontological) *biological* organization. Ernst Mayr (1982) observes this trend in introductory characterizations of biology, saying:

> “The formation of constitutive hierarchies is one of the most basic properties of living organisms. At each level there are different problems, different questions to be asked, and different theories to be formulated. *Each of these levels has given rise to a separate branch of biology*: molecules to molecular biology, cells to cytology, tissues to histology, and so forth, up to biogeography and the study of ecosystems. *Traditionally, the recognition of these hierarchical levels has been one of the ways of subdividing biology into fields*. To which particular level an investigator will turn, depends on his interests.” (Mayr 1982, 65)

This point should not be overemphasized, as positing a strong correspondence between nature and science is extremely problematic (Section 2.2.4; Section 3.2). Indeed, Reece et al. (2010) subsequently resists dividing biology itself along *well-defined* disciplinary boundaries that follow levels, and chooses rather to describe *the study of* biological phenomena from a more ecumenical perspective throughout the book. Nonetheless, the dual presence of ontological and epistemic modes attached to levels is continuously seen in the interspersing of names of textbook's chapters and units with terms that continuously shift between these ontological and epistemic connotations introduced by the discussion of the organizational levels of nature.[15]

This open treatment of global levels is recapitulated in other general textbooks as well. Like Reece et al., Sadava *et al.*'s (2008) *Life: The Science of Biology* implies a dual ontological-epistemological mode of applying levels of organization by stating that “[b]iology is *studied at* many levels of organization” (2008, 8, emphasis added). Like Solomon *et al.*, on the other hand, levels are defined by Sadava et al. exclusively by their compositional relations between

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[15] The chapter structure in the textbook's table of contents illustrates this to a small degree. For instance, some chapters are labeled according to the natural phenomena that are described (metabolism, the nervous system, the cell, photosynthesis), while others chapters and units are introduced with terms referring to the scientific discipline that investigates some areas of the biological world (genetics, “the *chemistry* of life”, ecology).

objects at lower levels, as the presence of phrases like “consists of” and “made of” once again make an overwhelming appearance.[16]

The conception of levels of organization found in general textbooks exhibits an extremely open character. This is visible in the criteria by which levels are characterized, and in the modes in which levels are applied.[17]

1.4.2 The Significance of 'Levels' in Biological Science

General textbooks like Reece *et al.* (2010) rely substantially on the concept of levels of organization to articulate the “major themes” of investigation and explanation in biology. *Campbell Biology* is exemplary on this point, and their preamble to introducing levels clearly sets out such a task for the levels concept:

> “A better approach [rather simply than memorizing facts] is to take a more active role *by connecting the many things you learn to a set of themes that pervade all of biology*. Focusing on a few *big ideas—ways of thinking about life that will still hold true decades from now*—will help you *organize and make sense of all the information you’ll encounter as you study biology*” (Reece *et al.* 2010, 3).

Looking again at their textbook depictions of levels illustrated in Figure 1.2, the shifting of definitional criteria by which levels are identified and demarcated from each other clearly

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[16] Their depiction of levels is illustrated in Sadava et al. 2008, 8.

[17] This survey of the biological textbook literature is at best preliminary, and represents another point of follow-up analysis to be pursued at a later time. For one thing, the epistemic significance of biological textbooks has not adequately been established in regards to other kinds of scientific texts such as original research articles, reviews, commentary, or other kinds of manuals. Moreover, the diversity of scientific textbook literature has only been touched on here; though the term 'textbook' seems to provoke distrust in philosophers for being 'merely introductory', textbooks are available for all degrees of specialization and experience in the sciences. Indeed, textbooks (both advanced and general) are routinely available in laboratories and scientific work spaces as references for researchers of all degrees of competence. Finally, discipline-specificity of textbooks represents another aspect in need of investigation, since, among reasons, although there are many issues that are treated in various different textbooks (such as protein folding, natural selection, and oxidative phosphorylation), these different textbooks themselves can vary starkly in their treatment of the respective issue. Each of these aspects of textbooks as kinds of scientific textbooks bears directly on questions concerning the character and significance of the levels concept.

resists saying too much concerning the particular character of levels. Instead of committing to one particular, comprehensive understanding of how 'levels' can exhaustively structure the world, the purpose of 'levels' in this and similar passages is to introduce in a basic fashion how problems of biological phenomena are constructed. The features of biological systems that biologists investigate are too nuanced to be captured by accounts that seek to offer a comprehensive conception of levels. Such features include "emergent" properties, pluralistic approaches to explanation, and the perspective-embedment of biological explanation. Ironically, this conceptual openness will also be the reason why philosophical conceptions of levels will not be sufficient to aid in constructing actual scientific explanations, as will be seen later (see Chapter 4, Chapter 5).

"Emergent" Properties

The first major theme of biology introduced by levels is the widespread presence of "emergent", or rather, *holistic* properties in nature.[18] This means that certain properties are manifested only by things located at a particular level, but not at other levels. This idea con be expressed using different definitional criteria for characterizing levels: "Emergent" can, on the one hand, comprise properties that are possessed by some things that are treated as whole, which are not by the parts out of which it is composed (McLaughlin 1992; Stephan 1999b). At the same time, it can also refer to properties that are simply 'located' at a particular levels, such as explanatory properties possessed by the generalizations, laws, or models that encompass the Regardless of the specific conception of levels one has, the existence of these holistic properties does not mean that lower levels are not relevant to understanding such behavior in biological systems, as the following passage makes clear:

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[18] Emergence remains a contentious issue in philosophy (McLaughlin 1992; Kim 1999; Stephan 1999a, 1999b; Theurer 2014). However, the term "emergent" here in fact expresses a much more innocuous conception of emergence, at least in philosophical sense of the word. In particular, the term here expresses only a "weak" form emergence that claims only the existence, and significance, of systemic properties, and is perfectly compatible with a materialistic universe (Stephan 1999b, 50). "Strong" emergence, on the other hand, asserts in addition the inability, in principle, to reduce the emergent property in question to the behavior of its constituents. That is, it is impossible (in principle) to account for the property in question by looking at the constituents of the system that manifests this property. Strongly emergent remains controversial, because it seems to violate the basic premise of materialism. For this reason, strong emergence goes much further in that it is also a *metaphysical thesis*, rather than only an epistemic one in the case of weak emergence. The term 'holistic' is preferable for exactly this reason.

> “[E]mergent [i.e. holistic] properties are *due to the arrangement and interactions of parts as complexity increases*. For example, although photosynthesis occurs in an intact chloroplast, it will not take place in a disorganized test-tube mixture of chlorophyll and other chloroplast molecules...*Emergent* [i.e. holistic] *properties are not unique to life.* A box of bicycle parts won’t take you anywhere, but if they are arranged in a certain way, you can pedal to your chosen destination. And while the graphite in a pencil “lead” and the diamond in a wedding ring are both pure carbon, they have very different appearances and properties due to the different arrangements of their carbon atoms. Both of these examples point out the importance of arrangement. *Compared to such nonliving examples, however, the unrivaled complexity of biological systems makes the emergent* [i.e. holistic] *properties of life especially challenging to study*.” (Reece et al. 2010, 3)[19]

The issues that holistic properties present to the study of biological phenomena demarcate decidedly different sets of questions than those engaged by philosophers who investigate emergence. In particular, this passage articulates several aspects of how systems are conceptualized as explanatory objects *of biology*. This passage also contains orienting comments that contextualize such properties in natural systems, understood hierarchically, *as biological*. Specifically, the possession of holistic properties by non-natural artifacts (like the bicycle in the above passage) make clear that (1) biological systems are not ontologically distinct from non-living systems, (2) the organization displayed in these systems possess a higher degree of complexity that distinguishes them decisively from non-living systems.

Pluralistic Approaches to Explanation

'Levels of organization' are used additionally to endorse a pluralist approach to explaining

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[19] Comparable statements to emergence are easily found in other textbooks as well. For instance, Solomon et al. (2010) also speaks of these holistic properties, also under the guise of emergence, saying: “[t]he whole is more than the sum of its parts. Each level has **emergent properties** [highlighted as a key term], characteristics not found at lower levels” (6; see also Reece et al. 2012, 3; Korn 2005). Ecological textbooks are especially rife with references to both levels and emergence.

biological phenomena. Reductionist and non-reductionist explanatory approaches[20] are often not sufficient by themselves (at least in the biological sciences) to account for the phenomenon for which an explanation is being sought (Brooks 2010, Ch.2). This creates a problem for working biologists, who are typically faced with either looking at lower levels (reductionist) or higher levels (non-reductionist) to find an adequate explanation for biological phenomena. Reece et al. express this as a basic dilemma facing all biologists:

> "Because the properties of life emerge from complex organization, scientists seeking to understand biological systems confront a dilemma. On the one hand, we cannot fully explain a higher level of order by breaking it down into its parts. A dissected animal no longer functions; a cell reduced to its chemical ingredients is no longer a cell. Disrupting a living system interferes with its functioning. On the other hand, something as complex as an organism or a cell cannot be analyzed without taking it apart....*Biologists must balance the reductionist strategy with the larger-scale, holistic*[21] *objective of understanding emergent properties*—how the parts of cells, organisms, and higher levels of order, such as ecosystems, work together." (Reece et al. 2010, 3)

Instead of choosing either a reductionist or non-reductionist approach to explaining a phenomenon, biologists need to instead consider how these approaches can concurrently contribute to constructing more adequate explanations. Both reductionist and non-reductionist approaches are useful in their own way, even if they are not sufficient by themselves.[22]

Perspective-Embedment of Biological Explanation

A third major issue that is broached by 'levels' in biology is the need to contextualize the perspective from which one constructs descriptive, explanatory statements, or even the

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[20] Roughly, seeking to construct explanations by attending to either, respectively, only the lower-level components of a given phenomenon, or only to the higher level at which that phenomenon is found.

[21] The use of "holistic" here lends support to the claim made above about how "emergent" is understood in these textbooks.

[22] Pluralistic explanations are also of interest to philosophers in constructing an alternative to reductionistic and anti-reductionistic explanations (see, e.g., Mitchell 2003; Brigandt 2013; Brooks 2010).

problems that scientists investigate (cf. Love and Brigandt 2012). Though levels typically demarcate different kinds of things along its ranks such as ecosystems, organisms, molecules, it must also be taken into account that the phenomenon one seeks to explain is embedded among other natural systems whose workings flow into one another. The concept of levels is aids one in articulating this embedment. In particular, it reinforces the fact that the selection of a particular system as the basis for investigating and explaining a given phenomenon as a *choice* that is made by scientists. Once again, Reece et al.:

> "A system is simply a combination of components that function together. *A biologist can study a system at any level of organization*. A single leaf cell can be considered a system, as can a frog, an ant colony, or a desert ecosystem. To understand how such systems work, it is not enough to have a "parts list," even a complete one. *Realizing this, many researchers are now complementing the reductionist approach with new strategies for studying whole systems*. This *change in perspective* is analogous to moving from ground level on a street corner, where you can observe local traffic, to a helicopter high above a city." (Reece et al. 2010, 3)

The importance of this theme becomes especially clear when combined with the other themes discussed above. Namely, when nature is represented in the fashion communicated by the levels concept, the different features that make a given phenomenon (and its explanation) *biological* present together a bundle of commitments that portray how explanations should be conceptualized (Brooks 2014).

1.5 The Concept of Hierarchy

One feature that probably all[23] conceptions of 'levels of organization' share with one another is

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[23] Quantifying the extent to which the levels concept designates a hierarchical structure ("all" or "most if not all" conceptions of levels) is not going to be dealt with here. Three reasons for this avoidance: First, formalistic "definitional language" of this kind is exactly the way in which philosophical analysis of science can lose its way when looking at concepts like this (i.e. Wimsatt 1994[2007], 203-4; see above). Second, looking at the importance of *hierarchy theory* in the context of understanding levels is far too large a topic to open up here (unfortunately). This will have to wait for another day for now. Third, looking at hierarchies seen as a formal term is a red herring for understanding levels in science anyway (see Section 1.5.1 below)

that they share a *hierarchical structure*. A hierarchy is an arrangement of items that is stratified into interrelated subsystems (usually illustrated vertically), which can in turn themselves be further divided into further subsystems (Simon 1962[1996], 184). The horizontal strata of this structure, or *ranks*, denote subsystems that designate some value or quality that is being ordered by the hierarchical system to which it belongs.[24] Level ranks in a hierarchy are stratified in relation to one another as *superordinate* or *subordinate*, i.e. 'higher' or 'lower', depending on what value or quality specifies the ordering criterion. Taken strictly, a 'hierarchy' is a formal term with no immediate ontological or epistemic commitments. Rather, it is simply a means of ordering sets of real or abstract things according to an inter-relatable feature they possess.

A hierarchy can be more characterized in formal terms as a *partially ordered* set (see Figure 1.5), meaning that a hierarchy is a system composed of elements ordered into an antisymmetric, reflexive, and transitive relationship (See Figure 1.5b). In other words, the elements of some hierarchical system S may themselves include subsets of elements. So, the elements {a,b,c} that compose S may of course have numerous individuals within them, i.e. $\{\{a_1,a_2\}\{b_1,b_2\}\{c_1,c_2\}\}$.

Hierarchical structures highlight several of the intuitive characteristics of levels of organization depicted in Section 1.4. Consider an ecosystem in terms of a hierarchically-structured system. Firstly, ecosystems (S) 'are made of', or 'contain'[25] within them communities (a), communities contain populations (b), and populations are made of individuals (c). This can be rewritten as a successive subsumption of subsets that is characterized by the overall set S: { Ecosystems { Community { Populations { Individuals } } } }. This list of sets is reflexive, since each rank is reiterated at the next higher rank. That is, individuals compose not only populations, but communities and ecosystems as well. It is also anti-symmetric, since populations are not composed of ecosystems (or communities). This

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[24] Once this value or quality is defined, these ranks can be demarcated into '*levels'* when a population of elements manifesting these values can be quantified. 'Levels' in this *neutral sense* (i.e. *not* 'of organization')is nothing more than a population of individual elements that correspond to a specific position within a hierarchy.

[25] These scare-quoted terms are meant only to leave room open to articulating the criteria by which levels are defined as composition-based or scale-based.

means that the ordering relation that holds for this hierarchy (composition) is unidirectional. Finally, it is also transitive, because communities share the same compositional hierarchy with ecosystems in relation to individual.

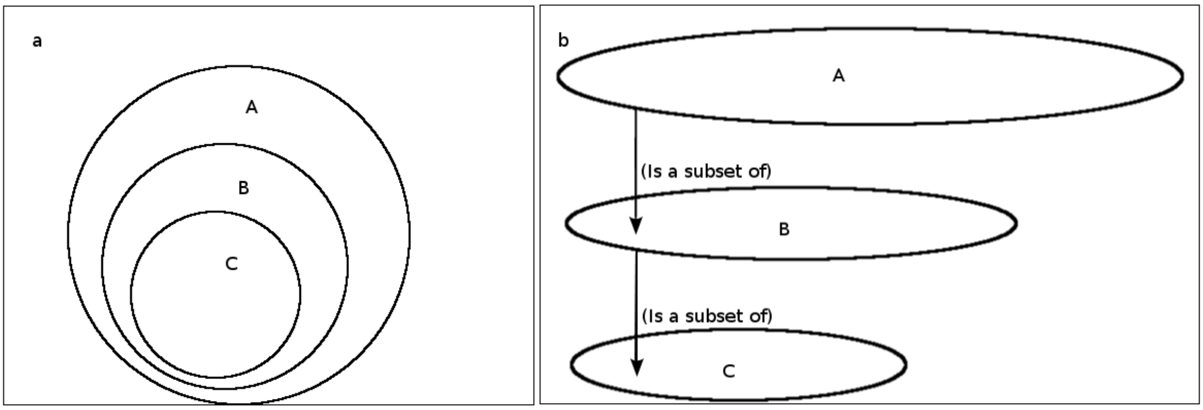

Figure 1.5 A hierarchy illustrated as a partially ordered set. In Figure 1.5a, One set (A) and it's two subsets (B and C) are given. In Figure 1.5b, this system is arranged into a hierarchy, meaning it is a partially ordered set. The structure in 1.5b is reflexive, because everything within it belongs to the overall set A; it is transitive, because B is a subset of A and C is a subset of B, hence C is a subset of A; and it is antisymmetrical, because B is a subset of A (and C is a subset of A), *but not vice versa*. One further note: This figure depicts a *nested* hierarchy, meaning that the subsets that constitute the hierarchy, meaning that each subset is a subset of the overarching set above it. This contrasts to a control hierarchy (not depicted here, which has bracket structure like a genealogical tree), which orders, or rather *sorts,* its elements according to some classificatory scheme (Salthe 1985, 9-10). Control hierarchies may be nested, but need not be, which leaves as an open question to what extent both of these kinds of hierarchies are distinct.

Hierarchical systems comprise a range of structural types (see Figure 1.6), depending on how each rank within the hierarchy is related to the next (Simon 1962[1996], 186). Simon distinguishes three kinds of branching structures among hierarchical systems. The first kind involves a *linear hierarchy*, where there is no branching between ranks. Ranks are related, as the name implies, linearly via a single connection. One example of a linear hierarchy is depicted in the *scala naturae*, or great chain of being, which purported to rank the grades of perfection from inferior non-living inanimate matter through humans to superior religious entities. The second kind of branching structure involves a *branching hierarchy*, in which there are at least two degrees of branching between ranks. The component subsystems of a branching hierarchy designate distinct subsystems that differ from one another. These subsystems may do different things, or at least designate different features that prohibit their co-variance in one single subsystem.[26]

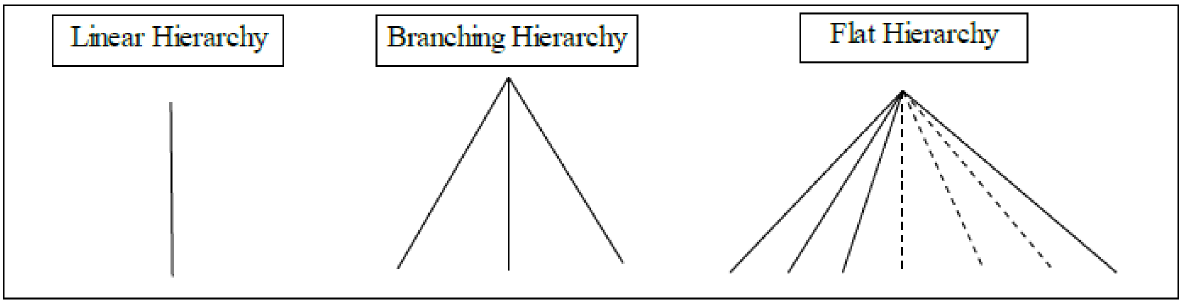

Figure 1.6 Types of Branching Structures in Hierarchies. See text for details.

An important question concerning the use of hierarchical structures as the basis for levels of organization concerns the content of the constituents that the hierarchy is expected to represent. Hierarchical structures, by themselves, are nothing more than a formal means of representing particular qualities that can be ranked into a partially ordered set. But *what* a hierarchical structure relates and *how* these things are related remain undefined by the application of *only* a *formal* hierarchy. These things need to be specified by the context in which it is applied. 'Levels of organization', on the other hand, designates a hierarchy whose elements comprise material entities or their features, or processes that populate the natural world. Hence, specifying further the hierarchical structure of 'levels' is done by clarifying how one understands the character of the levels concept (Section 1.4.1).

1.5.1 'Hierarchy' Does Not Exhaust 'Levels of Organization'

Though a hierarchical structure may be possessed by most if not all conceptions of levels of organization, the notion of a ‘hierarchy’ does not exhaust the concept of ‘levels’. Nonetheless, formal-based approaches focusing on hierarchies are sometimes taken to be exhaustive,

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[26] A third kind of branching structure, which will not be relevant in this dissertation, is a *flat hierarchy*. These kinds of hierarchies can have an indefinite to infinite number of lower-ranking elements. Allotropic forms of carbon such as graphite or diamonds constitute flat hierarchies, because the carbon atoms populate the first rank of their compositional hierarchies may span indefinitely. Likewise, samples of gas also constitute flat hierarchies, since the number of constituent gas molecules the make up the subordinate rank may be indefinite (*cf.* Aizawa and Gillet 2009).

exclusively sufficient, or otherwise privileged[27] in defining levels of organization in biology (Woodger 1929, ##; 1952; Bunge 1960, 1977b; Bossort *et al.* 1977; Kim 2002; Salthe 1985; 2009). Claims to this effect are typically statements of principle (Bossort *et al.* 1977; Salthe 2009) and/or responses to general criticisms of the levels concept, in particular the immense ambiguity that is attributed to it (e.g., Bunge 1960; Bossort *et al.* 1997; Kim 2002; cf. concerning ambiguity Craver 2007a 163; Potochnik and McGill 1012, 126). However, interpretations of levels that depend exclusively (or at least very heavily) on being explicable in the formalizable, set-theoretic terms of partially ordered sets fail to illuminate how scientists themselves conceive of levels (Section 1.3), and how organizational levels are used to aid scientists in analyzing and explaining complex phenomena (Section 1.4 and Section 1.5). This is problematic for several reasons. For one thing, it casts doubt on the legitimacy of the levels concept itself. To the extent that 'levels of organization' is directly translatable (and hence replaceable) to formally-defined set-theoretic terms (fleshed out perhaps by adding a few more assumptions concerning the types of relations its usage promotes), this leaves little motivation for acknowledging the concept's purported merit in contributing anything of its own to scientific investigation. Some are willing to bite this bullet (e.g., Kim 2002, 1-2), but this would mean abandoning the term 'levels of organization' as anything but a stand-in term for the purposes it is supposedly meant to fill. Nonetheless, formalistic approaches to explicating the levels concept leaves little room for the more particular aspects of scientists' particular interests in the usage of levels of organization in science (see especially Chapter 4).

Two further difficulties arise from focusing too heavily on formalistic conceptions of levels of organization. First, formalistic conceptions offer no account of the typical things that biologists wish to sort using levels of organization, nor how they are taken to be related. Hierarchical structures can organize many things into a stratified, level-like framework, encompassing both material and abstract content. Trophic levels in ecology, which rank the positions of organisms in the food chain, focus on abstract features concerning the energy consumption of many types of organisms that populate ecosystems. Likewise, corporations also rank individual people into a hierarchy based on abstract features based on, e.g., worker-

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[27] This is especially the case in the General Systems Theory literature, and in particular Hierarchy Theory, which, as mentioned above, unfortunately goes beyond the scope of the topics treated in this thesis. Another day.

boss relationships within that business, which in turn are elucidated by further abstract properties of those individuals such as power or control imposed on them in virtue of their membership to the system in question. On the other hand, material objects are also said to be divided into levels. Tissues and cells are both material things, and the interlevel relation that holds between them is taken to be an objective feature of the naturally occurring systems that biology studies. Stepping out of hierarchy theory, such abstract and material systems have very little in common with one another in terms of what motivates the particular scientific endeavors in analyzing them *as* hierarchically organized.[28] Similarly, the “making up” or “composing” relations between the subsystems and the whole system will be decisively different between varieties of cases. Secondly, formalistic conceptions of hierarchical structures cannot distinguish between different uses of the levels concept. The two common forms of hierarchical organization in biology include explanatory part-whole analysis of biological systems, and in classification schemes (Mayr 1982, 65; Grene 1987, 505). Though in both cases the tasks that scientists are undertaking are aided by implementing hierarchies to rank certain features, classification and explanation remain radically different epistemic enterprises. Formal criteria for articulating hierarchies, and hence levels, may hold across such different projects, but there must be some way of distinguishing such tasks within scientific practice, and more importantly the distinct issues that these tasks address (see Grene 1974).

In effect, reliance on formal-based approaches privilege formal philosophical approaches that emphasize conceptual analysis, which, for the reasons just mentioned, are not suitable for analyzing issues associated with the levels concept. Such claims reveal a bias in the usage of the levels concept towards reducing the issues uncovered here to a simple question of necessary and sufficient conditions; an issue, not surprisingly, best addressed using formal, analytic approaches. Formal-based approaches, by themselves, are not fruitful for understanding levels in biology, given the host of non-formal factors that motivate the use of levels in scientific practice.

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[28] The complexity of the respective systems is one feature that does justify abstracting away from the particular features of different kinds of systems, and analyzing their general, formal-based commonalities. Nonetheless, the extent to which complexity itself will hold generally over many different types of systems, and the sciences that investigate them, cannot be answered a priori. In fact, complexity is one of the central features that make 'levels of organization', rather than simply 'hierarchy', attractive in the first place.

More particularly, and ultimately, it can be said that given the issues introduced above, this dissertation is engaged in an entirely different approach to explicating the character and significance of the levels concept. The primary distinguishing point between the account offered here, and those of a more formalistic variety, can articulated in terms of methodology and in terms of the substantive issues that this works seeks to take up. Speaking first to the latter, it seems sufficiently clear that 'levels of organization' refers to a specific cluster of distinct ideas and practices concerning biological phenomena and the status of biology itself as a natural science, which cannot be captured by formalistic treatments of levels (Chapter 4 & 5; see also Grene 1974). Methodologically speaking, the interests motivating the analysis to follow diverge from what can, at quick glance, be taken up with the increasingly formal-based frameworks found in e.g. conceptual analysis. Instead, the issues addressed here will be taken up, specifically, in terms of an analytical project of analyzing biological concepts on the basis of their usage (Chapter 4), and in a 'synthetic' project that explicitly attempts to incorporate the rich but mostly forgotten (or ignored!) history of the concept's usage in biology in the twentieth century. It is a primary commitment here (by stipulation, not in-principle) the two cannot, or at least should not, be separated. In other words, and both methodological and analytically, 'levels' has a life of its own, prior to and ultimately outside of, studies of 'mere' hierarchies.[29]

1.6 The Structure of This Dissertation

The rest of this dissertation will be distributed into four chapters. Chapter 2 will offer an exegesis of the two most prominent conceptions of levels in philosophy. One of these, offered the layer-cake account of levels, was developed by Paul Oppenheim and Hilary Putnam in their famous (1958) paper defending the unity of science. Their conception of levels is

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[29] This is not to say that an analysis of the notion of 'hierarchy' would not offer significant contributions to the study of levels: indeed some of the intellectual forebearers of this dissertation (particularly Simon, and the authors of Pattee 1973) were instrumental in formulating the ideas articulated here. The point being made here is more the demarcation of the project laid out here, in *this* dissertation, which brings with it the requisite boundaries of space, time, and effort (see especially footnotes 23 & 27 above).

comprehensive in that they sought to offer a singular account by which to capture *all* instances of ‘levels’ in science. Moreover, it will be argued that the conception of levels emerging from the layer-cake account is in fact the default conception of levels in science, due to its widespread use by philosophers in the latter half of the 20th century. The other conception, offered in the mechanistic account of levels, is a rather new conception that was developed recently in the New Mechanist movement in the philosophy of science, and in particular by Carl Craver (2007a). This conception of levels follows highly contextualized approach to conceptualizing levels, and largely rejects the layer-cake account as a widely inaccurate conception of what levels are and how they are used in science.

In Chapter 3, a number of criticisms levied against the levels concept by philosophers and scientists will be discussed. As it turns out, there is a growing skepticism regarding the viability of the levels concept to perform any of the tasks that are often attributed to it. This *levels skepticism*, it will be argued, is in fact a result of the celebrity status of the layer-cake account, which itself is deeply problematic and designates the actual target of criticism by levels skeptics. Seen in this way, the criticisms of the levels skeptics turn out to be legitimate and sound, but fail to undermine the levels concept *in* general.

Chapter 4 will present an alternative account of levels, in which it will be argued that the levels concept exhibits a fragmentary character due to the modest incommensurability between particular instances of its usage. The *fragments* of the levels concept, i.e. the specific features that comprise the character of ‘levels’ within a particular instance document quite well the ‘package deal’ that the levels concept represents in biology. It will be further argued that despite this fragmentary character the levels concept exhibits a remarkably conserved significance across its instances of usage due to the well-defined epistemic goal that motivates the concept’s usage, i.e. to structure explanatory problems in biology. This account will be complemented by a detailed case study in biological research by turning to the construction of the explanation for oxidative phosphorylation by the chemiosmotic hypothesis offered by Peter Mitchell.

Finally, Chapter 5 will argue that the levels concept as it is used in contemporary biological research can be traced back to historical efforts of a group of researchers in biology during the opening decades of the 20th century known as *organicism*. The organicists, in particular a group centered in Cambridge known as the Theoretical Biology Club, are the ones responsible for developing and applying the levels concept as it is known today. This analysis will provide further justification for the fragmentary account of levels developed in Chapter 4. In particular, it will be revealed that the two insights offered by the fragmentary account, the fragmentary character of the levels concept and its overarching epistemic goal, are in fact products of the active development of the levels concept of the organicists working in Cambridge. Moreover, a distinct account of levels was even developed out of the organicists' efforts, though it remains largely unknown in philosophy, and largely forgotten in contemporary biology. This account, known as the *integrative account*, strongly resembles the fragmentary account, but due to the embedment of the former in debates present in biology at the time (especially the mechanist-vitalist dispute) the extent of this resemblance will be left as a historical observation that deserves further attention in the future.

Chapter Two: Philosophical Conceptions of Levels

2.1 Introduction

In philosophy, two conceptions of levels of organization are especially prominent. One of these conceptions stems from Oppenheim and Putnam (1958). This conception, known as the "layer-cake" or "pancake" account of levels, is rarely explicitly defended as such in writing, but continues to exert considerable influence in philosophical discussions. The layer-cake account of levels is characterized by its global scope, as well as (at least historically) by its association with the so-called unity of science thesis. This association has had far-reaching consequences for the concept of levels of organization. The other prominent conception of levels in philosophy stems from recent accounts of mechanistic explanation, particularly from Craver (2007a; 2007b; 2015), William Bechtel (w/ Craver 2007; 2008), and more recently by David Kaplan (2015). This account, which will here be called the mechanistic account of levels, defends a contextualized conception of levels that centers on defining what constitutes parthood within an explanatory mechanism. The mechanistic account of levels rejects all generalizability of claims involving levels to any overarching framework, and instead takes a particular level stratification to hold only in relation to a specific mechanism whose parts are distributed across different levels. Both the layer-cake and the mechanistic accounts of levels are defined in terms of compositional part-whole relations, though the way that each respective account understands these relations is significantly different.

2.2 The Layer-Cake Account of Levels

The "layer-cake" account of levels was first articulated by Paul Oppenheim and Hilary Putnam (1958) in their defense of the Unity of Science. This account of levels was developed to serve as a basis for articulating the micro-reduction relation by which the different branches of science reduce to one another as they move toward this Unity (Oppenheim and Putnam 1958, 9). This contextualization of the layer-cake account of levels in Oppenheim and

Putnam's larger project makes separating the two a subtle and complicated task. For one thing, without qualification, the “layer-cake account” can refer to both the account of levels, or to (several related) accounts of reductionism or anti-reductionism developed later by other philosophers, both of which link back to Oppenheim and Putnam's original publication.[30] This point will be returned to below.

A further point of complication concerns the extent of the layer-cake's presence in the philosophical literature. Exhaustively quantifying this presence in great detail would be both tedious and tangential[31]. Nonetheless, it is a valid observation that the layer-cake account widely persists in the philosophical literature as the default conception of levels of organization, and so will be discussed below (see Section 2.2.5; Section 3.3). This is particularly clear in the successor debates surrounding reductionism and anti-reductionism since the second half of the twentieth century (see especially Nagel 1961, ch. 11; Fodor 1972, 113; Kitcher 1984, 370-373; Churchland and Sejnowski 1992, 9, 15-17)[32]. Despite this widespread, if often tacit, acceptance of the layer-cake account, Oppenheim and Putnam's original (1958) paper remains the clearest articulation of the layer-cake account of levels, and so this section will focus on their developmental comments.

For Oppenheim and Putnam, the Unity of Science is an ideal state of science that would be realized when all the laws of science are reduced the laws of a single discipline (*ibid.* 4). The “layer-cake” moniker of their levels account has become a pejorative term for philosophers over time, due to the notorious problems identified in their argument for the Unity of Science, and their notion of micro-reduction. These problems have been well-documented elsewhere (see, for instance, Fodor 1974; Craver 2007a, ch.7), and do not deserved to be re-hashed here. Instead, this section will be solely concerned with the structure of the account of levels of organization arising out of this historical source, and its continued influence in the

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[30] In the text that follows “layer-cake account” will refer to the layer-cake account *of levels* unless otherwise noted.

[31] In Chapter 3 the presence of the layer-cake account in the nascent levels skepticism will be documented.

[32] The layer-cake account of levels is also prominent in other philosophical debates, particularly that of emergence and non-fundamental causality. The account is used in a very similar manner as here, and for this reason can for now simply be noted here.

philosophical literature. As a further exegetical note, Oppenheim and Putnam constructed their account of levels as a means of explicating their account of microreduction, which itself was used to explicate and defend their Unity of Science thesis (see especially Section 2.2.4 below). Hence, though their account of levels can be (and has been) extracted from these other two ideas, it is in this context that Oppenheim and Putnam articulate their conception of levels.

The layer-cake account of levels is illustrated below in Figure 2.1. In Oppenheim and Putnam's original (1958) paper, six different levels were postulated, but this list was left open with regard to what an exhaustive list of levels would look like.[33] The account is comprised of several characteristic features, all of which require short clarification. Subsequent references to the layer-cake model, both in reductionist and anti-reductionist contexts, have repeated these features, either in a modified form or for the purpose of criticizing them (Waters

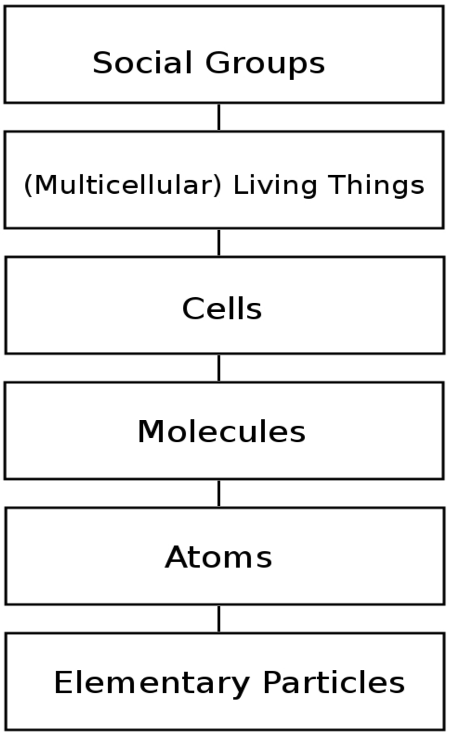

Figure 2.1 The layer-cake account of levels. See Text for Details.

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[33] Compiling an exhaustive list was not in their interest anyway, since the realization of Unity of Science would effectively eliminate all other scientific disciplines except for the most fundamental.

2010).These features include[34]:

1.) Global scope and comprehensive character: The scope of the account is unabashedly global, and is meant, strictly, to hold for all phenomena of the natural world. The account is also comprehensive, meaning that they took the structure of the world it postulated to hold *a priori*, i.e. before further empirical discoveries, for all instances where one could talk of levels (cf. Rueger and McGivern 2010, 381-2).
2.) Stepwise compositional continuity: All natural phenomena in the world are connected to each other via part-whole relations, and are exemplified stepwise at each level. Conversely, if something is a part of something, then it belongs to a level.
3.) Linearity of levels strata: Furthermore, the depiction of levels in the layer-cake account exhibits a non-branching hierarchical structure.
4.) Correspondence thesis: Each level designates a strong correspondence between a group of natural objects that together designate that particular level's rank, and a core scientific discipline that investigates, and explains, these phenomena.

2.2.1 Global Scope and Comprehensive Character

The scope of the layer-cake account encompasses the whole of nature. This is made clear by Oppenheim and Putnam in their characterization of the basic meaning of the Unity of Science thesis, for which their levels account is meant to present structure (1958, 3-4). Furthermore, the character of their account is *comprehensive*. That is, their conception of levels of organization is meant to encompass an exhaustive treatment of not only what levels of organization are *in all instances*, rather also how the things in the world that have not yet been discovered or described fits into its schema.

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[34] Of these features, stepwise compositional continuity and the correspondence thesis are the most "defining" characteristics of the layer-cake account (and, not coincidentally, the features most criticized of the account). Conversely, the presence of any *two* of these features are (definitely) sufficient for identifying any particular treatment of levels to be categorized as belonging to the "layer-cake" variety. In fact, the presence of any *one* of these feature (with the exception of linearity) is probably also sufficient to identify a conception as "layer-cake".

2.2.2 Stepwise Compositional Continuity

In addition to its universal scope, the layer-cake account claims that a *compositional continuity* exists in all natural phenomena from the subatomic to the cosmological. This means that all natural phenomena are related to each other by cumulative part-whole relations that are reiterated at each level. Additionally, and peculiar to the layer-cake account, there is a further condition that this compositional continuity of the world is structured in a *stepwise* fashion. This means that *all of* the so-called proper parts of a given whole at any given level L_n are located *exclusively* at the adjacent lower level of organization (L_{n-1}). This additional claim that the compositional continuity of the world is structured in a stepwise fashion is the source for the "layer-cake" moniker of the account.

Oppenheim and Putnam considered stepwise compositional continuity of levels of organization to be "an essential feature" of their reductionist-based argument for their Unity of Science thesis. Specifically, they utilize part-whole relations in their articulation of what a micro-reduction is, saying that "the objects in the universe of discourse of B_2 [the reduced branch of science] are wholes which possess a decomposition into proper parts *all of which* belong to the universe of discourse of B_1 [the reducing branch of science]" (Oppenheim and Putnam 1958, 6, emphasis added). This point is then repeated as a defining condition of a level, saying: "Anything of a given level except the lowest *must possess a decomposition into things belonging to the next lower level*" (ibid. 9, emphasis added). These passages highlight stepwise compositional continuity as probably the most important defining feature of the layer-cake account: The different levels of organization (summarized by their respective scientific branch B_n when speaking of micro-reduction), which together represent all the natural entities that populate the world, lie stacked on top of one another, demarcated by their respective universes of discourse.

This feature of the layer-cake account has three important implications that will be returned to later, particularly as points of criticism in the nascent skeptical arguments against the viability of the levels concept (see Chapter 3). First, for any given whole, the parts that compose it located at L_{n-1} *exhaustively* compose that whole. Second, this holds for not only given wholes, but also for entire levels: The totality of things located at a particular level of organization can be exhaustively decomposed into parts that are exclusively located at the neighboring adjacent level. Consequently, the image of nature that emerges from this depiction of levels is one in which each rank of the levels hierarchy can be cleanly demarcated from the other, giving the appearance of a layered cake (especially in illustrations, see figure 2.2).

The third consequence of stepwise compositional continuity, which follows from the first two consequences, is that each level of organization is both ontologically necessary and epistemologically sufficient to account for other levels. Ontologically speaking, the existence

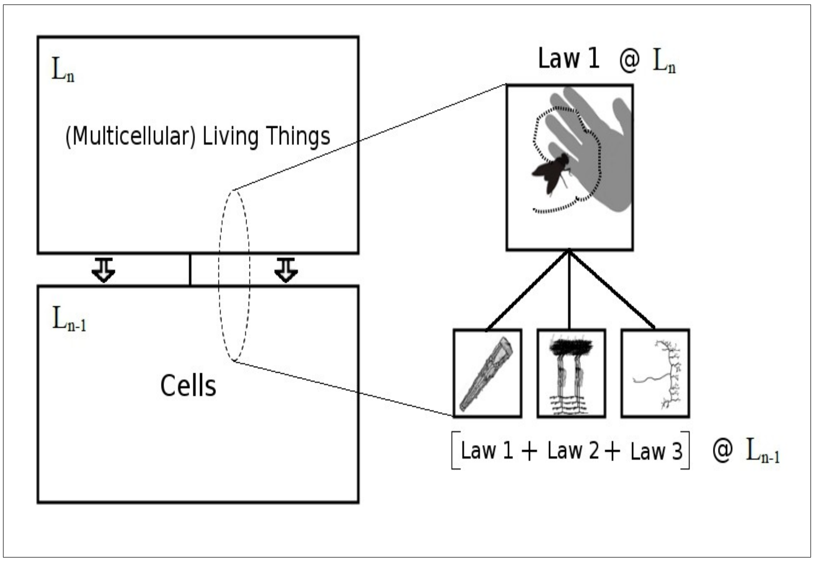

Figure 2.2 The microreduction relations in the layer-cake account. The left side depicts part of the hierarchy of levels represented by the layer-cake account illustrated above in Figure 2.1. The right side depicts a particular hypothetical microreduction that Oppenheim and Putnam argue is supported by their account. This microreduction entails deriving a higher-level law (here, “Law 1 @ L_n”), which corresponds to one entity at that level (say, in-flight navigation of a flying insect), from a number of other laws (here “[Law 1 + Law 2 + Law3] @ L_{n-1}”), which correspond to a number of proper parts of the respective whole to which they belong. For the layer-cake account, only the laws concerning each of these respective items matter, and, more importantly, these singular microreductions coalesce into a reduction of the entire level (and all of the entities in its universe of discourse. Hence, the branching structure of the hierarchy depicted in the image on the left can be misleading concerning the overall structure of levels of organization in the layer-cake account (see Section 2.2.3).

of each level (and, *ipso facto*, the things populating that level) depends necessarily on each level below it (except for a postulated "fundamental" level that bottoms-out the global hierarchy). This is a direct consequence of the claim that each level (and specifically the things populating that level) is *exhaustively* composed of things at the adjacently located lower level. Epistemologically speaking, the corresponding theory or theories that explain a particular level L_{n-1} is in itself sufficient for reducing the theory or theories located at the level of interest (L_n).

This, in turn, prohibits that levels can be "skipped", either ontologically or epistemologically, and is also meant to hold in-principle.[35] Oppenheim and Putnam specify:

> "We maintain that each of our levels is *necessary* in the sense that it would be utopian to suppose that one might reduce all the major theories or a whole branch [of science] concerned with any one of our six levels to a theory concerned with a lower level, skipping entirely the immediately lower level; and we maintain that our levels are *sufficient* in the sense that it would not be utopian to suppose that a major theory on any one of our levels might be directly reduced to the next lower level" (Oppenheim and Putnam 1958, 10, emphasis added).

Though the layer-cake account is vital for understanding theoretical reductionism (and anti-reductionism), it should be noted that the primary condition that Oppenheim and Putnam required to hold for their account of micro-reduction was the ability of one scientific discipline (B_1) to account for the content of another scientific discipline (B_2), following the Kemeny-Oppenheim definition of reduction to which they subscribe.[36] This is significant in that stepwise compositional continuity also holds between the *scientific disciplines* corresponding to levels of organization[37] highlights the conceptual distinctness of the account of levels that they develop from the rest of their Unity of Science project: Though levels of

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[35] However, Oppenheim and Putnam do hold that levels may be skipped for the sake of convenience (*ibid.*).

[36] Kemeny-Oppenheim reduction requires that, between two candidate lower- and higher-level theories, scientific theories T_1 and T_2 (respectively), the lower-level theory T_1 can explain the same phenomena better than T_2.This of course assumes that both theories attempt to explain the same set of observational data.

[37] In virtue of the correspondence thesis, see below.

organization, in virtue of the part-whole relations by which they are defined, are essential to understanding how reductionism will bring about the Unity of the Science,[38] the structure of nature as represented by the levels concept in the layer-cake account is, strictly speaking, postulated as an independent fact. In this way, reference to the layer-cake account is often treated both as a representation of the structure of the world and of the structure of science. Both of these ideas subsequently became entangled with the levels concept.

2.2.3 Linearity of Levels Strata

The layer-cake account of levels also exhibits a linear structure, with no branching between its strata. This is visible in both Figure 2.1 and Figure 2.2. The individual elements of each level of organization (i.e. the entities that belong to, e.g., the "level of the cell") are allotted a specific place in the hierarchy of nature, and accounted for by a "natural law" that accounts for that element's dynamics and behaviors. So, for each entity in nature, an exhaustive, lawlike statement can be given (at least for an ideally complete science). However, the picture is complicated by the observation that this seems to necessitate a branching structure between levels, since one whole is made of many parts. Nonetheless, the layer-cake account represents levels of organization in a linear manner (Oppenheim and Putnam 1958, 9; see also Craver 2007a, 172-173). The reason for this is that the particular relations between specific parts and wholes are unimportant to Oppenheim and Putnam's conception of levels. Rather, what is important is the overarching, generalized reductionist relation from the atomic to the cosmological, and the only way to capture such coarse-grained relations is to abstract away from the minute details of singular phenomena.

The linear structure of levels is a consequence of two aspects of the layer-cake account. The first is the account's stepwise compositional continuity feature, which, as just seen, separates levels into strictly demarcated part-whole relations that are represented in a stepwise fashion. The second aspect, mentioned briefly above, is the identification of levels with a specific

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[38] This is accomplished by designating a "potential microreducer", see Section 2.2.4.

"universe of discourse". The idea of a "universe of discourse" is meant to represent the total set of "things" that are studied by a given branch of science (ibid. 6). Oppenheim and Putnam referred to six different universes of discourse, which were illustrated above in figure 2.1.[39] These universes of discourse summarize the (lower-level) parts or the (higher-level) whole when then contrasted with their respective adjacent levels.

In Figure 2.2 above, this image is juxtaposed to a hypothetical token case of microreduction (i.e. the left side), wherein a branching structure is present. However, this kind of branching is misleading as a representative observation of the layer-cake account. As mentioned above, the various organizational levels are meant to ultimately be represented as a singular sets, which constitute the different "universes of discourse" of each distinct level and its corresponding science (see Section 2.2.4). Moreover, given the stepwise fashion by which one moves between levels in the layer-cake account with microreductionist framework in which Oppenheim and Putnam operate, this also excludes any significant branching between levels of organization. The universe of discourse to which a branch of science belongs is then used to identify the level to which it belongs. (ibid. 9)

Like compositional continuity, the linearity of the layer-cake account seems to be a corollary to the account of (micro-)reductionism that the account is meant to explicate. For the Unity of Science thesis to work, according to Oppenheim and Putnam, each universe of discourse, or rather each level of organization, must be reducible to the next without "skipping" any of the intermediate levels (see above). This epistemic necessity of each level, represented in the account by coalescing the various single disciplines located at each level into one singular branch B_n, coupled with the layer-cake account's universal scope and inherent commitment to the Unity of Science, makes this simplification of the structure of nature understandable. More specifically: Understandable, but not justifiably. By abstracting away from the particular entities in nature, and their specific compositional relations, these entities lose their distinctness, and are homogenized into a large clump of 'details' to be clarified as either reducible or irreducible (depending on which position one defends). This feature of the layer-

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[39] That this list is not exhaustive is unimportant, as the authors themselves were aware that their list was tentative.

cake account, as will be seen, is also widely disputed by critics of the account.

2.2.4 Correspondence Between Nature and Science

The layer-cake account of levels postulates a strong correspondence between the entities of nature represented by levels and the sciences that investigate these entities. In its strictest form, this *correspondence thesis* postulates more than just a passing association between nature and the study of nature. Rather, this correspondence postulates a 1:1 relation between a particular level of organization and a specific scientific discipline that investigates this level. This feature of the account, in addition to its claim of stepwise compositional continuity, is the most controversial features of the layer-cake account. Nevertheless, philosophical arguments in which the concept of 'levels of organization' is referenced, such as those for or against reductionism or anti-reductionism, often rely substantially on this feature of the layer-cake account for their constructive or critical comments (Churchland 1986, Ch. 7; Churchland and Churchland 1992; Waters 2010, 240)[40]. This reliance can already be seen in Oppenheim and Putnam's paper, where they heavily cite their levels framework as support for their notion of micro-reduction. As they say:

> "The *essential feature* of a micro-reduction is that the *branch* [of science] B_1 deals with the parts of the *objects* dealt with by B_2. We *must* suppose that *corresponding to each branch* we have *a specific universe of discourse* U_{Bi}; and that we have a part-whole relation, Pt [between these branches]." (Oppenheim and Putnam 1958, 6, emphasis added)

This passage highlights the strong form of correspondence that the authors took to hold between science and nature. In advocating the correspondence thesis, the "universe of discourse" attached to a branch of science becomes a stand-in term for a proper level of organization, as the two terms 'branch of science' and 'universe of discourse'become inter-

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[40] This point will be discussed in detail in Chapter 3, particularly Section 3.3.

defined with 'levels' in Oppenheim and Putnam's account.[41] However, the correspondence thesis introduces an especially problematic element of ambiguity to the levels concept. This ambiguity concerns what is represented by levels of organization in the first place: Do levels of organization represent things in the world that science investigates or do they represent epistemic tools of science that investigate nature?[42]

Whether the ontological ordering of things in the world or the epistemic ordering of the sciences and products of science should take precedence is not initially clear. The primary emphasis of Oppenheim and Putnam's original paper is clearly on articulating and defending their Unity of Science thesis, for which they offer their notion of microreduction in rder to illustrate how this Unity will be achieved. In turn, their account of levels is offered as a means to both explicate *and* defend their account of microreduction. Unfortunately, this is where the blurring of distinct ideas and concepts with the levels concept begins. Take, for instance, Oppenheim and Putnam's use of levels (here in the form of "composition" and "decomposition" as a means of *justifying* their account of microreduction. This is accomplished by designating a "potential microreducer", which exploits the levels concept in order to posit independent, tentative evidence that microreduction between different branches of sciences is possible (or probable). This is visible in the following passage:

> "We shall say that a Branch$_1$ is a *potential micro-reducer* of a Branch$_2$ *if the objects of the universe of discourse of* B_2 *are wholes which possess a decomposition into proper*

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[41] One caveat to this observation must be made. Oppenheim and Putnam expected the number of "core disciplines" covering the level hierarchy postulated by the layer-cake account to shrink over time as science came closer and closer to its reductionist Unity. Hence, the disciplines that correspond to the entities in nature (and summarized by their universes of discourse) constitute a transient set of epistemic constructions as "simplifying reductions" worked to coalesce the diverse disciplines of science into a representative *hard core discipline*. So, in reality, Oppenheim and Putnam expected the number of scientific disciplines to shrink: "[Following simplifying reductions in the process of the realizing Unity of Science] we often encounter a division into simply physics, biology, and social sciences" (1958, 28).

This would appear to have peculiar consequences for the levels of organization that are postulated to hold in nature, independently of science. Specifically: If the number of scientific disciplines shrinks over time, what will remain of the corresponding organizational levels in nature? Levels, understood as the universes of discourse manifesting the phenomena studied by science, will surely not disappear, despite any epistemic trends in philosophy or science. This would require that the new emerging disciplines constituting science would become increasingly multi-level and, consequently, the correspondence between science and nature would have to be modified to account for this trend.

[42] Craver (2007a, 174-6) has pointed this out, and takes it as a primary point of criticism against the layer-cake account. See Section Section 2.3.2).

> *parts all of which belong to the universe of discourse of B_1*. The definition *is the same as* the definition of 'micro-reduces' except for the omission of the clause 'B_2 is reduced to B_1'" (Oppenheim and Putnam 1958, 6; see Section 2.2.4.

This could speak for the precedence of the epistemic ordering of the sciences as the primary contribution resulting from the layer-cake account of levels. However, this contradict the underlying ontological connotation of levels, observed through the articulation of levels as encompassing (ontologically) distinct universes of discourse hierarchically connected by its compositional continuity.

Ultimately, the layer-cake account (given the correspondence thesis) emphasizes that both the ontological and epistemic modes of representing levels offer significant contributions to philosophy and science (see below). Remaining again with Oppenheim and Putnam, this was indeed the perceived contribution proffered by the original authors of the layer-cake account (independently of its role in structuring their reductive approach to the Unity of Science). Because of the correspondence thesis, a general structure of science that reliably reflects the structure of the world could be constructed (or so they thought). First, speaking to the epistemic ordering, they say:

> "The idea of reductive levels employed in our discussion suggests what may plausibly be regarded as a natural order of sciences. For this purpose, it suffices to take as 'fundamental disciplines' the branches corresponding to our levels [see figure 2.1 above]. It is understandable that many of the well-known orderings of things have a rough similarity to our reductive levels, and that corresponding orderings of sciences are more or less similar to our order of 6 'fundamental disciplines'" (Oppenheim and Putnam 1958, 28)

This affirmation of the layered structure of science, Oppenheim and Putnam claim, follows the layered structure of nature, as expressed by their layer-cake account because the former derives its justification by reliably representing the actual structure of the world. They continue:

> “But these other [historical][43] efforts [at structuring science] have apparently been made on more or less intuitive grounds; it does not seem to have been realized that *these orderings are 'natural' in a deeper sense*, of being based on the relation of potential micro-reducer obtaining between the branches of science” (*ibid.* emphasis added)

Modeling the structure of science on the structure of the natural world is offered by Oppenheim and Putnam as a novelty that had apparently been missed by others who have defended a similar structuring of science. Though this is a dubious claim to make in contemporary times, it is important for present purposes to see how the interwoven claims made by the layer-cake account continues to influence philosophical usage of the concept of levels. Perhaps Oppenheim and Putnam's dual-treatment of levels is simply a device with to make room or the Aristotelian tasks of philosophy, which, using their dual-treatment of levels, are actively coordinated with one another. Whichever interpretation one takes on concerning what levels fundamentally represent, it will have a corresponding structure already prepared for it, and vice versa.[44]

2.2.5 The Continued Influence of the Layer-Cake Account

The influence of the layer-cake account of levels is difficult to quantify definitively, due to its intricate entanglement with so many other particular ideas and general debates. The image of the world mediated by the layer-cake account of levels used by Oppenheim and Putnam to justify their account of microreduction, which was in turn used to achieve the Unity of

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[43] Oppenheim and Putnam do not offer a precise analysis of historical predecessors to their layer-cake account of science, but they do cite Ludwig von Bertalanffy and Auguste Comte as predecessors expressing a similar, hierarchical, representation of the sciences (Oppenheim and Putnam 1958,; 29f, 32f, respectively).

[44] More particularly, the respective ontological and epistemic orderings that Oppenheim and Putnam take levels to represent resembles Aristotle's distinction between *first* philosophy and *second* philosophy. That is, respectively, the study of what exists (ontology) and the study of that which studies existence (science, or rather Aristotelian physics) (cf. Bodnar 2012). Aristotle, like Oppenheim and Putnam, also argued for the simultaneous necessity of both enterprises (ibid.).

Science (for a critique of the Unity of Science, see, for instance, Fodor 1974; 1975, 10-12; Dupré 1993, 88; Steel 2004, 60). Unity of Science is achieved by constructing an ultimate theory of physics that collects all of the laws of science, corresponding to all levels of organization in the world, into one theory. This seems to result in the non-existence of any level of organization above the most fundamental: Since, according to Oppenheim and Putnam, the disciplines of science (which strictly correspond to those in nature) will eventually “reduce” to another discipline located at the level adjacently below it, levels seem to disappear as well (cf. Carrier and Finzer 2006, 271). For this reason, the Unity of Science, at least in this form, is not considered defensible in contemporary philosophical discussion.

Far more important than the levels concept's association with the Unity of Science is its subsequent and questionable association with various accounts of theoretical reductionism and anti-reductionism. This trend continued with later accounts of reduction, particularly in the debates surrounding Ernest Nagel's account of theoretical reduction (1961, ch. 11), which invigorated the discussion concerning theoretical reductionism.[45] Though whether, or the extent to which, Nagelian-inspired accounts of reduction can, or should, be associated with any conception of organizational levels is an open question, the layer-cake account is widely present in the literature surrounding reductionism in the biological sciences in general (see especially Beckner 1959, ch.9)[46].

This association of the layer-cake account of levels with reduction and reductionism has already been established in conjunction with Oppenheim and Putnam's (1958) paper. In a

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[45] It is a matter of debate to what extent Nagelian reduction needs to be associated with levels of organization at all. Raphael van Riel's recent (2011) defense of Nagel offers an especially clear articulation of what is required for Nagelian reduction, and implies that there is no strong *analytic* association with levels of organization at all (van Riel 2011, 270). This view is not without precedence, and other well-known defenses of Nagelian reduction have also avoided references to the levels concept (e.g., Schaffner 1967; Hooker 1981). However, it is also true that certain articulations of Nagelian-inspired reductionism have a vested interest in attaching Nagelian reduction with the notion of levels (e.g., Churchland and Churchland 1992). Looking to antireductionist positions, the role of levels is more clearly present, particularly as a vital background condition against which to articulate what reductionist and anti-reductionist positions amount to (e.g. Kitcher 1984; Jackson and Petit 1992).

[46] This controversy is exacerbated by both (1) Nagel's tendency to treat himself to levels-laced language in talking about the reduction relation (see, e.g., his treatment of the reduction of thermodynamics to statistical mechanics, Nagel 1961, 342) and (2) Nagel's own preoccupation with part-whole analyses in biology, which he took to be vital for capturing biological theorizing and explanation (see especially ibid., ch. 12).

similar fashion, the layer-cake account is especially prominent in accounts of anti-reductionism in biology. C. Kenneth Waters (2010), in criticizing the reductionism-anti-reductionism discussion in biology, identifies the layer-cake framework as a principal identifying feature of the debate, saying: “Layer-cake antireductionism is the dominant view among philosophers interested in this debate [of reductionism vs. antireductionism]” (2010, 244; Section 3.3; cf. also Love and Brigandt 2010). This point is exemplified quite clearly in Philip Kitcher's influential (1984) paper criticizing theoretical reductionist approaches in biology. In the following passages, Kitcher lays out an explicit place for levels of organization, and more specifically the layer-cake account, in his defense of anti-reductionism. This affirms several of the account's defining features, particularly its global scope and the correspondence thesis between the ordering of the world and the ordering of science[47]:

> “[One] ought to allow that, in the current practice of biology, nature is divided into levels which form the proper provinces of areas of biological study: molecular biology, cytology, histology, physiology, and so forth” (Kitcher 1984, 370).

This one statement identifies quite clearly a conception of levels that closely follows the layer-cake account. Like the reductionists, subscription to the concept of levels is not one of mere convenience, but rather a central premise in Kitcher's argument for anti-reductionism:

> “So far, anti-reductionism emerges as the thesis that there are autonomous levels of biological explanation. *Anti-reductionism construes the current division of biology not simply as a temporary feature of our science stemming from our cognitive imperfections but as the reflection of levels of organization in nature*”[48] (ibid. 371, emphasis

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[47] One feature of the layer-cake account that is conspicuously absent in Kitcher's paper is the stepwise condition of layer-cake compositional continuity. This is understandable, since the reductionism debate in biology has traditionally focused on whether Mendelian genetics can be reduced to molecular genetics. Correspondingly, the organizational levels that are identified in this tradition are, respectively, chromosomal and cellular levels, and the molecular levels. This focus was established by Schaffner's original (1967) reductionist claim that the former was in the process of Nagel-reducing the latter. The span between these respective levels is rather disparate, and for this reason the stepwise condition in which reduction was conceptualized by Oppenheim and Putnam is irrelevant to the debate that was later pursued.

[48] A similar argument was made by Jerry Fodor, in his direct rejoinder to Oppenheim and Putnam's Unity of

modified).

So, the concept of levels also plays a central role in the articulation of the anti-reductionist position. In particular, it communicates a thesis about the structure of the world and of science, against which the *denial* of reductionist claims is justified. This, interestingly, mirrors the arguments of Oppenheim and Putnam above. This affirmation of the layer-cake account by Kitcher is especially significant, because it highlights an overarching goal of applying the concept of levels of organization *in any form*. Specifically, the usage of the levels concept is a means of giving structure to the problem it is utilized in engaging, namely, the problem posed by the competing reductionist and anti-reductionist theses of science and the world (see Chapter 4, for more on this point as concerns the use of levels in science). Anti-reductionists like Kitcher (1984), like their reductionist counterparts, hence rely heavily on the levels concept, and particularly the layer-cake account, in order to give structure to the problem that they collectively engage, and to articulate their proposed respective solutions to this problem:

> "*[T]o the extent that we can make sense of the present explanatory structure within biology – that division of the field into subfields corresponding to levels of organization in nature – we can also understand the antireductionist doctrine.* In its minimal form, it is the claim that the commitment to several explanatory levels does not simply reflect our cognitive limitations" (ibid. 373, emphasis added)

The entanglement of the organizational levels as depicted by the layer-cake account with so many other positions and ideas offers a tentative explanation for the rampant ambiguity associated with the levels concept, at least in philosophy. As will be seen in the next chapter, much of the criticism heaped upon levels of organization as a nonviable theoretical concept is a result of the ideas stemming from the layer-cake account.

Science hypothesis (rather than their account of micro-reduction): "I am suggesting, roughly, that there are special sciences not because of the nature of our epistemic relation to the world, but because of the way the world is put together" (1974, 113). This supports the claim here that the structure of the world, as represented by the layer-cake account of levels, is a leverage point in the argumentation for both reductionist and anti-reductionist arguments. It should be said, though, that although Fodor's argument can, like Nagelian reduction, also arguably be made without reference to levels, Fodor still engages in levels-laced language to bring his point across (see, e.g., Fodor 1974, 112; and especially Fodor 1997, which is, in contrast to the former, completely saturated with references to levels).

2.3 The Mechanistic Account of Levels

Organizational levels are also a central element to the currently popular “New Mechanistic” approach to explanation in the biological sciences (Craver 2007a, Ch. 5; Bechtel 2008; Bechtel and Richardson 1993[2010], Introduction, Ch. 2). According to mechanist approaches, explaining a phenomenon proceeds by showing how it was produced by its component parts and activities (Machamer *et al.* 2000; Craver 2007a; Bechtel and Richardson 1993[2010]). Constructing such an explanation proceeds, approximately, in three steps: by characterizing the phenomenon of interest, identifying the component parts and activities responsible for the phenomenon, and describing the kinds of organization between the mechanism’s components. In turn, this often entails postulating a number of levels of organization, across which these items are distributed.

The usage of levels of organization in mechanistic explanation is much more streamlined than that found in the layer-cake account. Specifically, the levels concept is utilized as a means for explicating the structure of a mechanism, and thereby the structure of explanations in the biological sciences (see especially Craver 2001; Craver 2007, 163-164; Bechtel 2008, 22). However, the overall significance of the concept for the biological sciences is of secondary importance to the mechanists. The more important issue for mechanist philosophers is a working definition for the concept of a “mechanism”, and showing how exactly mechanisms contribute to a philosophical understanding of how explanations are constructed in science (Machamer *et al.* 2000; Bechtel and Abrahamsen 2006; Craver 2007a. Ch.4).

For this reason, the discussion of the mechanistic conception of levels in this section will serve primarily as an initial contrast to the layer-cake account discussed above. As will be seen here, the conception of levels developed by the mechanistic account is too narrow to serve for a general analysis of the levels concept in science or philosophy, at least outside the context of discussing (New) mechanistic explanation. Markus I. Eronen (2013, 2014) agrees with this conclusion (Eronen 2013, 1047), and has offered a number of compelling arguments that the mechanistic conception of levels is problematic. In its place, Eronen argues for a deflationary approach to the mechanistic account of levels. His motivation for this is that contextualized accounts of levels, and in particular the mechanistic account (Eronen 2013, 1044), typically utilize the label of "levels" as a stand-in term for another criterion for distinguishing between, or for relating, objects and processes, such as composition or scale (ibid. 1048-50). However, neither scale nor composition is synonymous with talk of levels, and without specifying clearly what "levels" refers to in a certain context, there is a strong tendency for this loose levels-talk to allow confusing and inconsistent ambiguities to creep into the discussion. (Eronen, 2014, 17) By referring to 'levels' when in fact the account in question requires *nothing more* than a way of, e.g., specifying part-whole relations or differentiating between kinds of interactions that occur at certain scales, this begs the question as to what the usefulness of levels can be in the first place (cf. Ch. 3 below). A significant part of the ambiguity that surrounds the concept of levels is hence preserved when an argument for the topic in question (like mechanistic explanation or downward causation) is developed in terms of levels, but another more precise notion clearly does all of the conceptual work. Therefore, Eronen concludes, the mechanistic conception of levels "is too limited as a theory of levels" to be of much use (Eronen 2013, 1047).

A mechanism is hierarchically arranged, and its elements stand in a part-whole (compositional) relationship with one another (Craver 2007a, 7, Ch. 4). These elements, comprise the mechanism's working parts[49], and are organized together in a way that produces the phenomenon. The total set of component parts and activities composing a mechanism in turn designate several levels of organization within the system of interest. The components (and derivatively the organizational levels at which these components are occupied) that are designated for a particular explanation are so designated only relative to the phenomenon for which the respective mechanism is described. A schematic for a multi-level mechanism is illustrated in below figure 2.3. Lower levels in this hierarchy are the components in mechanisms for the phenomenon, which is located at the highest level of the hierarchical

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[49] "Working parts" is a technical term in the mechanist literature. It stands for, briefly, only the individual components that interact within a particular mechanism that contribute to producing the phenomenon

layout.

This account of levels is markedly different from the layer-cake account. One of the most prominent observations, in fact, of the mechanistic account of levels is the tendency of its proponents to outright reject as much similarity to the layer-cake account as possible. The characteristic features that will be discussed here include the following:

(1) Local Scope and Radically Contextualized Character: According to the mechanistic account, levels are local in scope, and contextualized in character; that is, levels are not generalizable beyond the particular mechanism in which they are postulated. The character of mechanistic levels is radical in that levels can only be postulated relative to a phenomenon for which a mechanistic explanation is sought. This is the most significant feature of the mechanistic account of levels, and distinguishes it strongly from the layer-cake account.

(2) Principled Rejection of the Correspondence Thesis: The mechanistic account also rejects, principally, any significant correspondence between nature and science that resembles the correspondence thesis of the layer-cake account. This rejection also holds generally for any levels-mediated ordering of science, independently of the question whether the structure of science and nature are associated.

(3) Branching Structure: Unlike the layer-cake account, the mechanistic account of levels exhibits a branching structure, where the parts that compose the whole mechanism are distributed along different level stratifications. More importantly, the branching structure between levels signifies that particular parts at a given level are not uniformly related to one another outside of their particular relation to the whole to which they all belong.

(4) Constitutive Relevance: Levels of a mechanism are related via compositional relations, and what counts as a component of an explanatory mechanism is defined by its relevance in producing the phenomenon. This underlines the mechanist attitude that levels are explicitly ontological, not epistemic.

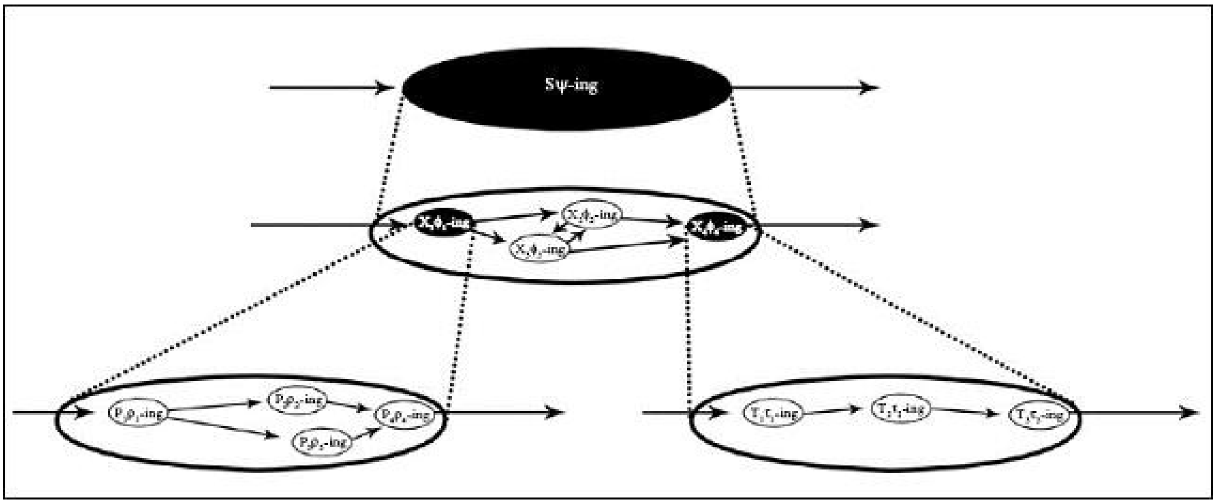

Figure 2.3 A multi-level mechanism with mechanisms as its components. The highest level (L_{n0}) represents the phenomenon (S_Ψ). The descending levels below the phenomenon designate a compositional hierarchy highlighting the relevant components required to produce the phenomenon occurring at (L_{n0}). Descending one rank, the next level below the phenomenon (L_{n-1}), the phenomenon may be decomposed into a set of parts (X_{1-4}) and activities (Φ_{1-4}). These things are in turn further decomposed into things at still lower organizational levels than the X_Φ level, which include, respectively, other parts and activities (namely, P_{1-4} and $\rho_{1-4,}$ and T_{1-3} and τ_{1-3}). These levels are then organized together to form the explanatory mechanism. Figure from Craver 2007a, 194.

2.3.1 Local Scope and Radically Contextualized Character

The first characteristic feature of the mechanistic account of levels is its *local scope* and *radically contextualized* scope. For the mechanistic account, 'levels of organization' only make sense in the context of a specific mechanism. More particularly, levels of organization can only be explicated relative to a particular phenomenon for which a mechanism is described. Carl Craver, one prominent proponent of the New Mechanist philosophy, articulates this feature of levels thusly:

> “[L]evels of mechanisms are far more local than the [layer-cake] image suggests. They are defined *only within a given compositional hierarchy*. Different levels of mechanisms are found in the spatial memory system, the circulatory system, the osmoregulatory

> system, and the visual system. How many levels there are, and which levels are included, are questions to be answered on a case-by-case basis by discovering which components at which size scales are explanatorily relevant for a given phenomenon. *They cannot be read off a menu of levels in advance*...My central point is that levels of mechanisms are defined componentially within a hierarchically organized mechanism, not by objective kinds identifiable independently of their organization in a mechanism." (Craver 2007a, 191; emphasis added)

Consequently, the character of the levels concept according to the mechanistic account, i.e. what levels can be taken to mean, is also radically contextualized. Claims involving a particular layout of levels, which is identified in terms of explanatory relevance (see Section 2.3.4) for detailing a particular mechanism cannot be extrapolated to other phenomena that, e.g., make reference to the same kinds of structures for its respective explanation. This immediately distances the mechanistic conception of levels from the layer-cake account. In contrast to the layer-cake account, the mechanistic account introduces the levels concept only insofar as it aids in uncovering the structure of a (particular) explanatory mechanism. This means that however a level is identified in a specific case, any claim regarding levels is only meant to hold *with respect to that particular case, to that particular mechanism*.

Indeed, the motivation for this radically contextualized approach to understanding levels is often expressed as a strong antipathy to the features of the layer-cake account. In this regard, advocates of the mechanistic account of levels sometimes argue as if any generalizability implies a commitment to Oppenheim and Putnam's (1958) conception of levels. Craver, for instance, clarifies the appeal of the mechanistic conception of levels in terms of its rejection of the layer-cake account. He says: "The idea of monolithic [layer-cake] levels of nature that I reject can be generated by abstracting from interlevel relations among particulars to interlevel relations among types". (Craver 2007a, 191). For this point, Craver introduces three different statements that make the contextualized approach of the mechanistic account clear. These statements include:

> “(a) *This* pyramidal cell is at a lower level of mechanisms than *this* hippocampus.
>
> (b) Pyramidal *cells* are at a lower level of mechanisms than *hippocampi*.
>
> (c) *Cells* are at a lower level of mechanisms than *organs*.” (ibid. emphasis added)

Claims involving levels in the mechanistic account include those like (a), which is strongly constrained to a certain cell in a particular hippocampus. Claims like (b) and (c), on the other hand, are identified by Craver as typical of “monolithic” accounts of levels like the layer-cake account.[50] Claims like these are unacceptable, he argues, because they contain an inherent ambiguity in them whereby it becomes unclear whether a global statement about the world is hidden within such claims (ibid. 192). More specifically, Craver is worried that claims like (b) and (c) can be interchangeably interpreted with the following claims: “(b1) The pyramidal cells that compose hippocampi are at lower levels than hippocampi, and (b2) *All* pyramidal cells are at a lower level than *all* hippocampi” (ibid. 191, emphasis added). While (b1) is “unproblematic and consistent” with the mechanistic account, claims like (b2) simply make no sense, because there is no embedding mechanism to give the things organized by levels in these claims a basis of comparison. As Craver says: “To put the point differently, on my view of levels, it makes no sense to ask if my heart is at a different level of mechanisms than my car's water pump because there is no mechanism containing the two (except in bizarre science-fiction cases, in which case talk of levels might be appropriate)” (ibid. 191). At a first glance, this may appear an odd shift in emphasis, but in fact points to an important motivation for the radically contextualized approach of the mechanistic account. Namely, *any* kind of general claim or statement containing levels that is not contextualized by the New Mechanist framework (in particular the presence of a mechanism) seems committed to something like the layer-cake account. And the layer-cake account, it seems, regularly produces conundrums involving ordering hearts and water pumps against one another in a layout of levels of organization. Once again, Craver (2007a):

> “As with my heart and the water pump, it makes no sense to ask if pyramidal cells are at

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[50] More particularly, Craver attributes statements like (b) to Wimsatt's prototype characterization of levels, and statements like (c) to the layer-cake account. This distinction will not be relevant here, because, according to Craver, both the statements of (b) and (c) both suffer from the same problems (ibid. 191-192).

> a lower level than hippocampi *generally* [as in the case of (b2) above]. Some pyramidal cells are at a lower mechanistic level than [i.e. compose] hippocampi, and some are not. Precisely the same ambiguity attends (c), the monolithic view of levels that Oppenheim and Putnam (1958) propose." (ibid. 192)

Though an antipathy to the layer-cake account is understandable (see especially Chapter 3), the radical extent to which levels of organization are contextualized in the mechanistic account is problematic.[51] In referring to levels of organization, scientists are interested in more than token explanatory statements that only hold in the context of one study or even one mechanism; i.e. they are interested in expressing *some* generality with their explanations. This generality may not end up being lawfulness or lawlikeness (especially in the biological sciences), but it seems unjustifiably construed to avoid any identification with the layer-cake account, be its particular conception of levels (as here), the theoretical reductionism with which it is associated (ibid. 230), or the Unity of Science thesis that it is meant to support (ibid. 193, Ch. 7). This in turn puts into question what precisely the mechanist means by their emphasis on contextualized characterizations of levels. Levels, officially, are only useful in the context of a *particular* mechanism. At the same time, though, given that statements like (b1) above "unproblematic and consistent" with the mechanistic account of levels, it seems plausible that the mechanistic account could be modified to accommodate more generality to its framework of levels. As it stands, however, the radically contextualized conceptualization of levels in the mechanistic account is far too restrictive to be of general use as an account of levels of organization in science.

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[51] Craver seems to have backed off from from the stance that "'levels of mechanisms' captures the *central explanatory sense* [alternatively: most relevant; ibid., 164] in which explanations in neuroscience (and elsewhere in the special sciences) span multiple levels." (2007a, 163; emphasis added), and now appears to defend a more blatantly pluralistic attitude (2015), but still emphasizes the primacy of the mechanistic account (ibid.).

2.3.2 Principled Rejection of Correspondence Between Science and Nature

Another characteristic feature of the mechanistic account is its principled rejection of any levels-mediated correspondence between nature and science. This rejection occurs in two steps. The first step involves the rejection of the postulated correspondence between the nature and science. This feature of the mechanistic account exploits a distinction in the concept of 'levels of organization', namely “levels of nature and “levels of science” (Craver 2007a, 171). “Levels of nature” comprises an ontological ordering of the objects of the world, whereas “levels of science” comprises an epistemic ordering of the units and products of science (e.g., scientific disciplines and theories or explanations, respectively).

The mechanistic account flatly rejects any direct levels-mediated correspondence between science and nature in both of these forms. Products of science (like theories and explanations) simply do not line up neatly with the objects of the world, regardless of how they are represented by levels of organization. Rather, theories and explanations in the biological sciences often refer to natural objects located multiple levels simultaneously, and actively incorporate interlevel connections into them (Schaffner 1993, 97-99; Craver 2007a, 9-16; Bechtel 2008, 148-157). Likewise, units of science (like scientific disciplines or fields) regularly investigate multiple levels simultaneously: nothing prohibits disciplines like molecular biology and ecology from investigating or explaining things at various organizational levels. Consequently, no strict correspondence exists between nature and science, at least as expressed by the levels concept.

The second step in rejecting the correspondence thesis involves a more general rejection of the coherence of an epistemic conception of levels (here, levels of science). The task of ordering scientific investigative or explanatory activities, and the products of those activities, into a sleek, well-defined hierarchical ordering simply does not work, the mechanists argue, because of the role that interdisciplinary contributions play in contemporary biological research. Similarly, individual researchers are also not beholden to any rigid, single-discipline approach. Consequently, "[biological disciplines like] [c]ontemporary neuroscience thus do not fit Oppenheim and Putnam's hierarchical structure. Fields, journals, and scientific organizations are now organized around interfield collaborations to such an extent that it is no longer possible to resolve [e.g.] neuroscience into well-defined strata of research" (ibid. 176).

Again, a strong motivation for this feature of the mechanistic account, in both of its steps, appears to be an attempt to distance the account from the layer-cake account offered by Oppenheim and Putnam (1958). In this regard, Craver articulates this point as the "primary criticism" of the layer-cake account, saying:

> "My *primary criticism*, however, is not of the simplicity or descriptive inadequacy of [the layer-cake account's] vision of the world...Rather, I object to the supposed correspondence between levels of nature, levels of units, and levels of products of science. Oppenheim and Putnam do not seem to recognize any difficulty in moving freely between these different conceptions of levels...In neuroscience [and other biological sciences], this tidy correspondence breaks down." (Craver 2007a, 174-175, emphasis added)

As commented above concerning the feature of contextualization of the mechanistic account, such an antipathy for the layer-cake account is not in itself dubious or problematic.[52] At the same time, it is one thing to reject an entire account, or rather the problematic elements of that account, and another thing to reject anything taken to resemble that account.[53]

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[52] The reasons for this will be explored in more detail in the following chapter.

[53] The degree to which levels can or cannot help to order epistemic items is unclear. Though it is clear that a sweeping, comprehensive account of such an ordering (like that offered by Oppenheim and Putnam (1958)) is unsatisfactory, a more local (but not radically local) ordering may be possible. A philosophical justification for this point will not be pursued in this dissertation, but rather will be taken as a primitive possibility because of its widespread prevalence in scientific literature (see especially Chapter 4 and Chapter 5). A tentative approach to dealing with this topic in a philosophical context is offered in Brooks (2014).

2.3.3 Branching Structure

Levels of organization in mechanisms exhibit a branching structure, rather than a linear one (see Figure 2.3 above). This feature of mechanistic levels captures two further aspects of mechanistic explanations. Firstly, it expresses the fact that the components of a mechanism do not designate homogeneous entities that are unified only in terms of being 'lower-level' to some whole. Rather, the components of a mechanism each contribute, in a very specific way, to the production of the phenomenon. In the layer-cake model, lower-level entities were grouped together into one unified “universe of discourse”, which designated the entities belonging to a particular level solely in terms of whether they were typically investigated by a corresponding science. Secondly, each component of a mechanism can itself be composed of several further sub-components, which are located at even lower levels than the item in question is located. Insofar as this is the case, the compositional hierarchies of the respective components are also distinct from one another. Craver and William Bechtel (2007) identify this as one of the principle advantages of conceptualizing levels according to the mechanistic account:

> “[L]evels of mechanisms are not monolithic divides across all of nature. Levels of mechanisms are defined locally, within the context of a given type of mechanism. One is thinking of levels as monolithic divides across all of nature when one thinks of levels as levels of sciences (e.g., economics, psychology, biology, chemistry, physics; see Oppenheim and Putnam 1958) or as levels of entities (e.g., societies, individuals, organs, molecules, atoms).” (Craver and Bechtel 2007, 550)

The branching structure that the mechanistic account introduces to the hierarchical ordering of levels is a strict improvement over the linear structure offered by the layer-cake model. Specifically, postulating a linear structure to the character of organizational levels only makes sense with an implicit commitment to some conception of the Unity of Science, which, as seen above, is one of the primary motives behind Oppenheim and Putnam's (1958) paper. This commitment, which the mechanistic account rejects, allows for differences between distinct entities, organized within or between levels, to be effectively expressed. Though the mechanistic account makes this point in the context of defending a particular account of explanation, this point can be evaluated on different merits (see especially Chapter 5).

2.3.4 Constitutive Relevance

Levels of organization in a mechanism comprise the interacting components that make up the behaviors of a phenomenon for which an explanation is sought. As explained above in Section 2.3.1, this means that organizational levels in the mechanistic account are defined, exclusively, in terms of the part-whole relations that hold within a mechanism between a specific phenomenon and its parts. However, identifying the levels of organization that compose a given mechanism is not done haphazardly, i.e. *completely* relativistically. Rather, each mechanism is accompanied by certain relevance criteria that serve to decide what levels (and more specifically the components located at these levels) actually compose that mechanism. These criteria specify whether the certain things constitute components of a mechanism or not, and, *ipso facto*, they also specify what levels of organization are involved in the working of that mechanism.

Though the specific details pertaining to what component is being discussed (or what level or levels are involved) will certainly be context-dependent, both will be identified by checking whether they exhibit *constitutive relevance* to the mechanism in question. Detailing what exactly constitutive relevance means, Craver specifies, goes hand in hand with whether or not the putative component is *explanatorily relevant* to the phenomenon in question. That is, a putative component for a mechanism will be constitutive of that mechanism if it is explanatorily relevant to that mechanism, and vice versa (Craver 2007b, 3). Establishing this relevance is accomplished by performing empirical tests on these prospective components, and the wholes to which they putatively belong. These tests, described by Craver as "interlevel experiments" (Craver 2007b, 12-13), are illustrated in Figure 2.4.

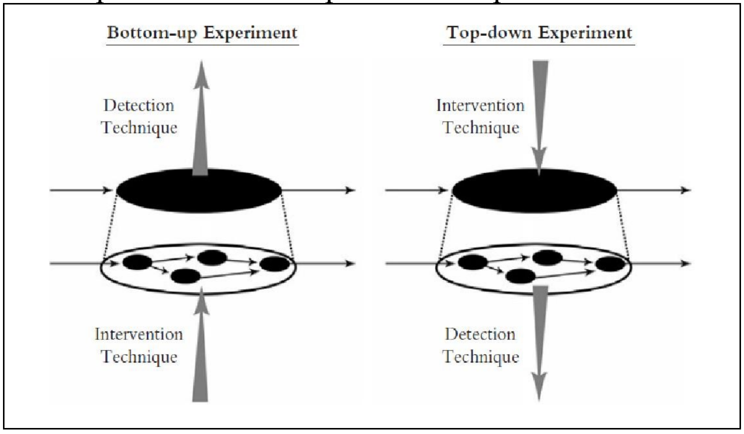

Figure 2.4 Interlevel experiments for testing constitutive relevance in a mechanism. Intervening to change a constituent part of a mechanism at a, respectively, higher or lower level of a mechanism reveals whether the lower level putative element in question is really a working part, i.e. component of that mechanism. When one can intervene both in a top-down and bottom-up manner, this means that the "mutual manipulability" condition of constitutive relevance is fulfilled (Craver 2007a, 151-154). Figure taken from Craver 2007a, 146 (cf. also Craver 2007b, 12).

These interlevel experiments operate by introducing a change to the mechanism, and observing whether a change occurs on another level. As Figure 2.4 shows, these experiments can be either bottom-up or top-down. In bottom-up experiments, one putative (lower-level) component is changed via experimental intervention. If a change occurs in the phenomenon (located at a high level), then the object or entity that was changed can be considered a component of the respective mechanism. Conversely, a specific change can also be introduced at the (higher) level of the phenomenon via experimental intervention, and the effects of that change can be tracked in a specific (lower-level) component. Using both of these kinds of tests together to determine the constituency of a mechanism results in the condition of "mutual manipulability" being met, whereby the components (and levels) belonging to an explanatory mechanism can be uncovered. At the same time however, the general character of these tests, the details of this "mutual manipulability" must be specified differently for different mechanisms and even different components within a single mechanism.

So, what counts as a component of a mechanism, and thereby what levels of organization are involved in the explanation of a particular phenomenon, is only specifiable on a case-by-case basis. Given this, and in stark contrast to the layer-cake account, the mechanistic account of levels allows for rampant level-skipping when searching for an explanation in the sense that stepwise compositional continuity is not present in real scientific part-whole relationships.[54] This point complements the discussion above in Section 2.3.1: In particular, the things that designate components of a mechanism will not be identified in terms of some inherently given relation to other things in the world (of which they are a part), but rather in terms of their location *within a given mechanism*. For this reason, the hierarchical layout of one particular mechanistic explanation may or may not be comparable to other hierarchical layouts given in other contexts. Not all levels of organization will be relevant to explaining all explananda.

This feature of the mechanistic account of levels also guarantees that the conception of levels that it offers will be strongly contextualized in character. Since levels of organization can only be specified in connection to a particular mechanism, after it can be specified what constitutes a component of that mechanism, this makes any generalizations concerning the levels concept (including their identity and characteristics) completely context-dependent.

2.4 Conclusion

The layer-cake account is the default conception of levels of organization in philosophy. It's depiction of levels, however, reveals that philosophers use the term interchangeably with many other ideas. Section 2.2 showed that extracting a conception of levels from the many references to the layer-cake account is a subtle task, because the concept is used, variously, as justification for one claim (such as the viability of Oppenheim and Putnam's micro-reduction relation, or as support for the anti-reductionism thesis in Kitcher (1984)). Nonetheless, when this conception is extracted from these other ideas, the characteristic features of the layer-cake account uncover a source of questionable ideas associated with the term.

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[54] See the discussion on “direct composition” in Section 3.2.1 below.

First, the scope of the layer-cake account is global, and is meant to hold for all entities of nature. This leads to difficulties when trying to articulate in detail what levels of organization represent about the world, since trying to find a singular account of what all things in the world have in common such that they are related together under one concept will prove difficult, if not impossible. In particular, the skeptical arguments against the concept of levels that have been developed in recent years focus on the attempt of the layer-cake account to accomplish this task. This issue will be the focus of the next chapter.

Secondly, the definitional criterion posited by the layer-cake account is one of part-whole composition. However, there is no one interpretation for what this exactly means for those who refer to the layer-cake account of levels. Oppenheim and Putnam (1958) avoided talking in concrete terms about the material relations between particular objects in nature, and instead relied on the ability of their micro-reduction relation to derive explanatory laws *about* the things in nature at a given level (L_n) from the laws *about other things composing* those things located at the next adjacent level (L_{n-1}). This strategy continued throughout other debates concerning reductionism, and was used widely by reductionists and anti-reductionists to articulate their respective positions. That is, though layer-cake levels of organization are posited as an objective feature of the world, their explication often relies on the epistemic relations for which they themselves are used to give structure.

Thirdly, the mode in which levels of organization are presented by the layer-cake account is both an epistemic and ontological. That is, levels of organization are depicted as representing both an ordering of the world, and a corresponding ordering of the sciences. This follows directly from the correspondence thesis, which is a central characteristic feature of the account, and is widely accepted by both reductionists and anti-reductionists that utilize the concept of levels.

Finally, the wide and tangled variety of uses of the levels concept by advocates of the layer-cake account belies an overarching feature found in instances of layer-cake depictions of levels. This feature comprises the use of 'levels of organization', as conceptualized by the layer-cake account, as a structural feature that shaped the debate in which it was embedded. As detailed in this section, the levels concept is applied in order to articulate the particular claims at stake in the debate surrounding reductionism and anti-reductionism. Furthermore, this is a goal that is Reductionist positions like that expressed in Oppenheim and Putnam (1958) rely on levels of organization in order to express the give meaning to their claim that sciences are moving toward Unity, and that this Unity would proceed as the sciences located at one level of organization would be reduced to the one located below it at the adjacent level below it. Anti-reductionists like Kitcher (1984), similarly, rely on the levels of organization to justify their assertions that higher-level disciplines will not reduce to lower-level ones. Further significant consequences of these widespread associations of the layer-cake account with other philosophical debates and positions will be discussed in the next chapter.

The mechanistic account of levels provides a stark counterpoint to the layer-cake conception of levels. In fact, almost every aspect of the mechanistic account comprises a direct rejection of some aspect of Oppenheim and Putnam's (1958) conception of levels. The mechanistic account shifts the focus of understanding levels from issues of unifying nature and science to issues of contextualized approaches to understanding scientific explanation, explanatory relevance, and actual scientific practice. Though these motivations are also directly responsible for the popularity of the New Mechanist philosophy, they also make the mechanistic conception of levels of limited use for a general analysis of the levels concept. For one thing, the mechanistic conception of levels only makes sense in the context of specifying what a *mechanism* is, and what it means for a *mechanism to explain*. Extrapolating this conception of levels outside of mechanistic explanation is not possible, due to the concept's dependence on a mechanism for contextualization.

Firstly, the scope of levels exhibited by this account is radically contextualized. For the mechanists, levels of organization are only useful insofar as they represent the structure of an explanatory mechanism. More specifically, levels of organization within a mechanism can only be identified and described in relation to a specific phenomenon, whose workings are to be uncovered by the mechanism that produces it. For this reason, levels are not generalizable beyond the instances of the particular mechanistic layout in which they are locally specified. This signifies a radical departure from the layer-cake account, which posited levels as encompassing the whole of nature, and as a portrayal of the structure of nature holding independently of science.

Secondly, the definitional criterion of levels exhibited by the mechanistic account is one of part-whole composition. Though this resembles the criterion used in the layer-cake account, the mechanistic account of levels conceptualizes composition in a radically different way than the former. Whereas the reductionists and anti-reductionists advocates of the layer-cake account expressed composition as the relations holding sum universes of discourse investigated by a “core” scientific discipline, the mechanists postulated *constitutive relevance* as a technical term by which to define the membership of a particular structure as a working component in a mechanism. The mechanists place great value in a clearly specifiable composition relation, but only because of its importance to understanding what a mechanism is and how it explains natural phenomena.

Finally, the mode in which levels are depicted is unambiguously ontological. Craver's (2007a, ch. 5) analysis of levels explicitly rejects any meaningful association with between levels of organization and scientific disciplines. Bechtel (2008) echoes these sentiments. Organizational levels, according to the mechanists, pick out actual entities in nature, and which disciplines investigate these entities are determined by context (i.e. relative to a particular phenomenon). Identifying levels in a mechanism is accomplished when mutual manipulability experiments can be accomplished.

This chapter has summarized and analyzed the two most prominent conceptions of levels of organization in philosophy. These two conceptions, the layer-cake account and the mechanistic account, are in many ways antipodal positions. For one thing, their characteristic features are completely different from one another. This, at least in for the mechanistic account, is deliberate, because of the numerous issues that the layer-cake introduces in its conception of levels. More importantly, both accounts of levels were tailored for very different types of issues and very different debates. The layer-cake account, originally embedded in Oppenheim and Putnam's argument for the Unity of Science, later became associated with the debates concerning theoretical reductionism and anti-reductionism. The problematic element of the account have endured in these embedding debates, leading to a general skepticism of the levels concept (see Ch. 3). The mechanistic conception of levels, on the other hand, is embedded in the New Mechanist framework of mechanistic explanation. Since this account is largely hostile of the classical layer-cake conception, and especially any generalized conception of levels, the account does not offer itself to further analysis at this time, given its inherent commitment to another concept, that of a 'mechanism'. Some steps have been taken to analyze the mechanistic conception of levels (notably, Eronen 2013; 2014), but reception of the mechanistic account of levels outside of its embedding framework of mechanistic explanation remains rather critical in terms of its importance to an overall conception of levels (ibid.).

Chapter Three: Levels Skepticism

3.1 Introduction

In recent years, a number of doubts have emerged against the use of the levels concept in philosophy and science, resulting in a growing overall attitude of *levels skepticism*. The crux of this skepticism, however, rests on philosophical reconstructions of levels, which were detailed in the last chapter. Several lines of argument have been constructed. Firstly, one line of argument holds that levels constitutes a *flawed* concept that, while perhaps capable of minimal refinement, does not have any useful application in either philosophy or science. Another line of skeptical argument holds that the concept of levels is not only useless, but also *misleading*. That is, skeptics claim that the notion of levels is a pernicious idea that leads to confusing or false ways of thinking about phenomena in biology. A third, more principled, criticism of the levels concept is the charge that its importance for science has been largely exaggerated by philosophers. That is, the concept of levels of organization is *irrelevant* to scientific practice, and has been wrongly emphasized by philosophers as an important term for characterizing the way that biologists construct knowledge of the world. These ideas must be considered, and disarmed, before any role for levels in the biological sciences can be entertained.

3.2 Levels – A Flawed, Misleading, and Irrelevant Concept?

Burton S. Guttman (1976) is particularly critical of the concept of levels. Guttman acknowledges both the ubiquity of the term in biology and the relative lack of any sustained analysis of its precise meaning (Guttman 1976, 112). However, Guttman also believes that a compelling defense of the levels concept will not be forthcoming, even if a sustained analysis of the concept were to be offered. He claims, rather, that the levels concept thrives, and *must* *thrive*, on its ambiguity, saying: “I contend that, if it is stated in any but the sloppiest and most general terms, it is a *useless* and even *misleading* concept” (Guttman 1976, 112; emphasis added). Angela Potochnik and Brian McGill (2012) share this skeptical attitude of looking for a defensible conception of levels, and assert furthermore that “[t]he search for a universal hierarchical ordering with any broad significance is futile” (Potochnik and McGill 133).

3.2.1 The Levels Concept is Flawed

The first argument against levels that will be considered is the charge that it is an inherently flawed and therefore useless concept for philosophy and science. Guttman (1976) and Potochnik and Brian McGill (2012) develop this line of thought particularly clearly. The concept of levels of organization, they argue, is useless because the descriptions of the world that it constructs are radically false, and so cannot support the various philosophical claims that it is purported to support.

Consider first the critical comments offered by Guttman. He begins by observing the widespread reference of the concept, citing two introductory textbooks that were common at the time. Guttman, himself a biologist and author of several introductory textbooks (*Biological Principles* 1971, *Understanding Biology* 1983, and *Biology* 1998) expresses his extreme disdain of the levels of organization concept in his (1976) paper “Is 'Levels of Organization' a Useful Biological Concept?”. In his commentary, Guttman entertains two different definitions of the levels concept, and finds both deeply problematic. The first interpretation focuses on the levels concept as a universalized statement of global compositional relations among the hierarchical strata, while the second focuses on levels as mediators of types of causal interactions between two (uni-level) systems. Attending to the former, compositional, statement of what levels of organization amounts to, Guttman entertains the following definition:

Compositional Definition: “[E]very system of level n is made *entirely* and *exclusively* of systems of level n-1.” (ibid. emphasis modified)

Interpreting the levels concept as positing compositional relations between levels in this way, Guttman claims, is “patently false”. His argument for this rests on the wide presence of counterexamples that falsify the “entirely” and “exclusively” qualifiers to the compositional “made of” relation offered in the definition. Entities or systems at one level (L_n) simply are not exhaustively nor entirely “made of” entities or systems at the adjacent lower level (L_{n-1}): Rather, there is an important sense in which entities or systems are composed of things at levels located at lower strata than the respective adjacent level (i.e. where $L_{n-x} < L_{n-1}$). For instance, in considering *blood* as an entity or system belonging to the tissue-level, it is obvious that blood is not exhaustively composed of the entities at the immediately adjacent level, i.e. cells. Rather, blood is somehow *directly composed* of a range of entities whose level-placement spans strata of various, *non-adjacent* altitudes in addition to germane cell entities like lymphocytes (white blood cells) and erythrocytes (red blood cells). Such entities include large- and small-scale biomolecules (so-called because they are synthesized by the living organism itself) such as proteins, sugars, and lipids (corresponding to the former) and vitamins, metabolites, and hormones (corresponding to the latter). Indeed, even physical things such as chemical molecular-level entities like water (which constitutes 92% of the liquid volume of blood) and molecular oxygen (O_2) also directly compose blood. This kind of counterexample can be replicated for entities in almost any chosen altitudinal stratum of the levels hierarchy overarching the biological world. In a similar manner, ecological ecosystems are not only composed of (adjacently located) communities of various populations, but also of non-biological parameters that also make up the ecological environment, such as soil constituents (bacteria, pesticides), sources of water, and temperature. Likewise, cells are not only made of organelles, but also of a host of proteins and macro- and micromolecules within the intracellular cellular matrix that do not directly compose the hierarchically intermediate organelle structures.

The point here is that “direct components” of the entities of any given level of organization will almost always include entities whose compositional relation to the system of interest is not mediated by the adjacent (L_{n-1}) level.[55] As a result, the levels concept, interpreted by the strict compositional criterion given above, does not appear to be a useful for capturing the structure of entities of the biological world. Potochnik and McGill (2012) endorse a similar conception of levels for their analysis (see, however, section 3.3.2), and argue that such a problematic conception of levels undercuts the metaphysical, epistemic-explanatory, and causal significance of levels. The main problem with the concept of levels, which undercuts all these facets of significance, is the "uniformity"[56] that the concept imposes onto nature. This agrees with the criticism of Guttman developed above. "Metaphysically" speaking, the "uniformity" in the above definition of levels (which they claim is most commonly encountered in science and philosophy) simply fails to reconstruct adequate depictions of the world. Potochnik and McGill enumerate:

> "Indeed, the very notion of stratified levels depends on not only the ubiquity, but also the uniformity, of part-whole composition. For strata to emerge, atoms must always compose molecules, populations must always compose communities, and so forth. But the uniformity of composition needed for stratified levels simply does not exist." (2012, 126)

Potochnik and McGill are cautious concerning their assertion that the composition-based descriptions of nature that emerge from the levels concept are false. In particular, they are specifically critical of the exhaustive and exclusive nature with which the concept of levels is developed. This "uniformity", they say, should not result in rejecting the claim that things are composed of other things, but rather how this compositional relation is spelled out: "It may be that every whole is composed of smaller parts. We do not question that claim here. But it is certainly not the case that every whole is composed of only parts at the next lower level" (*ibid.* 127). This, according to Potochnik and McGill, undercuts the metaphysical significance of levels, since composition is a major element belonging to the concept of levels.

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[55] Of course, L_n-level entities are *partially* composed of adjacent L_{n-1}-level entities notwithstanding the presence of such 'free-standing' direct components. See section 5.3.2.1.

[56] Their term "uniformity", as will be seen below, can be read as a direct consequence of the 'comprehensive character' of the conception of levels that they entertain.

This failure of the levels concept to construct accurate descriptions of the world also supposedly undercuts the concept's purported epistemic significance in organizing different explanatory statements based on levels (see below). In Chapter 2, the two conceptions of levels that were discussed emphasized that the world's hierarchical structure is of central significance to understanding how the concept aids scientific explanation. However, the levels skeptics also claim that the levels concept *alone* is not sufficient to draw any conclusions about explanatory efforts in science:

> "Most basically, granting the existence of part-whole composition and mereological supervenience is not sufficient support for the idea that *theories and representations* are related in these ways. Metaphysical determination is a relation among properties at different levels; *this does not straightforwardly dictate the explanatory or epistemic relationship among the theories that have been formulated about phenomena at different levels*." (Potochnik and McGill 2012, 130, emphasis modified; See also Guttman (1976, 113).

The conclusions that are drawn from the view of nature offered by levels of organization cannot be supported by such a simplistic representation of nature. This is sufficient to see that the concept of levels is not a useful concept for either science or philosophy. Hence, Potochnik and McGill conclude: "In our view, the many overly ambitious conclusions drawn from the simple fact of part-whole composition – and the persistence of those conclusions – demonstrate that *hierarchical stratification is not useful as a general conception of ecology or science*" (2012, 126; emphasis added). Guttman agrees with this conclusion, but hints that the apparent uselessness is only part of the problem with the levels concept: "If there is any other possible interpretation of the concept of levels of organization that is at all meaningful or useful, I would like to hear about it. Obviously, I consider it an idea that ought to be dropped or drastically deemphasized in all teaching" (1976, 113). Another problem with the levels concept, as Burton mentions in this passage, is that the levels concept is misleading. This problem will be discussed in the next section.

3.2.2 The Levels Concept is Misleading

The abundance of counterexamples to the above definition of levels does not only show the concept to be useless. Rather, the general uselessness resulting from the false examples produced by the levels concept also *misleads* scientists by supporting “dangerous ways of thinking” (Guttman 1976, 112) about the things that supposedly populate the different ranks of the hierarchy of the world. Biologists invested in this compositional interpretation of levels seriously misconstrue how biological phenomena are organized as objects of explanatory inquiry. This can be instantiated in two types of misconstruals. Firstly, the levels concept, interpreted as exhaustive composition relations between entities of adjacent levels, leads scientists to mistakenly categorize groups of entities under demarcational units that fundamentally misconstrue the differences between otherwise distinct entities that nominally *should* be grouped into the same level-bound type of entity. Take for example the level of 'organisms'. Organisms (here, L_n) are supposed to be exclusively and exhaustively composed of organs (L_{n-1}), which are composed of tissues (L_{n-2}), which are composed of cells (L_{n-3}). However, *organisms*, so construed, assumes a decisive bias towards conceptualizing organisms as *multicellular,* though there are clearly widespread examples of “organisms” that do not fit this description. Unicellular organisms[57] such as bacteria and archaebacteria form entire taxonomic domains separate from multicellular life forms, while other unicellular life such as various forms of algae, amoebae, and some fungi populate a diverse range of phyla within eukaryotic forms of life, thereby sharing their taxonomic classification with multicellular relatives (as is the case for fungi and algae). This issue can be reiterated in any respective compositional hierarchies that include such problematic taxa, and the conceptual confusion of determining what things like “organisms” (or algae or fungi, which appear to populate a number of distinct levels) are composed of is reiterated for each successive compositional stratum.

This quickly leads to a general conundrum that also undermines the significance and

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[57] Acellular organisms, if they exist (or better: insofar as things like viruses can clearly be designated as “organisms”), would be another problematic kind of “organism” that strays decisively from the organizational framework for nature that the present conception of levels gives us.

usefulness of the levels concept. For instance, when one attempts to clarify the component parts of unicellular *organisms*, there is a temptation to consider structural components like organelles within unicellular life as analogous 'organs'. Yet, according to the conception of levels entertained above, 'organelles' are supposed to designate their own organizational level, at least insofar as organisms themselves are composed (in whatever way) of cells. Moreover, the organizational significance of cell organelles like mitochondria in the somatic cells that compose multicellular organisms are then radically different for unicellular organisms composed of completely different kinds of structures. The units around which levels are demarcated seem to dissipate into a deeply confused misconstrual of nature. This misconstrual lies in the inherent conceptual confusion in the terms that reference to levels take as primary for giving structure to the world, against which the distinctions in nature it means to elucidate can be based. “Organism” and “organ” are themselves not conceptually clear, and this ambiguity is imported into the levels concept. Yet, given the stringent definition of levels most often entertained by scientists and philosophers (see Section3.2.1) purports to generalize the false organizational structure it represents to all of nature. This inference is, however, highly misleading.

A second misconstrual is offered by Guttman, building on the first just discussed. This is somewhat hyperbolic and will only be mentioned in passing. If, Guttman claims, scientists decide to sidestep the issues of clarifying the demarcational units by which levels should structure the world (such as “organism”, or “organ”, etc.), and choose instead to bite the conceptual bullet (thereby accepting the conceptual problems attached to the counterexamples that follow from the levels definition), the absurd conclusion must be drawn that scientists who study, e.g., unicellular life must be judged as not studying organisms.

A second interpretation of organizational levels is also entertained, and disparaged, by Guttman:

Interaction Mediator Definition: Interactions between systems of level n are *mediated through*

objects of level n-1 (or some other *specific* level less than n)[58]
(*ibid*, 113)

This definition, says Guttman, “would be a really interesting and useful generalization”. (*ibid*) If true, this definition of levels would allow scientists to construct generalized criteria for identifying salient kinds of interactions between the entities at any given level. Alas, this definition also runs afoul of numerous counterexamples like those mentioned above. The only difference being that the relation postulated by this levels definition is *interaction* rather than composition. Once again, nature seems to be more complex than is allowed by the levels concept. To see this, consider two organisms (organism level L_n) interacting as predator and prey, for instance a rattlesnake envenomating a rabbit. The interaction between these organisms will not be mediated exclusively by one single level, but by many levels simultaneously. The route of envenomation, i.e. delivery of toxins by the snake's fangs into the rabbit's body, may be tracked along several different organizational levels. The significance of these respective levels will be determined largely by a researcher's interest in isolating one or several of these levels, *instead of* others. Snake venom[59], whose active agents are composed of proteins or enzymes (the “molecular-level”), are already orders of magnitude lower in the hierarchical strata that make up this inter-*organismal* interaction, but the mediating effects that may attract the interest of a particular group of scientists (e.g. damage caused by the toxin's presence as an etiological agent for the rabbit's death) may be located at the tissue-level (dissolution of muscles), the organ-level (degeneration of circulatory elements), or even remain at the organism-level (death by shock). The salient types of interactions on which scientists may focus between two or more systems at a given level L_n are simply not mediated by only one single level L_{n-1}. Even granting that the mediating elements must not be adjacently located vis-a-vis the level of reference, it is a radically false expectation that the entities of *only* one other level should mediate the interactions of entities at another level.

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[58] This definitional criterion was not explored in the above sections, but nonetheless fits the leitmotif of ambiguity surrounding discussions on the levels concept.

[59] No kind of snake venom contains only a single active agent, hence toxin types like “neurotoxic” or “hemotoxic” are misnomers (Mackessy 2002).

The implication of the foregoing definition of levels is that lower-level "mediation" of interactions occurs between a type of entity or entities at a given reference level L_n will hold universally and wholesale. This, as for the compositional definition above, does not appear to be a viable conception concerning either the character or the significance of levels. The interactions in which organisms (or ecosystems, organs, tissues, etc.) engage are *not* mediated solely by one or several levels in any universally generalizable way. Pursuing this line of reasoning would result in an unwarranted and unmotivated law-like generalization of the form "all interactions between the entities of level L_n are mediated by the entities of level L_{n-x} or by entities located in a concrete constellation ($L_{n-x} + L_{n-x1} + \dots L_{n-xN}$)", which regardless of its expression implies that the only way conceive of levels, and their uses, is with reference to adjacent, neighboring levels. This, however, proceeds completely independently of what might be relevant for understanding what is going on at that respective level in the first place.

These kinds of misleading situations strengthen the conclusions of the levels skeptics that the levels concept is not viable. Guttman hence concludes: "If [concept of levels] were *only* useless, this issue would not be so important, but since it is misleading as well, I think it is time to let the idea die." (Guttman 1976, 113)

3.2.3 Are Levels of Organization Irrelevant to Science?

One final skeptical argument against the levels concept will be considered here only briefly. Though not explicitly articulated by level skeptics, this argument can be constructed from intermittent comments given levels skeptics, and concerns the basic motivation for looking at the concept of levels in the sciences at all. In other words: Is possible that the significance of 'levels of organization' for scientific research has simply been exaggerated by philosophers, and that the concept in reality carries no, or at least greatly reduced, importance for many ideas it is usually taken to express?

Interestingly, the commentary out of which this argument is found appears in conjunction with discussing the epistemic role supposedly carved out by levels of organization in biological practice. This supposed role of the levels concept in science, the skeptics claim, belies an actual *irrelevance* of levels for scientific practice. If true, this would undercut a vital motivation for any continued philosophical analysis of levels: If 'levels of organization' are unimportant for scientific practice, then the concept decisively fails to be significant in any way for philosophy or science.

This epistemic role, Guttman observes, "may be seen as an important way to organize the major ideas of biology for pedagogy, and...is commonly included among the definitive characteristics of living beings, since by definition an organism is 'organized'." (Guttman 1976, 112) In other words, one role that the levels concept plays in biology is to introduce themes that express the "major ideas" of biology (see Chapter 4). Potochnik and McGill also acknowledge this role of levels, especially in ecology. Noting the wide presence of the levels concept in a number of influence introductory textbooks to ecology, they say:

> "Editions of these textbooks have been around for decades and have been used to train most practicing ecologists today. (Indeed, the second author learned his introductory ecology from [*Ecology: Individuals, Populations, and Communities* (1986).] over 25 years ago.) The ecologists writing these textbooks were themselves trained to focus on hierarchical organization." (Potochnik and McGill 2012, 122)

However, if the skeptical arguments discussed in Section 2.3.1 and Section 2.3.2 are correct, it doesn't make much sense to apply to a useless and misleading term as a significant epistemic tool. Despite the observations that the concept is "frequently emphasized in introductory textbooks" (Guttman 1976, 112) acknowledged by the skeptics above, it follows that 'levels of organization' is simply a toy concept that gathers student intuitions together so that for their training as life scientists can begin. Eronen (2014) expresses a stronger suspicion of the overall relevance of levels, and downplays the presence of the levels concept both in textbooks and in the research literature, at least in the case of some conceptions of levels. He says that, in contrast to philosophical attempts to motivate the scientific importance of levels:

“In general, [philosophers such as] Bechtel and Craver [(2007),] may have exaggerated the importance of the notion of levels of mechanisms in science.” (Eronen, 2014, 11).

In contrast to the skeptics, this purported epistemic role attributed to the levels concept will be of substantial importance. This will be discussed in Chapter 4 and Chapter 5, where the usefulness of the levels concept will be defended in exactly its capacity to “organize the major ideas of biology.”

3.3 Considerations of Levels Skepticism

The general theme of skeptical arguments against (global conceptions of) levels is that *the biological world is more complicated than the levels concept can represent*. As pointed out by Guttman (1976) and Potochnik and McGill (2012), counterexamples abound with respect to the image of nature resulting from 'levels of organization'. Even worse, the general structure of these counterexamples apparently point to deep problems confronting any attempt to clarify what is meant by the term 'levels': Not only is the concept *useless* for scientific practice, it actively *misleads* scientists into implicitly accepting absurd claims about both the structure of biological world as well as disciplinary profiles of working scientists. Furthermore, another argument was independently constructed above, which claimed that philosophical interest in levels is unfounded, because the concept is in fact largely *irrelevant* to scientific practice. Rather, they say, philosophers have exaggerated the importance of the term for science. Each of these authors contend that the continued use of a comprehensive conception 'levels of organization' in further philosophical (and scientific) discussion is unwarranted.

3.3.1 A Straw-Man Conception of Levels

The arguments against the concept of levels considered above appear compelling, at least in their current form. However, their soundness is highly questionable. Though the arguments offered above are clearly meant to hold generally for the concept of levels, the authors of these arguments only entertain the conception of 'levels' given by the layer-cake account. Seen as arguments against *the layer-cake* notion of levels, the calls of skeptics to minimize or eliminate the levels concept are understandable, and even justified. For this reason, however, the levels skeptics direct their arguments towards a straw man. There are other ways to conceptualize the notion of levels, which should be kept distinct from the layer-cake account (see Section 2.3, Chapter 4; Chapter 5).

Recognizing the layer-cake conception of levels in the arguments against levels is straightforward. Recall from chapter 2 that the layer-cake conception of levels is identifiable by four characteristic features: (1) global scope, (2) stepwise compositional continuity, (3) linearity of levels strata, and (4) the correspondence thesis. Of these four features, (2) and (4) were said to be the most important for designating a particular account of levels as being “layer-cake”. One or both of these features are clearly presented as an identifying feature for 'levels of organization' in the arguments laid out above. Conceiving of interlevel connections as constituting a stepwise continuity is particularly important to levels skeptics' portrayal of levels of organization. Guttman is forthright in his working definition of levels wherein “every system of level n is made *entirely* and *exclusively* of systems of level n-1” (1976, 112, emphasis added). Likewise, Potochnik and McGill also heavily rely on this feature in their description of the “classical” account of levels:

> “The basic idea is that higher-level entities are composed of (*and only of*) lower-level entities, *but the prevalent concept of hierarchical organization involves stronger claims as well*. The compositional hierarchy is often taken to involve stratification into *discrete and universal levels* of organization. It is also often assumed that levels are nested, that is, that an entity at any level is composed of aggregated entities *at the next lower level.*” (Potochnik and McGill 2012, 121)[60]

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[60] Reconstructing Potochnik and McGill's precise conception of the “classical” account of levels is difficult, because they take the “classical” account to encompass three distinct sources. The first of these sources,

The correspondence thesis is also cited by the levels skeptics as a defining feature of levels *in general*. Waters is direct in this association, saying: “The *sciences of biology* [according to theoretical (anti-)reductionism] are like the *layers of a cake, with each layer aimed at explaining the phenomena that are best explained at the level of organization corresponding to that layer*...both [reductionism and anti-reductionism] advance 'layer-cake' pictures” (2010, 240).

Interestingly, in choosing the layer-cake notion of levels as their target of criticism, the levels skeptics also frequently cite the notion's association with the reductionism debate in order to characterize what they take to be levels. Further passages identifying what is meant by 'levels of organization' even openly cite the particular reductionist and anti-reductionists programs resulting from Oppenheim and Putnam's (1958) paper, and even the layer-cake theoretical (anti-)reductionism by its name, as an impetus for their critical comments. Once again, Potochnik and McGill: “This is the apex of the pyramid [of the classical account of levels] often used to represent the classic reductionist conception of the whole of science, which ultimately bottoms out at subatomic particles (Oppenheim and Putnam 1958).” (2012, 122). The above passage cited from Waters (2010, 240) is also especially clear in this association.[61]

These passages clearly identify the layer-cake account of levels as the respective authors' primary source for conceptualizing levels of organization. So, why is layer-cake not a legitimate target for criticizing the concept of levels of organization? The accusation here that the levels skeptics are attacking a straw-man can serve for some diagnostic remarks on getting the record straight with the role that levels of organization play in scientific practice. In order to motivate a renewed analysis of the concept of organizational levels in science, it would seem that the levels skeptics' emphasis on the layer-cake notion of levels is indicative of a

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identified here, is the layer-cake account developed by Oppenheim and Putnam (1958). The other two sources include introductory textbooks in science (*ibid.*) and a relatively unknown paper on organizational levels by James K. Feibleman (1954). Combining these three sources and labeling them as the “classical account of levels” is a grievous mistake, as these three sources each belong to completely different (global) conceptions of 'levels of organization'. The reasons for this will become clearer later, when the latter two of these sources are treated in turn in their proper context (see Ch. 5).

[61] This supports and expands upon the point already broached in Section 2.2.5, where the embedding frameworks of the layer-cake account was initially discussed.

tendency in philosophy to associate 'levels of organization' with a slew of unpopular ideas, particularly debates concerning theoretical (anti-)reductionism. This tendency, alone, could threaten any attempt to uncover the role of levels in scientific reasoning. Namely, whatever significance of the levels concept might possess, it will be unattainable if 'levels' are depicted as anything resembling the *layer-cake notion* of levels.

3.3.2 Guilt by Association: The Layer-Cake Account as the Default Conception of Levels

In Chapter 2, it was argued that the layer-cake account of levels is the default conception of levels held by many philosophers. As a consequence of this “default” status, it was also pointed out that the term 'levels' has become deeply associated with philosophical debates concerning especially theoretical (anti-)reductionism. This section will explore more deeply how the layer-cake notion of levels, as a result of its status as the default conception of levels, is responsible for much of the skeptical attitude that philosophers possess against the levels concept in general. The deep association of the layer-cake account of levels with debates surrounding theoretical reductionism introduces a problem in the way the levels skeptics analyze the concept of organizational levels. Namely, the embedment of levels within these debates conflates features taken to hold with the levels concept with various other commitments and ideas stemming from the layer-cake account of levels *in particular*. The argument levels skepticism that will emerge will be that insofar as the layer-cake account is used to identify 'levels' by the levels skeptics, this makes their criticisms unwarranted.

There are two facets to this dubious association, which need to be distinguished. First is the direct association of 'levels of organization' with the *layer-cake account of levels*. This has resulted in the belief that the levels concept is best characterized in terms of the account stemming back to Oppenheim and Putnam's original (1958) conception of levels, discussed in the last chapter. Guttman's treatment of levels shows this very clearly, and so will be emphasized in the below comments. The second facet is the tacit assumption, perhaps resulting from the first, that 'levels of organization' is indicative of one or another idea associated with the *layer-cake theoretical reductionism*. Potochnik and McGill (2012) are especially guilty of this association in their criticism of the levels concept, and so will be emphasized accordingly below.

Both of these associations are unwarranted, and serve to undermine the initial appeal of levels skepticism. Concerning the former association, the *layer-cake account of levels* is an extremely unattractive conception of levels, for reasons that are nicely pointed out by the skeptical arguments offered above. Concerning the second association, there is no reason to suppose that endorsing *some other* conception of levels commits one to an account of theoretical (anti-)reductionism, nor any of the elements of those accounts. Theoretical (anti-)reductionism is problematic for its own reasons, independently of one's conception of levels.

This situation has been perpetuated by the trend, started also by Oppenheim and Putnam and reiterated by later reductionists and anti-reductionists such as Kitcher (1984), to instrumentalize the layer-cake notion of levels as a central premise in their respective arguments and positions (see Section 2.2.5). Combined now with the tendency of most 'levels skeptics' to identify 'levels of organization' solely with the layer-cake conception of levels, it is a valid question to what extent the concept of 'levels of organization' is simply in “bad company” as a result of its past associations with layer-cake levels and layer-cake theoretical (anti-)reductionism.

3.3.3 Association of 'Levels' with 'Layer-cake Levels'

The layer-cake notion of levels is extremely problematic. Firstly, notice that the features the layer-cake account proposes to represent nature are extremely simplistic. In particular, the feature of *stepwise compositional continuity* asserted by the layer-cake account (section 2.2.2) restricts interlevel compositional relations between entities the elements that populate *only* adjacent (lower) levels. As a result of this, counterexamples are easily constructed to show that the compositional relations of a given biological phenomenon cannot be held to such overly stringent criteria. The rigid image of nature and science that follows from this feature of layer-cake levels (i.e. stepwise compositional continuity) simply fails to reconstruct any useful description of natural systems. For one thing, different things that directly compose a given entity in nature can be distributed across several levels, without any mediation by (higher) adjacent levels where other direct components are located. This was seen in the example of blood, which is located at the tissue level of organization.

Blood (L_n) is “made of” hormones (small biomolecules L_{n-3})[62] and chemical and atomic structures like H_2O and molecular oxygen (L_{n-4}, L_{n-5}, respectively) in a direct (not distal, i.e., not mediated by interspersing levels) and relevant sense that it is “made of” adjacently-located cell entities like hematocytes (L_{n-1}). This is not to say that there some parts located at the adjacent level that also directly compose things at the immediately adjacent lower level L_{n-1} (red and white blood cells in the case of blood). It would be quite spooky to think of “floating entities” whose composition wholly skip underlying adjacent levels; candidates for such entities that come to mind would include those housed in the legendarium of scientific obsolescence (entelechies, élan vital, phlogiston). In other words: some adjacently-located, underlying Ln-1 entities may be necessary to account *for the material existence* of L_n entities, but their role in detailing the composition of something located at a given level L_n is neither exclusive nor exhaustive.

Secondly, it is simply absurd to claim that there is anything approaching a strict 1-to-1 correspondence between the ontological levels constituting nature and epistemic levels constituting scientific disciplines. This feature of the layer-cake account has already been readily rejected by the New Mechanists (see Section 2.3). Though it may be a hasty conclusion that there is *no* association whatsoever between science and nature that levels can capture (see especially Section 5.4.3), the point is well-taken from the mechanist conception

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[62] This notation follows the intuitive textbook hierarchy of nature. The exact algebraic representation of the following levels' distance from the reference object (blood) is irrelevant. The point is simply that important components of almost any given biological entity are not exclusively, nor exhaustively, exhibited by that object's adjacent levels.

of levels that the layer-cake understanding of this relation is also extremely simplistic.

Criticism against conceiving compositional relations of biological phenomena *as occurring in a stepwise fashion* is hence completely sound and appropriate. Compositional relations in biology simply do not reflect this structure. Similarly, criticizing the strict correspondence between nature and science in the manner that the layer-cake envisions is equally acceptable. The layer-cake account of levels, from which these ideas stem, is therefore rightly criticized as useless and misleading. However, referring to 'levels of organization' does not commit one thereby to understand to a layer-cake understanding of levels. For this reason, the generalized character of the dismissal of the levels concept by the levels skeptics engages in attacking a straw-man.

3.3.4 Association of 'Levels' with Layer-Cake Reductionism

In their discussions, levels skeptics often veer from a discussion of the levels concept (or rather the layer-cake conception of levels) into a criticism of some particular aspect of layer-cake theoretical (anti-)reductionism. These tangential criticisms, however, sometimes result in making implicit or explicit assertions concerning the levels concept as either (1) indicative of, or (2) a product of, particular features of theoretical (anti-)reductionism. As claimed above, the reason for this lies in the tendency of some philosophers to conflate certain ideas or commitments endemic to debates about theoretical (anti-)reductionism to the levels concept (or rather, the layer-cake conception). This false association is also perpetrated by both proponents *and* by critics of theoretical (anti-)reductionism.

Two unattractive features of theoretical (anti-)reductionism that, unfortunately, have become especially associated with the levels concept will be discussed here. These include (1) the use of 'levels of organization' to, in itself, be designative of particular epistemic assertions of theoretical (anti-)reductionism, and (2) the levels concept somehow implicitly supporting theory-centered approaches to philosophy of science, wherein scientific theories are treated as primary or privileged epistemic units of science. Each of these features are problematic for their own reasons (see especially Hüttemann and Love 2012 and Kaiser 2012), but are especially troublesome in falsely motivating levels skepticism due to their unwarranted association with the levels concept.

So, it is also important to separate rejection of the layer-cake account *of (anti-)reductionism* generally from the rejection of the layer-cake account *of levels* in particular. Neither the Unity of the Science thesis defended by Oppenheim and Putnam (1958), nor the numerous accounts of theoretical reductionism and anti-reductionism commonly associated with the layer-cake account (e.g., Nagel 1961; Schaffner 1967; Hooker 1981; Churchland and Churchland 1992; Bickle 1998), are held in especially high regard among contemporary philosophers of biology (Wimsatt 1979; Steel 2004; Craver 2007a, ch. 7; Love and Brigandt 2010; Waters 2010; Hüttemann and Love 2012; Kaiser 2012). Bechtel and Richardson summarize this dismissive tone in their assertion that theoretical reductionist approaches are "utterly inapplicable" to case studies of explanation in the biological sciences (1993[2010], xvii). This is due to several unattractive features of theoretical reductionism, some of which are intertwined with the layer-cake notion of levels, due to the various philosophers using the latter to develop the former. Two features that are intertwined with 'levels' that will be discussed here include seeing levels as epistemic assertions of (anti-)reductionism, and placing emphasis on theories as privileged epistemic units.

1.) Levels as Epistemic Assertions of (Anti-)Reductionism

The layer-cake account of levels has come represent the epistemic assertions postulated between different theories which, according to the particular (anti-)reductionist argument one entertains, one theory is said to superior to the other. This conflation of levels and theories is committed, for instance, by Potochnik and McGill in their diagnosis of the levels concept:

> "[S]ome [reductionists] explicitly or implicitly consider *lower-level theories* to be epistemically more secure than *higher-level theories*. An example is *Oppenheim and*

> *Putnam's* (1958) suggestion that all scientific investigations ultimately may be vindicated by demonstrating their foundation in microphysical law" (2012, 125).

Similar assertions are also easily found in arguments for anti-reductionism.[63] So, for (anti-)reductionists, this conflation is expressed by assertions that lower-level theories are superior (for one reason or another) than higher-level ones, while anti-reductionists assert the opposite.[64] For this reason, and regardless of the details of a particular argument for or against (anti-)reductionism, 'levels of organization' is taken in these situations to embody the criteria by which these ideas of epistemic superiority were evaluated in the theory-based philosophical analyses. Potochnik and McGill are explicit on this, and do not shy away from pointing the finger at the levels concept for this state of affairs: "These supposed explanatory and epistemic significances of hierarchical organization arise from a common source, namely, assumptions regarding universal stratified levels, and how lower-level parts and their properties metaphysically determine higher-level objects and their properties." (2012, 130) Moreover, this conflation between levels and epistemic criteria regarding the evaluation of theories seems to be a particularly deep-seated idea in the minds of philosophers. This point is also alluded to by, again, Potochnik and McGill, imply that Oppenheim and Putnam (1958) are responsible for this trend:

> "To Oppenheim and Putnam, the only alternative seemed to be acknowledging nonphysical entities such as the élan vital or nonphysical soul, a repellant [sic] proposition for any sort of physicalist...Though this conception of epistemic vindication via reduction may now be out of favor, we suspect that its ghost lingers in a tendency to credit lower-level theories with greater epistemic security than higher-level theories. This would account for the tendency to assume that higher-level theories should be

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[63] Montalenti (in Ayala and Dobzhansky 1974, 18) occupies the other extreme in the appraisal of levels, claiming that the *mere existence* of multiple levels of organization (rather than only one fundamental level) is decisive evidence against reductionism.

[64] Arguments in support of these claims are varied. Reductionists, for instance, claim that lower-level theories are superior because they are more explanatorily robust (Bickle 1998), more "fundamental" (Kim 1998), or able to unify more of scientific knowledge than higher-level theories (Oppenheim and Putnam 1958). Anti-reductionists, on the other hand, claim that higher-level theories are superior because they e.g., contain relevant explanatory knowledge for the phenomenon in question (Kitcher 1984; Jackson and Petit 1992), or are simply irreducible to lower-level ones (Fodor 1972; Rosenberg 1985).

> rejected in favor of lower-level theories when they conflict" (2012, 129)

This point that Oppenheim and Putnam's (1958) arguments for reductionism continue to exercise considerable, if implicit, influence on the way that philosophers conceptualize reductionist explanation is surely correct (cf. Section 2.2.5). It is also quite convincing that the "ghost" lingering in this influence has much to do with the role that levels of organization played in the reductionist arguments that Oppenheim and Putnam offered. The analysis of Oppenheim and Putnam's conception of levels offered in Chapter 2 certainly vindicates this claim. However, it is a different thing entirely to assert that this state of affairs is due, solely, to "the" (global) notion of levels of organization. Rather, it seems more justified to assert that an unwarranted and poorly motivated association between the levels concept and theoretical reductionism (mediated by the layer-cake account) exists.

2.) Emphasis on Theories as Privileged Epistemic Units

Another false accusation against the concept of levels is its assumed role in supporting a theory-centered approach in the philosophy of science. This is also a direct result of the complicated, but ultimately incorrect, association of the concept of levels (understood as layer-cake levels) with theoretical reductionism. Traditionally, accounts of theoretical reductionism focus on developing reduction as a relation holding between scientific theories. "Scientific theories" are a technical concept in the philosophy of science, and are defined, roughly, as a set of terms referring to the entities and concepts about which the theory is postulated.[65] These terms are related together into statements that comprise the laws expressed by that theory (see especially Nagel 1961, ch. 11). Reduction, then, is typically understood as a relation postulated between two theories in which one theory is reduced to the other when the reducing theory is able to derive the laws and terms of the reduced theory from its own laws and terms. Kemeny and Oppenheim's (1956) account of reduction and Nagelian-type accounts of reduction (Nagel 1961; Schaffner 1967; Bickle 1998) differ slightly from one

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[65] This is the "syntactical" view of scientific theories. The competing "semantic" view of theories conceptualizes scientific theories as sets of models rather than sentences, allowing for a more flexible framework to work out how exactly reductionism proceeds (see especially Bickle 1998, ch. 3). This distinction here is irrelevant, however, as it is the emphasis on scientific theories that is considered unattractive.

another in the particular form that this reduction would proceed,[66] but both nonetheless ascribe a "distinguished epistemic role" to scientific theories in matters of reduction and reductionism (van Riel 2011, 361).

The most obvious connection between the levels concept and theory-based approaches to explanation and/or reduction found in theoretical reductionism is due to the correspondence thesis (Section 2.2.4). Though Oppenheim and Putnam (1958) heavily focused on the presence of scientific *disciplines* as the correspondent standing in relation to a particular level of organization, this was immediately abandoned in practice in order to develop their reduction relation. More specifically, in terms of the actual *reduction* that would take place between one (Ln) and another (Ln-1) level, this would proceed by focusing on how the respective theories of these different levels would line up to each other (see Section 2.2.2).

Scientific theories were privileged epistemic units for much of the twentieth century during the influence of positivist and post-positivist philosophy of science (Waters 1990, 126). The emphasis on theories in philosophical analysis of science (at least at that time) was motivated in part by a general desirability to conduct philosophy of science in a formalized manner. In particular, it was seen as particularly desirable to conduct philosophical inquiry of science (especially questions concerning scientific explanation) in a way that lent itself to logical analysis.[67] The analytical character of scientific theories articulated by theoretical (anti-)reductionists made theory-centered approaches to analyzing scientific knowledge an especially attractive framework for philosophers. As a result, a generalized "theory-bias"

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[66] In particular, Kemeny-Oppenheim reduction is an *indirect* relation, meaning that reduction is a relation between each respective theory and the phenomenon that both theories seek to explain, but not between the two theories. Reduction between theories in such instances is said to occur when one or the other theory fulfills a number of other criteria concerning, e.g., its sufficiency in accounting for features of the phenomenon that need to explaining. Nagelian-type reduction, on the other hand, is a *direct* relation between the two theories in question, and reduction is said to occur when one theory can derive the explanatory laws and terms from the reduced theory (as well as when other criteria are fulfilled such as, the reducing theory being more generalized in scope). These differences are irrelevant for the moment, as for present purposes it is only important to note that both privilege theories as epistemic units in their treatment of scientific explanation.

[67] This was certainly the case with the accounts of theoretical reduction defended by Kemeny and Oppenheim (1956) and Nagel (1961); reduction in both cases are types of derivations, and the characterization of scientific theories to fit into these accounts of reduction reflects this observation. More generally, the logical approach to analyzing scientific explanation in philosophy, embodied by the D-N model of explanation (Hempel and Oppenheim 1949), was the notoriously dominant throughout most of the twentieth century.

emerged in the philosophy of science (Waters 2010, 240; see also Hüttemann and Love 2012; Kaiser 2012).

In the philosophy of biology, focusing on theories as the primary epistemic unit of science was put into question. The most common argument against the focus on theories in philosophy of science calls into question the adequacy of theory-based approaches for capturing how life scientists themselves organize scientific knowledge. The formal manner in which theoretical reductionism is characterized places an important emphasis on the *in-principle* character in which it casts analyses of scientific knowledge.[68] Wimsatt observes that 'in principle' qualifiers for theoretical reductionist claims is usually a “dead giveaway” the account is unable to accommodate the contextualized and tentative character in which knowledge in biology is most often cast (1979, 357). More recently, Marie Kaiser has argued that this aspect of theoretical reduction blocks attention to “substantive” issues in favor of “formal” ones concerning reductive explanation in biology (see also Sarkar 1998). Issues such as characterizing the criteria by which an explanation is considered “reductive” in a given setting in biology, or coming to grips with the diversity in the kinds of cases of epistemic reduction in biology are completely missed by theoretical reductionism (Kaiser 2012).

Similarly, Waters (2010) criticizes theory-based approaches in philosophy of biology for missing investigative practices in biology (2010, 240, 246).[69] In his analysis, however, Waters also directly criticizes the layer-cake image of the science produced by the levels concept's association with theoretical reductionism. Consequently, the theory-based approaches of theoretical reductionism remain thoroughly intermeshed with the concept of levels. Rejecting one will mean rejecting the other, as the following passage makes clear:

> “Theory bias is ubiquitous, not just among theoretical reductionists and layer-cake

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[68] Later defenses of theoretical reductionism in the biological sciences attempted to prop up particular accounts of reduction to accommodate this commitment to offering in-principle arguments concerning some “future state” of biology, in which the conditions of theoretical reduction can take place. Kenneth Schaffner (1993, ch. 9) and John Bickle (1998, ch. 3), admitting that biological knowledge requires substantial revision and reconstruction before such reduction can take place, independently construct conditions into their accounts of theoretical reduction to take this into account.

[69] By focusing on theoretical developments in biology, he argues, we miss the actual influence that drove some of the most important discoveries in biology, such as Watson and Crick's discovery of the structure of DNA.

> antireductionists, but among philosophers of science in general. *Removing this bias will enable us to look beyond the layer-cake image* and see what Watson and Crick's discovery did for genetics and how the resulting development in genetics transformed scientific practice throughout much of biology." (Waters 2010, 240, emphasis added)

However, there are good reasons to doubt that theoretical reductionism necessarily requires a conception of levels at all, layer-cake or otherwise. The association between the notion of 'levels of organization' and theory-based approaches in philosophy of science is unwarranted, and serves only to make even more of a straw-man of the concept of levels of organization. The significance of the layer-cake conception of levels, and the layer-cake account of reductionism with which it is deeply embedded, is largely historical concerning an analysis of the character and significance. Furthermore, the problematic elements of theoretical reductionism, which are interchangeably referenced with the concept of levels, have been criticized time and again by philosophers of biology over the last few decades, quite independently of 'levels of organization'.

3.4 Conclusion

Despite the ubiquity of references to the levels concept in both philosophy and science, there also seem to be compelling reasons to doubt the concept's overall viability. Indeed, the lack of a systematic analysis of levels of organization in biology has left many of the intuitive ideas attached to the concept acutely underdeveloped. This itself may threaten to undermine the concept, and thereby *any* role that it could play for scientific research.

However, the soundness of the arguments offered by levels skepticism is highly questionable. The criteria out of which the problematic counterexamples are so easily constructed are consequences of an implicit commitment to the layer-cake conception of levels of organization. But it is not the case that such skepticism has done any work in convincingly grasping the notion of levels as it appears in scientific practice. Rather, the most common skeptical arguments offered by the levels skeptics identify a number of features belonging to a straw-man conception of levels, namely, that of the layer-cake account. This account of levels is extremely problematic, and in itself quite unattractive, and yet it is cited substantially as an innocent attempt to clarifying what is typically meant by levels of organization. With such a problematic initial description of levels, it is no wonder why the concept of levels of organization is judged to be useless and misleading.

Interestingly, the levels skeptics collectively claim that their understanding of levels stem from a conception commonly illustrated at the beginning of introductory biological textbooks. So the better question to ask is whether biologists themselves conceptualize 'levels of organization' resembles the layer-cake account. The answer to this, which will be detailed in the next chapter, is a resounding “no”. The analysis of the next chapter will reveal that (1) there is another way to approach conceptualizing levels that does not collapse into some form of the layer-cake account, and (2) that the epistemic tasks expected of the levels concept (detailed in section 1.4) actually are central for understanding the character and significance of the levels concept.

The conception of levels of organization utilized by the levels skeptics, i.e. that of the layer-cake account is predominantly *static.* In order to properly grasp the usefulness of the levels concept, one must be able to entertain how exactly the concept is operationalized by scientific practice. This, in turn, requires that one discard the hope for any comprehensive, *singular* conceptualization of the levels concept, and particularly the layer-cake account. The criticisms offered by the levels skeptics are easy to construct if the use of levels in a particular instance is not considered *in a contextualized fashion*: i.e. the research context in which it the concept appears will give boundaries of relevance to the object and the things of which it is composed. In fact, several kinds of uses are entertained by the levels skeptics, albeit in a dismissive manner. One of these is the epistemic role of the levels concept across many instances in which levels are used, which is written off as “mere introductory or pedagogical contexts of application” (Guttman 1976; cf. Eronen 2014). This use of levels will be investigated in the next chapter. As will be seen, levels skepticism is easily disarmed when one realizes that *levels of organization are not utilized univocally across the different ways that science is practiced*. A more sustained analysis of the levels concept will also allow a general response to the charge in Section 3.2.3 that the levels concept is irrelevant to scientific practice will require a more sustained response. For one thing, its motivation does not rest only on how one conceptualizes levels (like the layer-cake account), but *also* on an understanding of scientific practice. In particular, the charge of irrelevance challenges exactly those instances in science where the levels concept is thought, even by scientists themselves, to at least play *some* significant role.

Chapter Four: A Fragmentary Concept

4.1 Introduction

If the concept of “levels of organization” turned out to be a nothing more than a useless or misleading concept, this would be an astounding conclusion to ascertain. The ubiquity of references to levels in the biological sciences, seen throughout virtually all textbooks in biology and in its widespread use in research literature, at least demand that the term not be thrown aside casually (see Ch. 1). Nevertheless, the last two chapters have shown that much work is now required to make sense of the concept of levels of organization. In Chapter 2 it was seen that the two prominent accounts of levels of organization in philosophy are unsatisfying and problematic. Chapter 3 developed the problematic issues surrounding the levels concept into a general emerging 'levels skepticism' that advocates eliminating or strongly de-emphasizing the use of the concept.

Against this levels skepticism, this chapter will offer an alternative account with which to understand the character and significance of the concept of levels of organization in scientific practice. This account will posit a pluralist understanding of levels that embraces a wide variety of distinct but legitimate depictions of levels of organization. Like the mechanistic account of levels in Chapter 2, the account developed here holds that levels must be contextually determined to be of effective use. This contextualization, however, will not be as radical as the mechanistic account, and will only hold for the *character* of the levels concept.[70] In contrast to its character, the *significance* of levels exhibits relative stability across different contexts of usage. This significance is found in the *epistemic goal* motivating the use of the levels concept, which is to structure explanatory problems in biology. This idea will be developed by using an approach to analyzing scientific concepts recently constructed by Ingo Brigandt, who proposes the term “epistemic goal” as a significant means of analyzing

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[70] See Section 4.3 and 4.4 for an explanation of what is specifically meant with “content”.

the use of scientific concepts (Brigandt 2010; 2012).

Key to this account will be the claim that 'levels of organization' is a *fragmentary concept* (Section 4.2). A fragmentary concept, tentatively, is a scientific concept that exhibits strong variation across different contexts of usage in some, but not necessarily all, of its components of semantic content, while simultaneously exhibiting stability in the way that it is used. In the case of levels of organization, this will mean that though the levels concept exhibits strong variation across different usages in what is taken to be the *reference* and the *meaning* of 'levels of organization', the "*epistemic goal*" motivating the usage of levels is remarkably conserved across different contexts of usage (Section 4.3). The epistemic goal motivating the use of the levels concept is to provide structure to explanatory problems in science, particularly biology (Section 4.4). This allows for the significance of the concept to be extended beyond isolated instances of usage, even though the character of levels between contexts is determined contextually. This account of levels of organization will then be exemplified by looking to the explanation oxidative phosphorylation via chemiosmosis in the 1960's and 1970's (Section 4.5).

One general motivation for the pluralist framework developed here can be found in philosophical analyses of other concepts in biology that exhibit strong variation between contexts of usage. For instance, the so-called molecular concept of a "gene" is another fragmentary concept whose exact character and significance is hotly debated among philosophers and scientists. Like the concept of levels of organization, there are a number of interpretations for what the term "gene" can possibly mean or refer to, and a number of distinct accounts for what the concept can be taken to mean has led some to call for a radically contextualized approach to understanding genes, not unlike the mechanistic account in the case of levels (Kitcher 1992)[71]. However, despite this variation, and indeed *because of*

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[71] Kitcher's comments can serve as a quick sample of the spirit of this 'gene skepticism'. As he says: "What is a gene? Nucleic acid. How much? We don't need to say. There are many good ways to segment nucleic acid into genes – though not every way of segmenting nucleic acid is a useful way. Much of biology can be done without any principle of segmentation at all. Where segmentation is needed, there are alternative principles of different utility in different situations. There is no need to seek the Holy Grail of the unique correct principle. It is enough to adopt one and make one's choice clear. A species, so the cynic says, is anything a competent taxonomist chooses to call a species. We can reach the same level of genuine insight and the same level of overstatement in the case at hand. A gene is anything a competent biologist chooses to call a gene." (Kitcher 1992, 131)

it, the gene concept continues to facilitate scientific research across the various contexts in which it is used (Rheinberger 2000; Waters, 2004; 2006; Brigandt 2010)[72]. The concept of levels resembles that of the molecular gene concept in that both concepts display *some* unity in their respective cases due to a stable epistemic goal.

4.2 Semantic Variation and the Levels Concept

Semantic variation is a common feature of concepts in science, and especially those in biology (Burian *et al.* 1996*;* Kellert *et al.* 2006). Concepts such as 'gene' and 'species' have received a great deal of philosophical attention due to the complicated and controversial nature of understanding their many possible meanings (Griffiths and Stotz 2007; Ereshefsky 2010). The existence of such concepts need not lead to condemnation of their use in science, and this variation itself can be a source of insight for both scientists and philosophers into the dynamics of scientific reasoning. However, this variation must be organized into a framework that makes clear how these kinds of concepts can provide such insight. One such framework has recently been constructed by Ingo Brigandt (2010; 2012), and will be introduced in Section 4.3 below.

The variation exhibited by the levels concept in science is especially daunting. The diversity of ways that levels are represented in biology (as illustrated in Section 1.4) differ from one another in multiple ways, which will be analyzed in the rest of this section. Due to this variation, constructing a singular account of levels that covers, in a comprehensive manner, *all* depictions of levels throughout biology is extremely unlikely, because there doesn't appear to be a common standard by which to directly compare, on the basis of their content, the many different instances of 'levels' throughout biology (see Section 4.2.2; Love 2012).[73] This builds on and complements the result obtained in Chapter 3, where it was seen that comprehensive

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[72] To read particular arguments for this claim, please see the literature cited. In this chapter, the usefulness of semantic variation will only be considered for the case of levels of organization. In this regard, the literature on the character and significance of the gene concept will serve as a background assumption with which to correspondingly motivate the current analysis.

[73] The desirability of such an account is also questionable, given the problems that attempts at constructing such accounts pose (Chapter 5).

accounts of levels (like the layer-cake account) lead almost systematically to false and misleading descriptions of nature. Moreover, unlike terms like 'gene', 'levels of organization' possesses a less tangible status in biological reasoning due to 'levels' not being proper material entities which can be directly observed.

The semantic variation one encounters with level claims will require a *pluralistic account* to make sense of the concept of levels. Alan Love (2012) offers two initial observations to motivate this, which can be seen as conditions to consider when constructing an account of levels. Firstly, the content of particular characterizations of levels in actual scientific usage is contextually determined (Love 2012, 120). This means that the content of the term 'levels of organization' is determined from the perspective of a particular scientific discipline in which the term is applied in a concrete claim or statement, and accordingly is applied to a particular system or set of systems that a researcher working in this discipline is interested in investigating. Call this the condition of *contextuality* for understanding levels. Secondly, as a result of this contextuality, what the term 'levels of organization' will express in science will encompass a large diversity of different particular characterizations (*ibid*.). This means that particular level claims made across biology differ from one another concerning the specific features used to describe particular systems in terms of levels. For instance, the way that relations between certain systems and their parts are understood to hold, the temporal features that characterize the workings of that system, and even the way and degree in which the system is demarcated from its surrounding environment, can be characterized differently between and even within the particular disciplinary perspectives that construct these level claims. Call this the *plurality* condition for understanding scientific conceptions of levels.

These two conditions (contextuality and plurality) are sufficient to establish that the concept of levels exhibits *some kind of* variation in its use in science. However, the extent and character of this variation remains unclear: does the semantic variation exhibited by the levels concept really yield a *pluralism* about 'levels of organization' or could there be a *monistic*, that is singular or comprehensive, account lying behind the plurality of different depictions of levels in science? That is, despite the plurality of ways that levels are depicted in particular scientific claims, could there actually be some shared essential feature behind these depictions that can be captured in a comprehensive account of levels?[74] In what follows, it will become clear that the variation exhibited by the concept of 'levels of organization' is indicative of an underlying pluralism: There are many distinct ways of characterizing levels that may or may not share common semantic content across all cases. This pluralism, as will be seen, is distinct from that of the mechanistic account, and does not subscribe a radical contextualization.

The concept 'levels of organization' hence exhibits a *fragmentary character*. Calling the levels concept “fragmentary” is meant to combine three observations: (1) In particular instances, the character of 'levels' can be very well-defined, and an effective means of expressing ideas and thoughts about the system or phenomenon to which the claim involving levels is made. However, (2) the character of the levels concept, taken as across these instances, exhibits significant incommensurability (see Section 4.2.2) due to the variation between the different instances of usage, which makes their mutual comparison difficult. Nonetheless, (3) the significance of the levels concept is sufficiently unified due to a remarkably conserved epistemic goal that motivates otherwise different usages of the levels concept (this will be developed below in Section 4.4). In order to gain a better grasp on the fragmentary character of the levels concept, it will be useful to start laying out the extent and form of the variation the concept exhibits. This will be the task of the rest of this section.

The choice of wording in calling a concept 'fragmentary' is intentional, and is meant to constrain its application to a contemporary perspective. This contrasts with other appraisals of certain biological concepts as exhibiting a *'fragmentary'* status. Though these terms share the characteristic of attributing a variable character to a concept at a given point in time (especially in a contemporary setting), the latter term is more loaded in that it can imply a strong historical aspect to the manner in which this fragmented status can be understood. In particular, this label strongly implies an historical process by which a concept began, at a

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[74] This emphasizes a difference between the notions of *plurality* and *pluralism*, which need to be distinguished from one another. *Plurality* in the sciences represents “a feature of the present state of inquiry in a number of areas of scientific research […] These are characterized by multiple approaches, each revealing different facets of a phenomenon” (Kellert et al. 2006, ix). This stands in contrast to *pluralism*, which “is a view about this state of affairs: that [e.g.] plurality in science possibly represents an ineliminable character of scientific inquiry and knowledge” (ibid. ix-x). It is important to keep these ideas distinct, for, as just hinted, a singular, “monistic” account of levels is consistent with the plurality of different level depictions in the sciences, but not with a pluralistic account.

certain earlier period in history, *to fragment* from a (relatively) unified status in its former character or significance to a concept that exhibited increasing variation such that, at a later period of time,[75] no unified conception of that concept was empirically or conceptually tractable. Here philosophical analyses of the concept of a “gene” is especially instructive, as “the” gene concept has been observed as exhibiting a “fragmented” status by several authors (Dietrich 2000, 1139-1140; Griffiths and Stotz 2007, 101-102; Brigandt 2010, 31). In each of these instances, the authors draw this conclusion from the history of the *semantic change* in the gene concept as the source for the variation that the concept exhibits in a contemporary setting. Michael Dietrich makes this clear when in his statement that “[t]he problem of the [contemporary concept of the] gene is rooted in the *fragmentation of the classical gene concept*”, which, in the context of the transition from the Mendelian (classical) concept of the gene to the molecular concept of the gene in the middle of the twentieth century, made this “fragmentation” “an *historical* inevitability” (Dietrich 2000, 1139-1140, emphasis added; cf. Rheinberger 2000). In a similar fashion, Brigandt asserts a similar history-oriented process in the transition from the “classical” molecular gene concept (i.e. the original molecular gene concept as construed in the 1950's-1960's) to the “contemporary” molecular gene concept (i.e. the molecular gene concept as conceived after the 1960's). Brigandt characterizes this process as one leading to the current fragmented status of the molecular gene concept:

> “While the classical molecular concept featured a unified vision of genes, the contemporary gene concept is a more *fragmented concept*, in that different scientists offer different characterizations of what genes are and use different structural criteria of individuating genes, *leading to a situation where* [from a contemporary perspective] the term 'gene' refers to different categories in different contexts” (Brigandt 2010, 31, emphasis added).

The contemporary sense of a concept being fragmented, as expressed by the term “fragmentary”, is captured in the second half of this passage. That is, “fragmentary” refers to a current situation of science in which the character of a concept exhibits the traits described

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[75] Perhaps trivially, this phrase “point in time” is not meant to as a particular date or year (though the possibility is not ruled out), but rather as general points of index from which an author makes their claim, e.g.: “The gene concept in the 1920's-1930's” vs. “The gene concept in the 1950's-1960's”.

above concerning the levels concept: clear and well-defined in particular instances, but variable (indeed incommensurable) across contexts of usage. In the case of the levels concept, the historical aspects of this fragmentation, though fascinating, will not be analyzed here.[76]

4.2.1 Fragments of the Levels Concept

Though the semantic content that is expressed using the term 'levels' may be different between different instances, the particular variation between these instances of usage can be identified in one or more of the following elements that are expressed by the term 'levels'. This list reflects the elements discussed in Section 1.4, but here are more readily classifiable with respect to conceptual content.

The Entities Designated by Level Claims

First, and most obviously, are the particular things that are designated by claims involving levels. What exactly is designated is tied closely to how the other fragments are set by each respective level claim. Depending on how the definitional criteria that inform the meaning of levels (see below) is set, level claims relying on part-whole compositional relations between levels will designate different things than claims relying on scale. Likewise, the mode in which levels are articulated are important, as some claims designate ontological items, such as entities (e.g., cells, ecosystems, molecules – Reece et al. 2010, 3-5), while others designate epistemic items that are found at certain levels (e.g., explanations, scientific disciplines – Reece et al. 2010, ibid.; Woodward 2010). While ontological items appear to take priority, epistemic items are often cited as accompanying them as the items most important for the context in which the respective level claim is made. Though ontological items may be strongly implied (even when not explicit), the importance of epistemic items designated by certain level claims may be more significant for the scientific task in question (Grillner et al. 2005).

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[76] Chapter 5 will deal with the historical aspects of the levels concept in biology. There, it will be seen that there was no "fragmentation" in the sense described here; i.e. where a comprehensive concept *became* fragmented. Rather, the fragmentary character of the levels concept was present from the beginning.

Scope of Application

Another important element of variation in level claims is the *scope* of entities in the world over which the levels concept is quantified. The scope of levels can range between *global* and increasingly *local* breadths. Like the point above concerning the particular things designated by levels claims, the scope of particular these claims can apply to both ontological and epistemological things. Perhaps the most readily accessible depiction of levels is in the hierarchical view of the world often found in introductory science textbooks, and often reiterated in the research literature. Such views are global because they extend to all things in the natural world. Local depictions of levels are also commonly found in science, both in advanced textbooks books as well as in the research literature. Local depictions of levels contrast with global counterparts in that the stratifications that are represented in these depictions are made in relation to a more specialized disciplinary perspective, rather than in relation to the study of biology as a whole, where global depictions sometimes extend to the entirety of nature. The range of the scope in level claims can be appreciated by taking the philosophical accounts of levels discussed in Chapter 2, which represent the extreme poles of a spectrum: The layer-cake account, on the one hand, is universal and comprehensive, while the mechanistic account on the other hand is radically contextualized and local. Levels claims can, however, also occupy a degree of generality or locality between these accounts as well.

Definitional Criterion of Content

Another important dimension of variation concerns the *definitional criterion of level content*. The definitional criterion characterizes *what* is being represented in the use of levels of organization in the first place. The two most prominent criteria that are used, as discussed above, include *composition* (i.e. part-whole relations), and *scale* (i.e. a graduated range of values related by magnitude). Recent philosophical literature on levels has focused on which of these criteria is more constructive for explicating levels of organization in science (Craver 2007a, Craver and Bechtel 2007, and Findlay and Thagard 2012 prefer composition, while Rueger and McGivern 2010; Potochnik and McGill 2012, and Eronen 2013; 2014 favor scale). Though scale has recently received increased attention, no general account for levels of organization based on a scale criterion has yet been offered.[77] The two major accounts of

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[77] One exception may be Wimsatt (1994[2007]), who argues that scale is one major criterion for differentiating levels. However, as seen in Chapter 1, Wimsatt's account of levels is still preliminary, and a detailed analysis

levels in philosophy, the layer-cake account and the mechanist account, both heavily favor part-whole composition as the definitional criterion to explicate levels. In science the situation is more nuanced, and both criteria are frequently used interchangeably, sometimes in the same context (Section 1.4).

Mode of Presentation

Yet another dimension of variation in the meaning of levels concerns the mode in which levels are applied. Specifically, are levels meant to represent an ontological ordering of things in the world or an epistemological ordering of things in science? Whereas the hierarchical image of the world presented in scientific textbooks is presented as an ontological claim (Section 1.4), the ordering of things like scientific disciplines or the knowledge associated with these disciplines is also commonly emphasized by other uses of the levels concept (Oppenheim and Putnam 1958; Kitcher 1984; Grillner et al. 2005; Wimsatt [1994]2007; see Chapter 5). All of these modes are commonly applied in the scientific literature. Representing these modes together remains a highly contentious issue, for, when understood too strictly, can be a decisive flaw in the articulation of levels. This was the case with the layer-cake account (cf. Craver 2007a, 171). However, it is still premature to prohibit that levels of organization have *any* association with the units and products of science (cf. Section 2.3), as this too is an insight into the constructive use of levels in scientific research (see Chapter 5 for more on this).

4.2.2 A Common Standard for Comparing Level Claims in Biology

One way to better structure the semantic variation observed in the levels concept is in terms of the "incommensurability" between particular instances in which levels are characterized. The idea of "incommensurability" as it will be used here refers to the inability to compare different uses of a particular scientific term as it used in different contexts of usage, and will be discussed in more detail below.[78] This follows Love's (2012) use of this idea to articulate

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of whether scale as a criterion for levels can accomplish what is expected of the levels concept in science and philosophy remains an open question.

[78] The term "incommensurability" originally stems from the works of Thomas Kuhn and Paul Feyerabend.

the challenge of making sense of 'levels of organization' in science:

> "Whether the different representations of hierarchical relations in [e.g.] causal explanations[79] found in diverse sciences can be combined or integrated is a question of *hierarchical representation commensurability*: is there a common standard or hierarchy to which heterogeneous hierarchical representations can be reduced or unified?" (Love 2012, 116)

The contextuality condition mentioned above specified that the content of level claims is made from the perspective of a particular discipline in which the term 'levels' is applied. This discipline-bound aspect of level claims already constrains the applicability of the term 'level' in a decisive way that in turn inhibits direct comparison of particular level claims between different disciplinary perspectives. Three initial reasons can be given for this. Firstly, the specific content that a discipline-bound perspective attributes to the concept will be constructed from the conceptual resources that inform that discipline's way of investigating nature. As a result of this, different things are designated as the constituents of the different 'levels' that are postulated in another given instance. Secondly, and closely related to this, the manner in which a particular discipline demarcates a phenomenon that is described using levels language will also be tailored to the interests and resources that inform the way that discipline in question selects its objects of study. Thirdly, the content that is given from a particular perspective will also be evaluated using the knowledge that is endemic to that discipline, but not necessarily to others. As a consequence of this, the way that 'levels of organization' is applied in different instances will differ in such a way that comparison between these different instances will be difficult to reconcile with one another. These three observations allow for a basic understanding concerning how different uses of the levels

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Kuhn in particular developed several distinct notions of incommensurability over his career, of which the "semantic" variety related to the one described here is only one (Bird 2013; see also Kuhn 1982). Other notions of incommensurability include, respectively, methodological and theoretical incommensurability. The use of the term "incommensurability" is not meant to encapsulate traditional philosophy of science discussions about commensurability, but rather a more pedestrian observation of that salient differences in the content of particular level claims make any straightforward comparison between these claims difficult to pursue without first properly contextualizing (i) how each fragment of the concept is informed in a given case and (ii) how each of these fragments is weighted in terms of its importance for that given case.

[79] In this paper, Love is discussing the role of levels in evaluating claims of downward causation. This is irrelevant to the present discussion, as the point holds despite this particular focus in his paper.

concept can be said to be “incommensurable”.

Two further caveats concerning differences in the use of the levels concept in science complicate matters further. Firstly, the modes (see the foregoing section) in which the term 'levels' is applied can differ both *within* and *between* disciplinary perspectives. Since the term 'levels of organization' can itself often comprise a 'package deal' combining an assortment of ontological and epistemological claims, this can make interpreting even particular level claims a delicate matter. Depending on how the fragments of the levels concept are determined in a given instance, various claims can differ at least in terms of (1) a set of entities in the world that are directly referred to as a hierarchically organized system, but sometimes also (2) a set of investigative techniques and methods associated with the structures and processes referred to in (1), and (3) explanatory generalizations associated with (1) or (2). The information in (1) constitutes the 'levels of organization' claim proper and is primarily ontological, while (2) and (3) are epistemic claims non-trivially associated with the these level claims. The specific emphasis that is given in particular level claims to these different kinds of information, i.e., the *mode* in which the levels concept is applied, can vary between these three kinds of information depending on what the speaker wishes to communicate by using the term 'levels of organization'.

For this reason, the mode of a level claim can decisively influence how variation in other parts of the concept can be understood. If, for instance, a claim involving levels applies the term in a manner that emphasizes epistemic information (corresponding to (2) or (3) in the foregoing paragraph), then the things designated by that levels claim may or may not include entities and processes in nature, but rather will designate (at least primarily, given the purpose for applying levels in that mode), e.g., epistemic units or products of science. In intradisciplinary settings, dealing with this variation can be challenging when levels claims in that discipline are not clear on the modes in which these claims are applied. More challenging, however, is when these claims are directed to *other* disciplines that designate different things with their level claims, express different scopes in those claims, and apply their level claims in different modes. Hence, both intra- and interdisciplinary kinds of level claims introduce substantial opportunities for semantic variation of the levels concept to arise.

Secondly, different disciplines regularly refer to the same entities in their own respective level claims. The degree to which these respective claims differ can lead to obstacles in communication between researchers that belong to different disciplines in addition to basic concerns of incommensurability described above. Specifically, when different disciplinary perspectives each work on investigating a common phenomenon that is distributed across different organizational levels, the degree to which specific level claims attached to these respective disciplines resemble or differ from one another will become extremely important for how (or whether) these disciplines can coordinate their efforts together to collaboratively investigate the phenomenon. For now it is only important to note this kind of situation as yet another aspect of the variation endemic to the concept of levels, but can be made clear in the following manner. A “cell” is a very important biological entity for studying and explaining living phenomena, and is often designated as a “level” in many explanations or descriptions across biological disciplines. However, a “cell” can be characterized in many different ways, or vary in explanatory significance depending on one's disciplinary perspective, and the perceived relationship between a “cell” seen as a structural unit and the phenomenon that is being investigated.

The prospects for articulating a comprehensive, global account of levels that explicates the character and significance of levels throughout science (like the layer-cake account) are extremely doubtful. The challenges of the levels skeptics discussed in Chapter 3 against such types of accounts document quite well the problems that hinder attempts to construct a singular conception of levels that extends to all of nature. The use of the weaker idea of “semantic incommensurability” here expands on this point. Specifically, since there is no *a priori* common standard by which to directly compare the content of different level claims in science, it can be concluded that the plurality of different depictions of levels in science is indicative of a *pluralistic* rather than a comprehensive, i.e. *monistic* concept. The reason for this is the contextualized manner in which the content of claims involving the term 'levels' is determined.

Turning back now to the 'incommensurability' of level claims, it should be clear that what is *not* meant by the term is that the content of different level claims are not comparable *in principle*, but rather that comparing level claims cannot rely on a unified or unifiable concept of levels, given the actual variation displayed between different usages of the term 'levels'. Indeed, given now that the variation of the levels concept has been given more tentative structure with the fragmentary layout that the concept exhibits, comparison between different level claims is now not only possible, but also a constructive endeavor for teasing out the more specific implications that different level claims bring to bear on the tasks for which they are used. In this way, "incommensurability" is of a more modest variety, which Kuhn distinguished as "local incommensurability": "There is no common measure. But lack of a common measure does not make comparison impossible. On the contrary, incommensurable magnitudes [of this modest variety] can be compared to any required degree of approximation" (Kuhn 1982, 670). Hence, the fragmentary framework offered here is a means of showing that different level claims are in fact comparable.

4.3 A Framework for Analyzing Semantic Variation in Biological Concepts

Ingo Brigandt (2010; 2012) has recently articulated a useful framework in which to analyze semantic variation of concepts in biology.[80] The framework that he offers is novel in that he construes it as a use-oriented methodological guideline for analyzing both semantic change and variation in specifically *biological* concepts (Brigandt 2012, 78-79). The key motivation of this framework is that it strives to contextualize semantic variation of concepts in their actual use in scientific practice. Traditional approaches to analyzing scientific concepts often overlook the importance of context in biological concepts, which, given the amount of semantic variation one often encounters, makes them unfit for analyzing how concepts in biology are treated, (see section 4.3 below).[81] Instead, what is needed, especially in the case of

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[80] Brigandt himself emphasized the relevance of his account for both conceptual change *and* for semantic variation. For the account of levels being developed here, only the latter issue is relevant here. Hence, the purpose of the discussion here is to analyze the state of affairs in present day science, where different contexts are not individuated by, e.g., theories or paradigms, but rather different instances of usage that are localized by other embedding factors, i.e. disciplinary setting.

[81] What this means will be explained in detail momentarily.

'levels', is a means for analyzing semantic variation that specifically aims at understanding why variation itself is sometimes an unavoidable, and even desirable, feature for biological concepts. Whereas traditional approaches attempt to explain away semantic variation by searching for one or several essential properties shared between instances of a term (Putnam 1973), Brigandt argues that philosophers should (at least sometimes) embrace variation as an important aspect of the way that concepts are used in biology. Particularly, this variation can be an important source of insight into scientific practice, specifically the role of context in generating reasoning patterns in science. Brigandt explains: “The philosopher has to account for how scientists can *legitimately modify a term's definition.* Likewise, a term's usage may vary across different disciplines...The philosophical task is to understand why such a variation in a term's meaning need not lead to a breakdown of communication across different researchers” (2010, 20-1).

The framework that Brigandt constructs begins by offering a layout of conceptual content. According to this layout, analyzing a scientific concept is done by three looking at three features of its content, including its reference, meaning (or inferential role, as Brigandt calls it), and epistemic goal (Brigandt 2010, 21-22). The first two are components of semantic content (reference and meaning), and are more familiar to philosophical analyses of scientific concepts. The third feature (epistemic goal) constitutes the novel proposal of Brigandt's account. The epistemic goal of a concept refers to the purpose motivating the use of that concept, which in contrast to the reference or meaning of a concept, is rarely expressed explicitly by a statement involving that concept. Rather, it is expressed implicitly and encompasses a collection of criteria by which the use of a concept can be evaluated.

Out of this framework, Brigandt argues that the epistemic goal of a concept can also constitute the basis for minimally unifying a concept (2010, 19-20, 36). This “unification”, preliminarily, is articulated by the ability of a concept's (stable) epistemic goal to account for variation observed in other components of a concept (Section 4.3.2, 4.3.3). One interesting consequence that this account supports is that semantic variation (in some but not all of a concept's semantic components) is a conditionally *attractive* feature of some concepts in biology. Both of these points make Brigandt's framework especially well-suited for analyzing the levels concept given the strong variation that the term 'levels of organization' exhibits.

This framework will be illustrated by building on work done on the molecular concept of the gene, which Brigandt also uses to make the tenets of his framework clear. A "gene" in the molecular sense used here is some kind of sequence of nucleic acids that codes for a protein or RNA product of some kind, rather than (or in addition to) an abstract unit of hereditary (see e.g. Pearson 2006, 399). The contemporary concept of a "molecular gene" is another fragmentary concept[82] that exhibits significant semantic variation in contemporary biology (Brigandt 2010, 31; see also Burian et al. 1996; Dietrich 2000; Griffiths and Stotz 2007).[83] For this reason, this case will be important for framing the discussion of levels to follow below. The molecular gene concept is significant because, like the levels concept, both reference and its meaning of a "gene" exhibit variation between different contexts of usage among biologists. That is, there are several distinct, but legitimate, ways of specifying the content both for what a gene is and how it is applied (i.e. its meaning), and also in the things that the concept is taken to refer to (i.e. its reference). Despite this variation, Brigandt claims that the molecular gene concept demonstrates at least "some unity underlying the various uses of the term" (2010, 34).

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[82] As mentioned above, the term "fragmented" strongly implies an historical aspect of a scientific concept by which that concept *becomes* fragmented over a period of time. It also implies, e.g., that the concept in question was, at an earlier time, relatively unified in its character and/or significance, whether as an observation of the convictions held by scientists at that point in history, or as a matter of fact regarding how the concept was in fact used at that time.

[83] The "classical" gene concept refers to a way of conceptualizing genes as a means of predicting patterns of inheritance observed in phenotypic traits. In contrast, the "molecular" gene concept refers to another conception of genes that is meant to explain how genes produce their molecular products (such as RNAs and proteins) (Brigandt 2010, 28, 34). This distinction is important in that the gene concept is analyzed in philosophy as an instance of semantic change *and* semantic variation. 'Semantic *change*' refers, roughly, to change in the meaning or reference of a concept over time. This distinguishes it from semantic *variation* due to a more prominent historical role in tracking differences in concept usage. The shift from the classical gene concept to the molecular gene concept is a straightforward case of semantic *change* in a scientific concept over time (cf. Bechtel and Richardson 1993[2010], Ch. 8). Brigandt claims that his framework for analyzing biological concept can account for cases of *both* semantic change and variation (ibid. 25; 2013, 75). Though related, the analysis here will not take a position on semantic change, either generally or in the specific case of levels of organization.

4.3.1 Components of Semantic Content and the Molecular Gene Concept

The first component of content is the concept's *referent*:

1.) <u>The Concept's *Referent*</u>: The reference of a concept constitutes the thing to which a term refers in an expression containing that term. The referent of a concept is typically taken to be an entity 'out there in the world' about which a speaker wishes to speak. For instance, “H_2O” is said to be the referent for the concept “water”.

The thing to which a molecular “gene” is taken to refer can vary strongly between different contexts. Due to the collection of processes that comprise splicing, it becomes difficult to say what nucleic acid *entity* designates a gene. During splicing, non-coding segments of the DNA template that are transcribed into the pre-mRNA (called introns) are removed from the primary transcript, and the remaining segments that *do* code for a particular product (called exons) are joined together (in protein-coding sequences) to form the mature mRNA, which is sent to the ribosome for direct production of the protein. Here, three physical distinct entities (the DNA template, pre-mRNA, the mRNA) each can be the referent for a ‘gene’. So, what ensemble of nucleic acids qualifies as “*the”* referent for the gene concept? The answer, it turns out, is that there is no single answer, because different entities are designated by different research contexts that use the concept of a gene (Griffiths and Stotz 2007, 85).

The ambiguity attached to setting a referent for genes is now directly acknowledged in major scientific journals, which propose that the label of “gene” now needs to accommodate a variety of constellations of different nucleic acid structures, both DNA- and RNA-based, to account for the referent of genes. One article in *Nature* comments on the “slippery” character of the gene concept:

> “[T]he cell’s protein-building apparatus requires a number of RNA molecules as well as proteins to operate. But the finding of ‘microRNAs’ and other RNA molecules now

> known to be vital in controlling many cellular processes in plants and animals, and the newly revealed ferment of RNA transcription, contributes to the view that RNA actively processes and carries out the instructions in the genome. Perhaps the regions that make non-coding RNA should also carry the status of genes, if not the name itself. (Pearson 2006, 400)

Likewise, in an article in *Science*, another commenter states that the "distributions of exons, promoters, gene start sites, and other DNA features [processed and regulated in large part by RNA structures] and the existence of widespread transcription suggest that a *multidimensional* network regulates gene expression" (Pennisi 2007, 1556, emphasis added). The "multidimensional" nature of gene expression here refers in part to the plurality of different nucleic acid structures, both DNA- and RNA-based, that are directly related to the creation of the molecular products that arise out of "genes" (ibid. 1555). That is, all the possible referents of the gene concept play a role somewhere.

Burian et al (1996) suggest that the solution to deciding on what the term "gene" refers to for all cases of usage must rest on the purposes informing usage:

> "There are two types of hereditary material, after all [i.e., RNA and DNA], and given significant enough differences in function we might choose, indeed some have chosen, to reserve the term 'gene' for the [sic] DNA. The usefulness of definitions truly does depend on purpose. For some purposes it is useful to choose a more restrictive definition and for others to adopt a more liberal one. Such choices affect how elegantly issues can be discussed and conveyed, but they need not affect the range of facts that can be captured" (Burian et al 1996, 19).

Their reasoning for this is that something more is needed to account for why one particular entity or another is *chosen* to be the referent for the gene concept. This cannot be accomplished by only looking at well-established empirical facts about what the details of the "hereditary material" that constitutes genes *is*, because biological research clearly designates distinct yet equally legitimate referents.

The second component of conceptual content Brigandt discusses is the concept's *meaning*:

2.) <u>The Concept's *Meaning*</u>: The meaning of a concept is typically taken to comprise a set of beliefs about the concept's referent (see below) held by the speaker that enables them to reliably communicate ideas about the concept.[84] The content of these beliefs identify certain properties that are attributed to the referent. For instance, the belief that "electrons are negatively charged" posits a property ("negatively charged") that it attributes to or associates with the referent (an "electron"), which is represented by the speaker in virtue of that person possessing the concept "electron". These properties can be found, e.g., in the definition given to the concept.[85]

Like the referent for a gene, the meaning of the concept "gene" also exhibits variation in scientific usage. This is easily seen by considering the context-sensitivity of deciding on what information should be used for defining a "gene" in different instances. Defining a gene in a given situation often proceeds by identifying the relation a gene possesses to the product for which it codes. Though it was once believed that each gene codes for exactly one protein (a one-one relation), it is now known that many different relations obtain between certain genes and their protein products; one gene can relate to several products (one-many), many genes can relate to one product (many-one), and many genes can relate to many products (many-many) (Pearson 2006; Brigandt 2010, 31-32). These differences are more than merely conventional; these differences lie in the variable ways whereby the genetic 'information' of a 'gene' is extracted from DNA in the genome and 'processed' along the way at each step of its expression, especially during transcription. The products of gene expression, after all are different from each other and also do different things. So, similarly to the differences in the referent, differences in the meaning of a gene are also supported by well-established empirical knowledge about what genes do. Whichever definition is chosen in a given instance will be

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[84] Brigandt's understanding of meaning is an extension of "conceptual role" (or "inferential role") semantics, which emphasizes the *use* of concept in communication or social interaction for determining meaning (Block 1998).

[85] The "definition" given to a concept is not an exhaustive term containing *all* information which specifies the meaning of a given concept. The purpose of focusing on a concept's definition here is simply to direct the discussion towards highlighting that meaning in biological concepts (here molecular concept of genes) exhibit variation.

determined by what the study in question requires a gene to be, making a singular meaning for "gene" elusive.

4.3.2 Epistemic Goals of Concept Usage

In addition to meaning and reference, Brigandt's framework for semantic variation introduces third feature for analyzing scientific concepts, i.e. *the epistemic goal*:

3.) The Concept's *Epistemic Goal*: The epistemic goal of a concept specifies an aim or aims that motivate the use of a concept (Brigandt 2010, 23; 2012, 77-78). As the name implies, this aim is epistemic in nature and specifies a certain task to be achieved by applying a certain concept (such as pursuing an explanation for a particular phenomenon). Epistemic goals also specify epistemic standards by which to evaluate the use of a concept in achieving the task it is meant to accomplish (Brigandt 2010, 24; 2012, 78). Such standards may include, e.g., evidential standards to assess empirical claims that make use of the respective concept, or criteria that specify criteria for explanatory adequacy; that is, by what standards different attempts at explanation can be judged as better or worse.

The epistemic goal of a concept differs from a concept's meaning in several important respects. Most importantly, epistemic goals do not comprise a set of beliefs, empirical descriptions, or definitions, but rather specify a set of *epistemic values* (Brigandt 2012, 78). The information represented by the epistemic goal of a term hence operates in a very different manner than its meaning. Whereas meaning contains representational information about a term's referent (such as a definition or empirical description) and specifies rules regarding how a respective concept is to be used, an epistemic goal specifies certain values, i.e. aims and standards, which guide the use of a concept towards accomplishing a certain task (Brigandt 2012, 97).

A second important difference between a concept's meaning and its epistemic goal is that the values expressed by the latter are determined by the concept's use in the scientific community, rather than an individual who uses the concept (Brigandt 2010, 23). Epistemic goals are hence not always explicitly expressed with a concept's use, unlike the meaning or reference of that concept. Instead, it can be implicitly expressed with a particular term as a property possessed by that term in virtue of being embedded in one or several scientific disciplines.

For this reason, introducing the epistemic goal of a concept is not meant to expand the number of components of semantic content, on par with the meaning and reference of a term. Rather, the reason for postulating epistemic goals is specifically to aid in analyzing cases of semantic change and variation that are philosophically challenging. Its justification should be measured in terms of whether and to what degree it can help explain why a particular concept exhibits variation in its use (Brigandt 2012, 98-99). Brigandt specifies:

> “My tenet is not that every scientific concept can be assigned a unique epistemic goal or a clearly delineated set of epistemic goals, or that this idea can be fruitfully applied to all scientific fields. Rather, my claim is that epistemic goals can be assigned to those central concepts (at least in biology) that underwent conceptual change [or exhibit variation], such that this semantic change [or variation] can be explained in these terms.” (Brigandt 2010, 23: see also 2012, 78-79)

At the same time, Brigandt acknowledges that epistemic goals can themselves exhibit variation, or can be one among many different resources that inform the use of a scientific concept. This is exhibited in the (historical) shift from the classical to the molecular gene concept (ibid.). For instance, whereas the epistemic goal of the classical (Mendelian) concept of a gene is to predict patterns of inheritance observed in phenotypic traits, the epistemic goal of the molecular gene is to explain how genes “bring about their molecular products” (Brigandt 2010, 28).[86] In this case, though differences in a concept's epistemic goal can be

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[86] As mentioned above, the difference between the classical and molecular gene concepts is better viewed as a case of semantic *change* over time, rather than semantic *variation* due to the historical element at play in the emergence and development of the distinction between the two concepts. The point here is simply to point out that semantic differences in a particular concept (here ‘gene’, but equally so for ‘level’) can also rest on differences in the epistemic goal attributed to a particular concept, even when this results in the creation of distinct concepts.

cause to split that concept into multiple *distinct* concepts, it also shows how *stable* epistemic goals, insofar as they can be identified, can result in unifying an otherwise fragmentary concept. Brigandt explains:

> “While a scientific community often uses several concepts and theoretical resources to pursue a particular explanatory or investigative goal, in *some* cases such an epistemic goal (or set of epistemic goals) *can be* tied to an *individual* scientific concept, in that the rationale of the introduction or continued use of a central theoretical concept is to pursue this epistemic goal” (Brigandt 2010, 23; emphasis modified).

So, with respect to its status as a feature of concept usage, an epistemic goal is pragmatic rather than principled. It is meant to aid philosophical analysis of actual concept use in scientific practice, where the case at hand is warranted for looking at the information expressed by that goal (i.e. the aim and standards informing the use of the concept). One kind of case that especially warrants consideration of a concept's epistemic goal is when that concept exhibits variation in its other semantic components, which is in some way incommensurable.

4.3.3 Unifying Fragmentary Concepts under their Epistemic Goal

When a particular claim involving a certain concept is made, the information specified in the epistemic goal of that concept can allow for comparisons between different particular claims involving that concept. It does this in the following way: Since the epistemic standards expressed by a concept's goal are applied relative to a task that the use of a concept should achieve (i.e. the aim of a concept), then it becomes a legitimate question to what extent different uses of that concept actually achieve this goal. The answer, or answers, to this question can be assessed by using these standards, which follow from the epistemic values informing the concept's goal.

The appeal of attending to the epistemic goal of a concept is that the values it encompasses can serve to in some sense unify a fragmentary concept. Very roughly, to unify a concept is to connect different uses of that concept previously thought to be unrelated. This proceeds by uncovering some commonality shared by each different instance of a given concept. However, this vague sense "unify" requires further clarification. Consider the distinction of two notions of unification articulated by Dietrich (2000) concerning the molecular gene concept:

> "When considering the problem of the gene then we must drive a wedge between the scientific values of *generality* and *unification*. The problem of the gene should be decomposed into two [distinct] problems: Is it necessary or desirable to have a *comprehensive* or generalized concept of the gene? and Is it necessary or desirable to have a *unifying* concept of the gene?" (Dietrich 2000, 1140, emphasis added)

The purpose for distinguishing between these two ways of "unifying" is extremely important. Whereas other approaches to "unifying" concepts tend to focus on stronger forms of commonality, like uncovering a hidden essential property or referent that all instances of a concept share, epistemic goals unify in a much weaker sense. What this means will be articulated in more detail below, but for now the sense of "unify" used here is meant to specifically contrast with stronger forms of unifying that attempt to reconstruct a *comprehensive* concept that unites all uses of the word. The layer-cake account is a comprehensive account of the levels concept.

One major motivation for using epistemic goals to account for semantic variation is that traditional discussions have tended to focus only on a term's meaning and reference to account for semantic variation in scientific concepts. These discussions have tended appeal to a hidden comprehensive character in that concept in order to overcome incommensurable semantic variation. One such approach is to try and uncover a common reference for the concept in question that exhibits variation. This approach is exemplified by Hilary Putnam (1973), who proposed that the concept's referent exhibits a "transtheoretical character" that unites otherwise distinct uses of the concept, which have incommensurable meanings. This "transtheoretical character" postulates a comprehensive account of a concept in that it attributes a singular, unchanging character to the concept's referent, which remains stable independent from changes in the descriptions or beliefs that speakers use to inform their usage of a concept, where further nontrivial modifications to that concept are not possible. Semantic variation is hence dealt with, because even if different utterances describe or attribute different meanings to a particular concept, like 'gene' and 'level', each of these utterance nevertheless designate the same referent, to which each refers. Variants of this solution to incommensurable semantic variation oscillate between whether a stable referent is uniquely designated by properties given in descriptions occurring in the meaning of a concept (descriptivist theories of reference, e.g., Russell 1905) or whether the referent itself determines how those descriptions successfully refer (causal theories of reference, e.g., Putnam 1973, and Kripke 1980).

Appealing to the meaning or reference of a concept to account for semantic variation in biological concepts is unsatisfactory for two reasons. First, and most obviously, both the reference and the meaning of many biological terms are already known to strongly vary between contexts of usage. As seen in the above sections, it is possible to identify several distinct referents *and* meanings for the molecular concept of a gene. Yet at the same time the empirical research that informs the gene concept, i.e. contemporary genetics, is a well-established scientific discipline that regularly produces robust and reliable knowledge about the phenomena that it studies. The same situation holds for the levels concept, as seen in Section 4.2. Hence, focusing on the reference or meaning of such biological concepts is not helpful for accounting for the variation that they exhibit.

A second reason that such approaches are unsatisfactory, which builds on the first, is that the search for the “transtheoretical character” of biological concepts like 'gene' or 'levels' necessitates abstracting away from the actual scientific context in which the respective concept is used. This makes “general” theories of meaning and reference even more inadequate for analyzing biological concepts, because their results make them empirically vacuous, and hence inapplicable to the way that scientists themselves use these concepts in their own reasoning patterns. Burian et al. (1996) emphasize this point in their criticism of both descriptivist and causal theories of reference. Focusing, again, on the gene concept in particular, they say that:

> “The strength of a non-descriptive approach [to accounting for semantic variation][87] – whether for reference, or meaning, or both – is that it establishes continuity by abstracting altogether from the content of belief, by removing all descriptive content from concepts and from the determination of reference. It therefore eliminates problems with comparability and commensurability. The price this exacts is enormous: genes become the *Dinge an sich* responsible for the phenomena of trait transmission...Such descriptively empty concepts cannot readily be connected with chromosomes, protein, DNA, or RNA. Thus they cannot be used to reconstruct the actual debates in the history of genetics” (Burian et al. 1996, 18-19).

In the case of the molecular gene, different uses of the gene concept are unified not because of some ephemeral transtheoretical character, but rather because each strives towards achieving a stable overarching epistemic goal that each particular instance of the concept applies in a contextually determined way. This goal sets an explanatory aim (i.e., how does a sequence of nucleic acids bring about, or *explain*, a particular molecular product?) and an accompanying set of standards by which attempts to fulfill this aim are evaluated (such as explanatory adequacy criteria). In other words, there is a common “generic” epistemic goal that these different applications of the (molecular) gene concept, whose details are filled out by the *specific* epistemic goal that informs the ways that the concept is used in a given circumstance. Since the concept of a gene exhibits stark variation concerning, e.g., what it can refer to, and what its particular meanings might be, the prospects of constructing a generalized, *comprehensive* gene concept is widely seen to be a lost cause, and in any case irrelevant for clarifying its use in scientific practice (Waters 2004).

In contrast to dealing with semantic variation by constructing a comprehensive conception of

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[87] “Non-descriptive approaches” to accounting for semantic variation in this passage refers to causal theories of reference (e.g., Putnam 1973; Kripke 1980), which are one major family of theories of meaning in philosophy quickly mentioned above. The major details of these theories are not important here. Rather, what is important is the idea that these traditional approaches to analyzing semantic content that focus on other components of content (i.e. reference and/or meaning) in order to uncover a concept's “transtheoretical character” are not useful for analyzing biological concepts (such as the molecular gene concept and, as will claimed below, the levels concept) that exhibit strong variation. On that token, it deserves mentioning that Burian et al. also reject the adequacy of descriptivist theories of meaning, for similar reasons (1996, 21).

a concept that strongly unifies all the different uses of that concept, unifying a fragmentary concept by appealing to its epistemic goal offers a substantially weaker, but nonetheless significant approach to understanding unification of concepts. Specifically, epistemic goals unify fragmentary concepts by revealing that different uses of a concept share a commonality in the form of a shared motivation that informs that concept's use. Brigandt offers two reasons why this weakened kind of unification is attractive. First, the information contained in an epistemic goal can actually explain *why* scientists form different beliefs about the concept in question (Brigandt 2012, 95; see also 2010, 24). Focusing on the epistemic goal of a concept, and in particular the aim that this goal specifies, the variation of a concept can be grouped together under an overarching purpose that informs all the different uses of the term that otherwise conflict. At the same time, the epistemic standards that are also specified by a concept's epistemic goal allow for the specific form of the epistemic goal pursued by, e.g., a particular research group, to be evaluated against the overarching form that unifies different uses of the concept.

Consider again the contemporary molecular gene concept. Though the particular meaning and reference of a 'gene' varies from instance to instance, the overarching epistemic goal of the molecular gene concept remains the same: i.e. to explain how genes “bring about their molecular products” (Brigandt 2010, 28). In each different instance in which the gene concept is used in this capacity, the generic epistemic goal is applied in using local criteria for articulating how exactly this goal is met. In contrast, focusing on only the meaning of a term can only reveal *how*, e.g., the beliefs belonging to a concept are formulated, or various definitions for a concept were constructed. This may be sufficient for establishing *that* a concept exhibits variation, and what the character of this variation is. Insofar as these differences are incommensurable with one another, this will not help account for this variation.

Secondly, an epistemic goal can also show why semantic variation in fact can be an attractive aspect for a scientific concept. Recall from above that given that semantic variation is sometimes an unavoidable state of affairs for biological concepts, philosophical analysis should seek to explain why the incommensurability between different uses of a particular concept does not hinder scientists from effectively sharing one another's ideas. Unifying a fragmentary concept by appealing to a shared epistemic goal accomplishes this by accounting for why a concept's variation promotes communication between researchers (ibid. 35, 37). In this way, the partial unification offered by a concept's epistemic goal hence constructs a role for context in understanding the use of scientific concepts.

4.4 The Epistemic Goal of 'Levels of Organization'

Using Brigandt's framework for analyzing semantic variation, the levels concept can now be given more structure. Particularly, the marked variation seen in different uses of levels can be reconstructed in a similar manner laid out in the review of the molecular gene concept discussed above. Like the gene concept,[88] 'levels of organization' exhibits a fragmentary character in that there are multiple distinct ways of determining its content: The particular character of a specific claim involving levels is specified in a contextualized manner. The different elements ("fragments") that constitute the content of particular level claims were summarized in Section 4.2.1. Corresponding to the "reference" of level claims are (1) the actual things designated by levels (be those natural or epistemic entities) as well as (2) the scope of application in which the level claim in question is taken to hold. The "meaning" of level claims corresponds, accordingly, to (3) the definitional criteria used to identify levels and (4) the mode in which the concept of levels is applied in a given instance.

The semantic variation that the levels concept exhibits was also characterized in Section 4.2.2. The degree of this variation is substantial, though level claims are capable of effective clarity in particular instances of usage (even this requires substantial reconstruction in these instances when the authors are vague in their characterizations of levels). Specifically, the variation of

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[88] The purpose of using the gene concept as a case study is not to directly join the discussion of levels to the more established debate about gene concepts. Rather, the purpose is only to point out that even otherwise well-established biological concepts can exhibit semantic variation in a way that demands a more significant role for context for determining that concept's character and significance. Additionally, that these concepts exhibit stark variation does not necessitate eliminating either of them from scientific use. Even so, the situations observed in the 'gene' and 'levels' are not identical, and their differences need to be carefully differentiated from each other.

the levels concept that is observed *between* different uses reveals different meanings. This is due to the character of level claims being contextually determined, which means that the content expressed by the term 'levels' is set not only by the specific interests of a particular scientist using the term, but more importantly by the disciplinary context informing that particular use. Consequently, there is no common standard with which to directly compare content of these different uses on the basis of their semantic content. More importantly, this immense variation exhibited by the concept makes essentialist approaches to proposing a comprehensively unified conception of the levels of organization untenable, since the referent and meaning of different usages of the levels concept does not reveal any "transtheoretical character".

Notwithstanding the major differences between genes and levels, there is a more important similarity that connects these two cases. Namely, despite the stark variation each concept exhibits between uses, each also possesses a relative stable epistemic goal motivating the use of each respective concept. This stability serves to partially unify the levels concept, just as it does the molecular gene concept.

The epistemic goal of 'levels of organization' is to *structure explanatory problems*. Explanatory problems are problems concerning the construction of an explanation for a certain phenomenon. These may include basic questions such as "what would be an adequate explanation for phenomenon x?", i.e. how a particular kind of explanation can be pursued for a given phenomenon, or more nuanced questions such as compiling a basic understanding of the phenomenon itself, i.e. "what is this phenomenon x in the first place, for which we seek an explanation?" Other explanatory problems that are structured by levels may concern special issues that frustrate the search for an explanation, such as "what sort of issues hinder constructing an explanation for phenomenon x?" That is, in case there are shortcomings or obstacles in trying to explain a given phenomenon, it is important to identify possible sources of these shortcomings so that they can be addressed. Explanatory problems hence need not have to pertain only to the construction of the actual, ultimate explanation that is constructed for particular phenomenon, but rather may also encompass problems pertaining to conceptualizing other tasks that are equally important to working towards constructing an explanation. Though the specific problems facing any given group of scientists may vary from instance to instance throughout biology, the content of 'levels of organization', properly informed by the contextually-determined content, is uniquely capable of providing a scaffolding by which these kinds of problems can be dealt with.

4.4.1 How Levels of Organization Structure Problems

How, then, do levels "*structure problems*"? The specific manner in which levels provide structure to explanatory problems is tied to the way in which particular level claims are formulated. Recall from Chapter 1 that claims involving levels center around articulating a description of some system or systems in nature (or indeed the entirety of nature), which are laid out hierarchically. The form of these claims that apply the levels concept can be descriptive or hypothetical, which will be analyzed below. Both kinds of claims can structure explanatory problems, in different but complementary ways. Additionally, the constituent items referred to in the hierarchical layout of different level claims may include (a) the material entities that "make up" a phenomenon for which an explanation is being sought *or* (b) the disciplinary resources used to investigate, explain, or characterize that phenomenon. The epistemic goal of levels hence accommodates whichever mode one chooses to express out of the "package deal" of ontological and epistemic information that can inform the usage of the levels concept in any particular instance.

4.4.2 Descriptive Level Claims

Descriptive level claims are descriptive in that they make active claims concerning the organization of the system in question. This allows a first kind of problem structuring accomplished by the levels concept to be identified. Namely, this *imposes* a hierarchically organized layout to a particular system under investigation, which orders different items that belong to that system into strata that are articulated as constituent to that system. Using this description, and in particular the parts of the system and their organization, scientists acquire a basic ability to navigate within a system, e.g., by localizing specific effects and processes that occur within the particular system, or by tracing the investigative and explanatory statements made about the behavior of that system back to those parts. Even this minimal kind of structuring can contribute crucial information to the construction of an explanation.

For one thing, knowing what a system is made of and how it is organized is crucial for explaining a phenomenon. In particular, the organization underlying a biological phenomenon is a significant determinant of the phenomenon's behavior, i.e. how it works. Consider the analogy of an unassembled bicycle; obviously the bicycle will not work if the parts are not arranged in the correct way. In the same manner, biological phenomena depend on a “correct assembly” in order to function properly. The organization of living things differs from non-living systems in an important fashion, however. Namely, disturbing the organization of parts in living things can fatally disturb the system's workings in unknown ways such that the phenomenon becomes unreachable by investigative methods. On the other hand, removing the chain of a bike will make it unusable, but will not permanently 'break' it, since it can be reassembled. This occurs because organized wholes in biology can manifest completely different properties than those manifested by their parts in isolation from the whole. As a consequence, and unlike non-living systems such as a bicycle, biological phenomena cannot be adequately characterized by *only* looking at the parts out of which it is made.

Descriptive level claims structure problems not only by providing descriptive information about a system's constituents and their organization. They also provide the means of identifying and characterizing a phenomenon and the things that compose it: what constitutes a phenomenon at a given level is not only its lower level constituents, but also the organization of these parts. The arrangement of entities that constitute a phenomenon can be distributed across several levels of organization. The object of inquiry, i.e. the phenomenon, can be seen as perched at a particular organizational level (or levels) that is flanked both above and below by still other levels that contain structures important for explaining that phenomenon. Lower levels comprise the parts or processes that are known or suspected to compose the phenomenon, while higher levels comprise structures and processes to which the phenomenon belongs. This distinction is not principled, as a biological phenomenon can itself be composed of one or several embedding systems. The distinction between a phenomenon and its embedding system(s) is simply meant to capture the observation that constructing an explanation for certain biological phenomena is a product of how science works to reveal the details of natural phenomena via explanation. Nature, after all, does not always reveal its secrets willingly, and requires active interpretation on the part of scientists in defining the explanatory tasks to which they turn their efforts.

4.4.3 Hypothetical Level Claims

Hypothetical level claims resemble what Darden (1991) calls research strategies. These claims assume a hierarchical description is already given, or at least possible, for a particular system under investigation and then exploit this description by *suggesting* 'where to go' in order to deal with the explanatory problem at hand. More concretely, hypothetical level claims are suggestions that involve “moving to a different level of organization” (cf. Darden 1991, 253-254) in order to introduce new level-bound resources into the treatment of a given problem. These resources correspond to new constituent items that modify the content of the hierarchical description of the system.

Like the rest of the items constituting the hierarchical description of a system, the new items introduced to a hierarchy can be material, i.e. when they include entities or properties that are added to the hierarchy, or epistemic, i.e., when a particular investigative technique or explanatory approach is added to the way that the hierarchy is understood. They are level-bound in the sense that they are associated with items found at a particular level of organization that are not at found at other levels. In this way, “moving to another level of organization” means that new, level-bound, material parts of a system should be considered in the treatment of a problem, or that new resources or perspectives should be considered in the treatment of a problem.

“Moving to a new level” entails that the prior hierarchical layout of the system in question is modified in some way. Generally speaking, there are two senses in which this modification occurs. In one sense, the modification that occurs is primarily of epistemic significance in that the level to which scientists “move” is already represented in the hierarchical layout being offered in the description. That is, the overall hierarchical layout description of the system remains intact. The shift that occurs concerns the way that scientists appraise how the level in question contributes to the problem being treated. For instance, though a particular level may be, ontologically speaking, already well-defined and understood, for a particular problem being treated that level may acquire new significance in terms of what insight may be provided by the items found at that level. This may be the result of new knowledge about the items that populate that level, e.g., the discovery of new entities or properties of known entities or a new discoveries concerning the how those entities behave. This new knowledge may also be the result of new methods (or new interpretations of old methods) by which the material entities of a level are investigated. In another sense, the hierarchical layout of a system may also be modified by adding a new level or levels that was not represented beforehand.

In both senses of “moving” to a new level, the suggestion that is made by a hypothetical level claim is that we should *shift our attention* to a particular level or aspect of an already present level that, up until that point, has been left unattended. The “movement” pertains to one or another altitude within the overall number of levels (L_n) of the hierarchical strata given in the description of a system. Regardless of whether the description of the system is modified by adding new levels or by ascribing a new significance to already-existing ones, the “movement” that is made will be “look upwards”, “look downwards”, or “looking again” in a system.

The new resources that are acquired by moving to different levels of organization can structure explanatory problems in two specific ways, which were quickly mentioned above. Firstly, hypothetical level claims can *provide new insight* (cf. Darden 1991, 253) into a problem that cannot be solved using the resources already on offer at the level or levels from which one starts with an initial description of the system. For instance, the behavior of new entities found at a newly introduced level may provide insight by explaining an aspect of a phenomenon that beforehand could not be explained. In the case of constructing an explanation for oxidative phosphorylation (also shortened to ox-phos, see Section 4.5 below), one of the key insights made in constructing the chemiosmotic mechanism was to postulate new, higher-level, structures in the mitochondrion as part of the system constituting oxidative phosphorylation in order to account for how ATP is produced.

Secondly, hypothetical level claims are also made in order to *change* or *modify the problem itself*. Particularly, by moving up or down one or several levels, researchers also acquire new resources by which to change the way that problem is posed, or the conditions under which that problem can be considered solved. In the case of ox-phos, one of the key contributions that allowed for an explanation for ox-phos to be constructed was that the problem that researchers took themselves to be solving had to be changed in a substantial way. This involved introducing a more 'biological' characterization of ox-phos, which postulated that explaining ox-phos was not merely a manner of finding the right *chemical constituents* with which to fill the gaps of the chemical reactions known to constitute the production of ATP. Rather, the problem involved introducing higher-level organizational features into thinking about how to situate the chemical items already known to constitute ox-phos into the system in which they were embedded.

Problems can also be modified in more multifaceted ways, which can be clearly seen in interdisciplinary problems that seek to combine many different organizational and disciplinary perspectives in order to explain a complex phenomenon. In these situations a framework of levels of organization can aid in structuring the way that different disciplines negotiate how they take their epistemic resources to interact with each other in the search for an explanation of a phenomenon that each discipline is trying to explain. Providing structure to this kind of explanatory problem will involve treating distinct constituent problems that different disciplinary perspective pose of the phenomenon. There, it will be seen that this task is one that a framework of levels of organization is uniquely able to treat. In particular, attempting to integrate the different disciplinary resources together to construct an adequate explanation for motion adaptation, what was considered to be the problem itself changed several times over the past six decades.

4.5 Case Study for the Use of Levels: The Explanation of Oxidative Phosphorylation

During the 1960's and 1970's one of the principle scientific problems that engaged biochemists and molecular biologists was trying to understand how living systems produce energy necessary to sustain life (Weber 2005, 92). This problem comprised detailing the processes by which ATP (adenosine *tri*phosphate) is constructed from ADP (adenosine *di*sphosphate) and an inorganic phosphate group, in a series of reactions known as oxidative phosphorylation (hereafter abbreviated as ox-phos). The explanation of ox-phos is a well-documented case of biological discovery, and was one of the most controversial areas of research in the biological sciences during the middle of the twentieth century (Prebble 2012, 699-700; see also Bechtel 2006, 220-221).

The discovery of the mechanism for oxidative phosphorylation is a particularly compelling case for the decisive importance that organization distributed across several levels of organization can exhibit for explaining complex biological phenomena. Two aspects of the ox-phos case are especially pertinent in this regard: (1) Accounting for the organization of the chemiosmotic mechanism for ox-phos required that researchers move to a higher level of organization in order to account for chemiosmosis, and (2) this upward shift in levels was accompanied by a change in the character of the problem from a chemical one to a biological one. The key to understanding both of these aspects of the discovery of ox-phos, both as an empirical case and as an epistemic debate among the researchers investigating ox-phos, focused the role of ATP synthase in the production of ATP (Prebble 2002; Weber 2005, 91; Bechtel 2006, 219). Ontologically speaking, ATP synthase designates an interlevel junction in the chemiosmotic mechanism of ox-phos whereby the chemical-molecular entities driving metabolism (particularly protons, ATP, ADP, and the phosphate group) interact with higher-level entities (especially the inner mitochondrial membrane) in the production of ATP. This interlevel positioning of ATP synthase turned out to be one of the primary explanatory contributions of the chemiosmostic hypothesis proposed by Peter Mitchell, who would be awarded the Nobel Prize for his research into ox-phos. In terms of the scientific debate surrounding the search for the (unknown but highly debated) role of ATP synthase, one decisive error that hindered constructing the chemiosmotic explanation of ox-phos was the widespread expectation that ox-phos would be accounted for solely in terms of chemical processes. Particularly, it was expected that the explanation of ox-phos would revolve primarily around detailing redox reactions driving the construction of ATP from ADP with the aid of a “chemical intermediate”, whose existence was widely anticipated but ultimately repudiated (Allchin 1998; see also Prebble 2002; 2012). In other words, ox-phos was conceived as a *chemical problem* that would be solved using only chemical entities and processes, and the investigative resources of biochemistry. The solution to explaining ox-phos, however, required viewing ox-phos as a *biological problem* (Prebble 2012; see Section 4.5.2), which necessitated bringing higher-level resources to bear on the overall task of explaining ox-phos.

In this regard, the introduction of new levels of organization, as will be seen, decisively contributed to the explanation of ox-phos. This occurred not by replacing the other levels involved with the investigation of ox-phos, but rather by complementing the descriptive layout in which the metabolic reactions occur. This modification allowed previously acquired knowledge of the reactions constituting ox-phos to be given its proper structure. For this reason, an analysis of this case exhibits clearly the use of levels in a relatively *intra*disciplinary setting, namely biochemistry. More particularly, casting this historical episode of biochemical research in terms of levels of organization demonstrates in an effective way the usefulness of the levels concept as the pursuit of the concept's epistemic goal, i.e., to structure an explanatory problem. On the one hand, levels of organization are used in an expository sense, which can be seen in the description of the chemiosmostic mechanism proposed by Mitchell to explain ox-phos (Section 4.5.1). On the other hand, levels also plays a hypothetical role in Mitchell's reasoning concerning the way that the problem of ox-phos should be investigated (Section 4.5.2; Brooks 2014 discusses a case of multidisciplinary case).

4.5.1 Ox-phos as a Multi-level Phenomenon

Ox-phos is one of the primary metabolic pathway by which much of life on Earth (at least aerobic organisms) produce the energy needed to sustain living processes. By far the most important source of energy in living things comes from Adenosine triphosphate (ATP), which is constructed from Adenosine diphosphate (ADP) and an additional inorganic phosphate group.[89] The process by which ox-phos produces energy is called chemiosmosis, and was proposed by Peter Mitchell (first in 1961, and later revised in 1966 and 1974, respectively).

Chemiosmosis works by transporting H^+ ions (protons) along the inner membrane space of the mitochondrion via an electron transport chain (see Figure 4.1). These protons, initially found in the matrix of the mitochondrion after being harvested from NADH (i.e. $NADH \rightarrow NAD^- + H^+$) provided by other metabolic processes occurring in the mitochondrion (e.g., glycolosis and the citric acid cycle), are actively transferred outside of the mitochondrial matrix by large enzyme complexes and then moved along the inner membrane of the mitochondrion, where the electron transport chain is located. Once outside the matrix, the protons are then guided, together with a number of electrons, along the inner membrane by a series of reduction-oxidation (redox) reactions, whereby the electrons are accepted (reduced), and then relinquished (oxidized) by the components that make up the outer lining inner membrane. The protons are then decoupled from the electrons, and transported back into the mitochondrial matrix by the ATP synthase, where they bond with waiting phosphate groups to ADP molecules, forming ATP. The transportation of the protons back into the mitochondrial matrix by the ATP synthase is initiated by creation of a proton gradient (i.e. a differential concentration of protons) that accumulates along both sides of the mitochondrial inner membrane and is built up by the redox reactions occurring in the electron transport chain.

The significance of Mitchell's chemiosmotic hypothesis here is encapsulated in two contributions to the explanation of ox-phos. First was his novel characterization of the role of

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[89] Hence the name of oxidative phosphorylation: The *phosphorylation* refers to addition of an extra inorganic phosphate group to an ADP molecule, and is powered by a chain of oxidizing and reducing reactions, from which the moniker *oxidative* comes. See below for details.

ATP synthase (Prebble 2001; Allchin 2002). In contrast to other hypotheses about the workings of ATP synthase (see below), Mitchell conceived of the enzyme in terms of part of an overall mechanism (i.e. chemiosmosis) that included higher-level structures of the mitochondrion itself. In particular, the inclusion of the inner mitochondrial membrane as an important structure in which ATP synthase (as well as the protein complexes that delivered protons from the matrix to the intermembrane space) acts *as a part* marked the introduction of

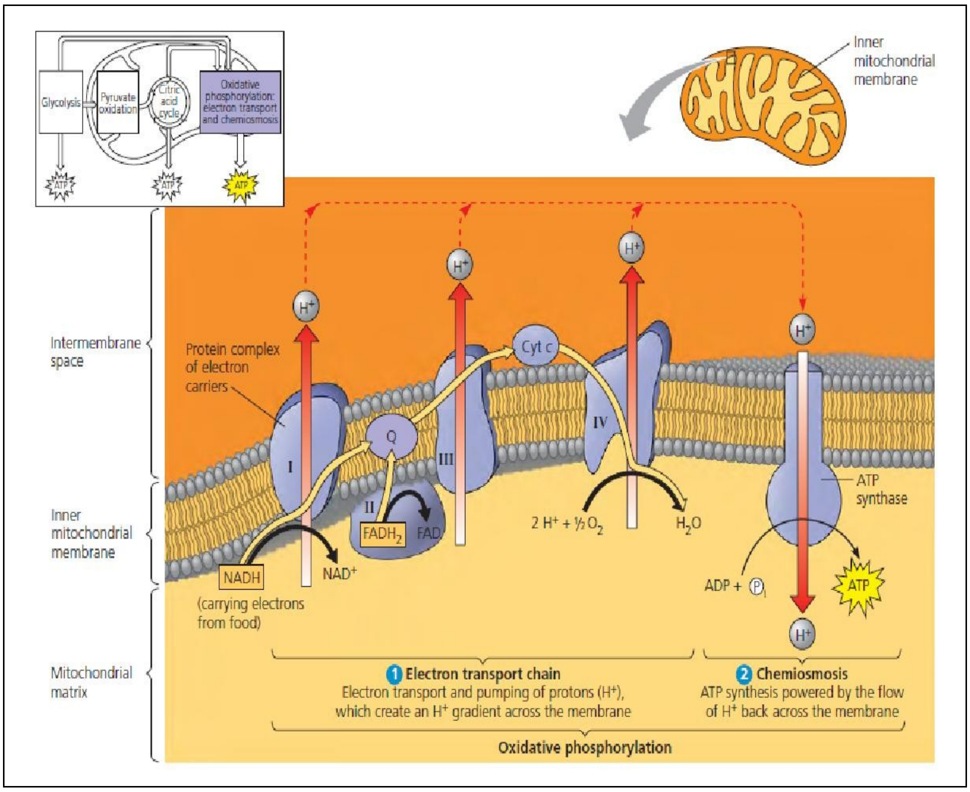

Figure 4.1 Oxidative phosphorylation via chemiosmosis. Mitchell's contribution to the explanation of ox-phos, called the chemiosmotic hypothesis, comprised two contributions. The first contribution was the postulation of an electron transport chain that harvested protons. These are illustrated as (1) and (2) in the image. Moreover, the depiction of multiple levels here is elegantly built into the representation of ox-phos. The whole mitochondrion, depicted in the upper right-hand corner as the embedding system of ox-phos, is connected to the processes responsible for producing ATP via an implied size scale (visible by the alignment of colors between it and the main image). This turns out to be more than contextualization, because of the role of higher-level structural components constituting these processes (especially the boundary created by the inner mitochondrial membrane). Image taken from Reece et al. (2010, 175).

higher level structures into the explanation of ox-phos. The second important contribution of Mitchell's chemiosmotic hypothesis was the postulation of a proton gradient, which guides the protons for the production of ATP from the donor NADH coenzymes along the electron transport chain and through the ATP synthase to the waiting ADP molecules (and phosphate group). The significance of this novel postulation was the overall organization that this imposed onto the entire ox-phos process, which was built around the higher-level structures introduced into the explanation of ox-phos. Specifically, ox-phos (and more specifically chemiosmosis) is structured *around* the cellular structures of the mitochondrion. Though the origin, and destination, of the protons fueling the production of ATP are within the matrix, the path by which they are guided along the steps of ox-phos became woven around structures *on both sides* of the inner mitochondrial membrane (see again Figure 4.1).

Both of these postulations (the flow of protons through ATP synthase and the proton gradient) and the novel developments that accompanied them (the introduction of higher-level structures and the organizational framing that this imposed on the phenomenon) had a decisive impact on the study of ox-phos. For one thing, it completely changed the way that ox-phos was understood to work, as until that time it was believed that ox-phos occurred completely within the mitochondrial matrix. This accounted for several important problems that until then posed decisive obstacles to uncovering how ox-phos worked. One of the most acute obstacles blocking the explanation of ox-phos was, in fact, the tendency of other hypotheses to ignore higher-level organizational features of the mitochondrion, and model the known steps of the reactions constituting ox-phos completely within the mitochondrial matrix. However, the constituency of the matrix proved to be a highly unstable medium in which to try and replicate the construction of ATP, and other hypotheses for ox-phos were unable to show how the production of ATP was regulated. By removing an important part of the ox-phos reaction – the transport of protons – from the matrix (where it was too unstable to effectively account for the reactions leading to ATP production), this provided one of the key empirical motivations for the chemiosmotic hypothesis, and ultimately allowed it take on its full explanatory significance (Allchin 1998; Prebble 2012; see also Mitchell et al. 1978). Another obstacle that was removed by Mitchell's chemiosmostic hypothesis was the expected discovery of a "chemical intermediate" that would bridge the gap between the reactants involved in ox-phos (especially NADH, ATP synthase, and ATP/ADP/Phosphate). The significance of this development will be discussed further in Section 4.5.2.

The chemiosmotic hypothesis offered by Mitchell comprises the use of levels to provide new insight into the problem of explaining ox-phos. Specifically, the insight provided by introducing a higher level of organization structured this problem by adding higher-level material entities into the description of the overall system. The chemiosmotic hypothesis “moved to a new level” by adding the boundaries constituted by the ATP synthase and the protein complexes through which both the protons and electrons within the mitochondrion interact with the inner mitochondrial membrane separating the mitochondrial matrix and the intermembrane space. As a consequence, the mechanism by which ox-phos works (i.e. chemiosmosis) was able to be characterized, and identified as the actual explanation for the production of ATP in living cells (Boyer et al. 1978). Before Mitchell proposed his chemiosmotic hypothesis, the description of the problem of ox-phos comprised a single level of organization, constituted solely by chemical constituents. However, in order for the importance of the chemiosmotic hypothesis to have its full impact, the problem of ox-phos itself also had to be changed. The significance of these developments is for this reason strongly coupled to another important, and hypothetical, use of levels in the ox-phos debate, which will now be discussed.

4.5.2 The Shift from Chemical to Biological Problem

Initially, Mitchell's idea of chemiosmosis received little attention when it was first proposed in 1961, and indeed experimental evidence was not forthcoming in support for Mitchell's work (Allchin 2002, 162; Prebble 2012, 710-711; see also Weber 2005, 103). Instead, when Mitchell first published his ideas, several competing hypotheses about the mechanism for oxidative phosphorylation were considered more probable forerunner explanations. Each of these other hypotheses enjoyed varying degrees of empirical support, but this support fluctuated strongly from year to year in the 1960's as new experimental findings were produced and new interpretations of established experimental results were considered

(Prebble 2012, 710)[90]. For this reason, none of the hypotheses were able to garner consensus in the scientific communities working on oxidative phosphorylation, leading sometimes to acrimonious debate among the main researchers on the issue (Bechtel 2006, 220; Prebble, 2002).

In contrast to this, what had achieved consensus among researchers before the acceptance of Mitchell's proposal was that the search for the explanation of ox-phos was a thoroughly *chemical problem*. Roughly, this meant that the phenomenon of ox-phos was characterized at a single level of organization, one constituted by chemical compounds and their reactions, the description of which designated these chemical constituents as the only relevant material entities required to account for the production of ATP. Conversely, the expectation of researchers was that the explanation of ox-phos would also encompass *only* chemical constituents. The commitment of the biochemical research community to this characterization of the problem becomes apparent in the widespread expectation at the time that an intermediate reactant would be discovered, by which the mechanism of ox-phos would be uncovered. Specifically, it was a completely unknown what could regulate the substantial amount of energy that involved in harvesting protons from (oxidizing) NADH molecules in a sustainable manner so as to fuel the coupling of phosphate to (phosphorylating) ADP. Without regulation, the production of ATP occurs very quickly, and produces a vast overproduction of energy than is needed for (or capable of) sustaining living processes. The importance of this point as an obstacle to explaining ox-phos is appreciated by considering as an analogy the combustion of gasoline in an automobile: Simply igniting the gasoline will not fuel the automobile, and is in a very obvious way counterproductive to the functioning of the vehicle. Rather, the combustion of the gasoline, like the production of ATP, must be regulated so that only enough energy is created as is needed by the car (or the organism) to run.

In order to fill this gap, the biochemist E.C. Slater postulated a "high-energy chemical intermediate" in 1953 as a way to link the oxidation and phosphorylation reactions that were known to occur in the production of ATP (Slater 1953; Mitchell 1961; see also Prebble 2012, 702-703). The empirical function of this intermediate was to serve as a reservoir for the high

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[90] Prebble goes on to document these hypotheses and the major sources of evidence that were used to evaluate these different hypotheses (ibid. 707-712). These details will be passed over here for considerations of space.

amount of energy present in the series of reactions, so that the production of ATP could proceed in a regulated manner.

The high anticipation that this chemical intermediate would be soon be discovered, and hence the conviction in biochemistry that ox-phos was a 'chemical' problem, is explained by two historical features of biochemical research into metabolism in the mid-20th century. First, it was already widely believed that metabolism in general was a (purely) chemical phenomenon, at least in terms of the task of explaining how it works. This attitude can be seen as a product of three historical phases[91] of biochemical research in the early to mid-twentieth century, spanning approximately from the 1930's to the 1970's. (cf. Prebble 2012, 701-702; see also Bechtel 2006, 219-220). The first phase began with the discovery and description of glycolosis, which ignited research interest in metabolism, and was central to the formation of biochemistry as its own discipline (Prebble 2012, 702.). This culminated in biochemists laying out a “theoretical vision” for biochemists to construct the basis for a comprehensive “metabolic map” for all forms of metabolism in living things. (See Prebble 2010 for an in-depth analysis) The creation of this metabolic map, starting in the 1930's, was constructed out of the main metabolic pathways that had already been discovered or were in the process of being discovered. The second phase was constituted by researchers attempting to fill in the specific reaction mechanisms that made up the pathways of this map. The key to these first two phases was the strong interest among biochemists in accomplishing the “theoretical vision” encapsulated in the metabolic map in purely chemical terms (Prebble 2012, 702, 718-719). In particular, it was during this phase that the chemical intermediate for ox-phos was proposed by Slater in 1953 (Ibid. 702). Slater's postulation of the chemical intermediate during this phase is hence, to a large degree, a product of the historical development of biochemistry up until that time, which proceeded in terms of filling out chemical reactions using the material entities of only a single level of organization.

Another historical factor complemented the influence of the “theoretical vision” of biochemistry in characterizing ox-phos as a chemical problem. Namely, by the beginning of the third phase of biochemical research into metabolism, which encompassed the “ox-phos

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[91] The first two phases are especially important here, as the third phase encompasses the “ox-phos wars” occurring after Mitchell's (1961) publication (Prebble 2002).

wars” following the publication of Mitchell's chemiosmotic hypothesis (Prebble 2002), most of the (chemical) components constituting ox-phos were already well-described. For instance, it was widely known that the synthesis of ATP from ADP was responsible for the creation of energy in the cell and ultimately for the whole organism (Weber 2005, 92-93; Bechtel 2006, 192). It was also well known that the locus of energy creation was within the mitochondrion of the cell (or chloroplast in the case of plant production of ATP, called photosynthetic phosphorylation). Moreover, other mechanisms for metabolism had already been discovered by the time, including glycolosis (discovered in the 1910's by Gustav Embden, Otto Meyerhof, and Jakub Parnas) and the citric acid cycle, also known as the Krebs cycle (discovered in 1937 by Hans Adolf Krebs), but neither could account for sufficient energy needed to power living processes of organisms.[92] Indeed it was even known that these other processes provided ox-phos with some of its primary reactants (e.g., NADH produced by the Krebs cycle is the source of protons that are combined with O_2 during chemiosmosis). Experimental evidence had also convincingly shown that the phosphorylation reaction between ADP and ATP was driven in large part by a series of oxidizing reactions that transported protons harvested from NADH. However, *how* exactly this occurred in the mitochondrion was not known. Most importantly, it was also known that ATP synthase was the primary enzyme responsible for harvesting the $^{\text{protons}}$ from these redox reactions, thereby driving ox-phos (Prebble 2012; Allchin 2002). Hence, not only was the consideration of ox-phos as a chemical problem a product of the historical development of biochemistry at the time, the conviction underlying it seemed to be close to empirical consummation.

These two factors made Slater's proposal[93] immensely influential among biochemists not only because of the elegance of his empirical work, but for the overarching characterization, manifested in the postulation of the high-energy intermediate, that the search for the explanation of ox-phos was a thoroughly chemical endeavor. Douglas Allchin characterizes

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[92] For perspective, ox-phos produces approximately 7 times the amount of ATP than both glycolosis and the Krebs cycle *combined*. Specifically, per molecule of glucose, glycolosis and the Krebs cycle each produce 2 molecules of ATP (for a total of four from both sources), while ox-phos produces 26-28 molecules of ATP per glucose (Reece et al. 2010, 176).

[93] The context for Slater's postulation of the chemical intermediate was as part of his own hypothesis for explaining ox-phos, which came to be known as the “chemical hypothesis”. Despite this misleading baptism, Slater's chemical hypothesis was only one of the many “chemical” hypotheses that were offered at the time. Slater's proposal itself was quickly discarded as insufficient, but other hypotheses about the mechanism for ox-phos also actively built in his mysterious chemical intermediate into their own proposals.

the situation in biochemistry as follows:

> “The problem – and it resisted being solved for many years – was: how is energy transferred from the electron transport chain to ATP? In the early 1950's biochemists viewed energy as transferred in billiard-ball-like fashion from molecule to molecule, like batons in a relay race. The challenge was to trace the path and to isolate and identify the intermediate steps and the enzymes along the way. *One could thus reconstitute the system* in vitro. In 1953 E.C. Slater made an analogy between ox-phos and another well-known reaction and hypothesized an intermediate step or steps. This would involve *a yet unidentified molecule or molecules with a high-energy chemical bond*...Slater's 'chemical' hypothesis *thus came directly out of and embodied the [perceived] strengths of the biochemists' tradition*” (Allchin 1998, 6, emphasis added)

Because of this, anticipations were high that the chemical intermediate would soon be discovered. However, there was one problem with this proposal: the chemical intermediate doesn't exist. The perceived need for this high-energy chemical intermediate represented not only a substantial empirical barrier to the explanation of ox-phos, it constituted a theoretical barrier created by the biochemical community itself that barred further progress towards constructing this explanation.

Mitchell's chemiosmotic hypothesis instigated a decisive shift in the way that the problem of ox-phos itself was characterized. This shift involved the proposal that the problem of ox-phos itself required incorporating “biological” features of the embedding system in which the ox-phos reactions occurred (i.e. specific structural features the mitochondrion). These biological features, including the mitochondrial membrane and the creation of the proton gradient, can be seen in the description of chemiosmosis given above in Section 4.5.1. Ultimately, it was the inclusion of these higher-level features that ox-phos was able to be explained. However, the focus by the biochemical community on a chemical characterization of ox-phos, e.g., as seen in the search for the phlogistonal[94] chemical intermediate, meant that this insight would

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[94] With 'phlogistonal' is meant: of or relating to the non-existence of a hypothetical substance or idea (cf. phlogiston), where that substance or idea is postulated to explain or account for a scientific mystery and whose existence or discovery is for a time highly anticipated.

not be captured.

Mitchell's motivation for his chemiosmotic hypothesis was informed by a completely different perspective on how to conceptualize the task of explaining ox-phos. This perspective involved positing completely different kinds of properties to biological entities due to his conviction that lower levels, alone, are unable to account for the chemical reactions constituting ox-phos *in a living organism.*[95] Prebble (2001) identifies the impetus of Mitchell's thinking in this regard to the juxtaposition of different, wholly speculative, philosophical concepts that Mitchell postulated in private writings, which, Prebble convincingly argues, motivated Mitchell's thinking about scientific phenomena. These “philosophical concepts” included the notions of a “statid”, “fluctid”, and “fluctoid” (Prebble 2001, 442), which represent three fundamental kinds of abstract entities populating the world. The notions correspond, respectively, to a static, component object, a simple component process, and, most importantly, an object constantly involved in a dynamic process. For considerations of space, two summary considerations[96] are important for the discussion here: Firstly, calling a particular phenomenon a “fluctoid” ostensibly implies ascribing a holistic character to that phenomenon, in the sense that the phenomenon possesses properties irreducible, and yet constituted by, simpler forms of matter that compose it (ibid.; Prebble and Weber 2003, 50; see also Section 5.3.1). In this way, the notions of a statid and a fluctid are, in a sense, “simpler” than a fluctoid, but each kind of entity is equally necessary for accounting for all the phenomena of the natural world. “Fluctoids” for Mitchell comprised, quintessentially, biological phenomena that could only be partially explained using investigative approaches that treated them in a static fashion (i.e. as fluctids and statids).[97] Secondly, Mitchell's personal philosophy was inspired by his interest by a philosophical movement in biological research during the first decades of the 20th century called *organicism*. In particular, the writings of Joseph Woodger and Joseph Needham were directly responsible for Mitchell's thoughts on

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[95] That the levels concept captures this insight into Mitchell's thinking is a novel contribution to philosophical discussions of oxidative phosphorylation, and will be unpacked in the rest of this chapter.

[96] Mitchell's personal philosophy is analyzed at great length in Prebble and Weber's (2003) biography of Peter Mitchell, particularly in Chapter 4.

[97] For instance, one quintessential property of being a fluctoid was the ability to self-regulate internal processes by interacting with the entity's immediate environment (Prebble and Weber 2003, 49-50). This property, which Mitchell motivated by citing the living cell as an exemplary case, is one of the central properties identified in living things as a means of demarcating them from non-living things.

fluctoids, and specifically its status as holistic-biological concept by which to (1) differentiate life from non-life and (2) articulate the distinct challenges of properly explaining living and non-living phenomena (Prebble 2001, 444-446). This point is of substantial importance, as will become clear in the next chapter, where the Cambridge organicists efforts to develop the levels concept as a scientific concept will be analyzed in their own right.

The effect of this philosophical conviction concerning holistic ("biological") properties of living systems is palpable in even Mitchell's early writings on chemiosmosis. Here, as in later writings, the role of the levels concept (particularly the suggestion to "move to a new level") in his reasoning about ox-phos is undeniable. Indeed, Mitchell's original articulation of his chemiosmotic hypothesis is decisively shaped by the use of levels of organization as a tool to re-structure the problem of ox-phos. This becomes astoundingly clear in the way that he relates his hypothesis to the chemical conception of the problem of ox-phos held by the biochemical community at large:

> "At present, the orthodox view of the coupling of phosphorylation to electron and hydrogen transfer in oxidative and photosynthetic phosphorylation *stems from knowledge of substrate-level phosphorylation*...There are a number of facts about the systems catalyzing oxidative and photosynthetic phosphorylation that are generally acknowledged to be difficult to reconcile with this *orthodox (chemical) view* of the mechanism of coupling: (a) The hypothetical *'high-energy' intermediates...are elusive to identification*. (b) *It is not clear why* phosphorylation should be so closely associated with *membranous structures*" (Mitchell 1961, 144-145, emphasis added)."

This passage accomplishes two things, which are illustrated by the highlighted terms: First, it expressly identifies the ox-phos problem, as understood at the time by the biochemical community, as being located at one level of organization (that of a "substrate"). Mitchell uses this as the basis for calling the orthodox characterization of the problem as the "chemical view". Secondly, it identifies several difficulties that this characterization of the problem creates for the explanation of ox-phos, which, he goes on to argue, his chemiosmotic hypothesis is capable of solving.[98] Specifically, Mitchell points out that by incorporating a new level of organization into the characterization of the problem of ox-phos, his chemiosmotic hypothesis is capable of dealing with both (a) the difficulty in finding the highly-anticipated chemical intermediate (i.e., the intermediates "do not exist" (ibid. 148), and (b) accounting for why ox-phos is "so closely associated with membranous structures" (i.e. because new types of structures are required to adequately explain ox-phos) (ibid. Mitchell 1966, 1509). Here, again, the key to understanding the changes that the chemiosmotic hypothesis would bring to the problem of ox-phos is expressed as a hypothetical level claim. In Mitchell's own words:

> "The purpose of this article is to suggest that in view of the difficulties confronting the orthodox chemical conception of coupling in [ox-phos], one might now profitably consider the basic requirements and potentialities of a type of mechanism that is based directly on the group translocation conception [i.e. how H^+ protons are transferred and regulated in the ox-phos reaction]. This type of mechanism *differs fundamentally* from the orthodox one in that it *depends absolutely on a supramolecular organization of the enzyme systems concerned*. Such *supramolecularly organized systems* can exhibit what I have called chemi-osmotic coupling" (Mitchell 1961, 145, emphasis added).

Recall that in 1961, there was no *direct* evidence for Mitchell's chemiosmostic mechanisms, as he himself admits that the hypothesis exploits already existing research as "circumstantial" support for his ideas (ibid.). Instead, at the time of his first publication on chemiosmosis, Mitchell claimed that his real contribution to the investigation of ox-phos was to change the way that biochemists conceived of the explanatory task facing them. This would involve, Mitchell believed, not only introducing new level-bound resources into the description of the ox-phos system, but also an accompanying change in the explanatory significance of these resources, which he makes clear in the conclusion of his (1961) paper: "This simple hypothesis also has the merit that it represents the result of carrying to its logical conclusion the present trend towards *recognizing the equivalent status of supramolecular and molecular features in the channelling of chemical processes in living organisms*" (Mitchell 1961, 148).

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[98] Mitchell discusses six difficulties in total, but the two cited have already been established for the discussion, and are sufficient for the point being made.

Other historians and philosophers of biology, in their analyses of Mitchell's manifold contributions to the explanation of ox-phos, support the contention here that the impact of the chemiosmotic hypothesis, at least initially, was not the empirical success it exhibited (this would come later), but rather the shift in the kind of problem biochemists saw themselves as engaging. For instance, John Prebble writes that:

> “When the weaknesses of Slater's approach began to be apparent around 1960, new approaches became desirable *if only to widen thinking in the field* and new hypotheses emerged...The contribution of Mitchell *highlights the importance of a biological approach to biochemical problems.* His approach lack[ed] the skills of a chemist and the appreciation of proteins but exploit[ed] the growing knowledge of biological membranes.” (Prebble 2012, 707, emphasis added)

Likewise, Allchin (1998) points out the direct empirical relevance of Mitchell's 'biological' characterization of the problem would later have on the eventual explanation of ox-phos, despite the counterintuitive changes to approaching how ox-phos needed to be understood, at least according to the prevailing wisdom in biochemistry at the time:

> “To someone accustomed to picturing chemical reactions in terms of something like the bouncing ping pong ball model of gases, the *spatial aspect of these processes* [such as respecting level-bound distinctions between components of the metabolic system] as proposed by Mitchell were strange indeed. The chemiosmotic formulation implied experimentally, for instance, that *one could not* – as biochemists like Racker and Slater generally did – *simply tear apart the mitochondrion, isolate its essential components, throw them back together again in a test tube an expect them to work*” (Allchin 1998, 7-8).

The case of oxidative phosphorylation therefore exemplifies not only the use of the levels concept to pursue a very particular epistemic goal in a real (and highly significant) case of biological research, it offers to shed new light on *why* Peter Mitchell's chemiosmotic hypothesis was in fact so influential.

4.6 Conclusion

According to the account of levels articulated here, the concept of 'levels of organization' is a fragmentary concept whose character exhibits multiple distinct, yet legitimate, particular forms across different contexts of usage. Simultaneously, this pluralist character of the levels concept is complemented by a relatively stable epistemic goal across these different contexts, i.e. to structure explanatory problems. This account was exemplified at length in the explanation of oxidative phosphorylation, which demonstrates the epistemic goal developed in Section 4.4 motivating the use of levels in both a descriptive and hypothetical manners.

The account of levels developed here differs strongly from the other philosophical accounts of levels analyzed in Chapter 2. In contrast to the layer-cake account, levels are not rigid, monolithic, and comprehensive, but rather encompass a broad range of instances of the concept whose overarching character is determined contextually, i.e. from a particular disciplinary perspective. In this respect, the account offered here nominally agrees with the mechanistic account in treating level claims as contextually determined claims. However, the account offered here also differs from the mechanistic account in that the character of the levels concept as developed here is not *hopelessly* contextual, i.e. individual uses of levels are restricted to only a particular phenomenon. Instead, some degree of general applicability holds for the use of the levels concept, though no claim was made to the precise extent of this application. Finally, the account offered here differs from both the layer-cake and mechanistic accounts in that it treats the levels concept independently from any specific embedding philosophical projects, such as the Unity of Science, theoretical reductionism, or mechanistic explanation. Though there may be an indisputable role for levels in understanding these other respective projects, the purpose of the analysis given here is to understand the character and significance of levels of organization in science, and in particular the biological sciences. At the same time, however, though the account developed here shows that levels may be treated independently of any embedding philosophical project, it also argues that the concept of levels can thrive only when the context in which it is applied is well-defined (see also Eronen 2013). Though the character of a specific use of the concept of levels is determined in a contextualized manner, the significance of the term (embodied by the concept's epistemic goal) shows the concept of levels to be of wide interest to the biological sciences.

Chapter Five: The Organicist Roots of the Levels Concept

5.1 Introduction

Turning now towards a more sustained analysis of the levels concept, this chapter will turn to the historical usage of the concept in biology. In this chapter, the origin of the concept of "levels of organization" in contemporary biology will be traced to the organicist movement of the 1920's and 1930's.[99]

At the beginning of the 20th century, a number of interrelated debates concerning the nature of life and how best to explain living phenomena were occurring in both philosophy and science. These debates included the positions known as *mechanism, vitalism,* and *emergentism*.[100] At the backdrop of this state of affairs, *organicism* was a movement in the biological sciences that began to take shape in the 1910's and the 1920's, and was conceived by its proponents as an alternative to the other intellectual positions engaged in these debates (Section 5.2). The organicist movement produced prescient ideas about the disciplinary structure of biology as a whole and more particularly the nature of biological phenomena as scientific objects of investigation and explanation. Organicist writers forcefully argued for the autonomy of biology and its phenomena from the physical sciences, and for its acknowledgment as in itself a legitimate natural science. In this endeavor, they postulated a pluralistic conception of biology, where different biological disciplines constitute distinct, non-reducible, and independently necessary areas of inquiry. **[101]** Concurrent to this interest in the structure of

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[99] Philosophical interest in the organicist movement is rapidly growing in contemporary philosophy of biology (see especially Nicholson 2010, 2012; Gibson 2013; Baedke 2013; Nicholson and Gawne 2014). This chapter is hence meant also as a contribution to this growing body of literature, in addition to its contribution the overall thesis being developed in this dissertation.

[100] The issues surrounding emergentism were more centered about the nature of the mind and phenomenal consciousness. The emergentists nevertheless took their cue from the vitalists, and argued for a levels-based understanding of articulating qualitatively new properties than the physical things out of which they were composed. This will be discussed below in Section 5.2.

[101] This understanding of pluralism relates both to biology *as a whole* and to the *particular disciplines* that

biology as a branch of science, organicist writers also argued that a new conception of biological phenomena was necessary in order to construct *adequate explanations* for the phenomena encountered by biologists (Section 5.3). This conception centered on the postulation of biological entities and processes as continuous with, but ultimately distinct from, physical and chemical phenomena.

The linchpin of these ideas, and consequently for the philosophical identity of the organicist movement, was a sophisticated conception of levels of organization (Abir-Am 1987, 12; cf. Gilbert and Sarkar 2000, 3; see Sections 5.3 and 5.4). The organicist view of levels of organization was actively developed by its proponents, after borrowing the term “levels of reality” (alternatively, “levels of being”) from the concurrent, but ultimately independent, debate regarding emergentism (Section 5.2; but cf. Blitz 1992, 151-156). The program of organicism, which was unorthodox[102] for the time, applied the levels concept to express the significance of both the undeniable explanatory and methodological successes of the mechanist program in biology with a more subtle and sophisticated articulation of the importance of “holistic” features of biological phenomena, in contrast to vitalism's more vulgar and problematic claims (Section 5.2).

The organicists' interest in, and initial development of, the levels concept lay the groundwork for a more general account of levels, which later came to be known in biology as “integrative levels of organization” (Needham 1937[1943]; Novikoff 1945a; Feibleman 1954; Siqueiros and Umerez 2007; see Section 5.4). This account continued to influence biological thought well after the decline of organicism. In fact, the levels-mediated view of the world offered by organicism, and many of the ideas that the organicists expressed for biological explanation using this account, are still widely present today in the biological literature. The *integrative account* of levels represents relatively unknown conception of levels in philosophy, and so will be detailed here in Section 5.4.

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belong to biology. See Section 5.5 for more.

[102] Unorthodox at least, given the official narrative of the history of philosophical interest in biology as given by philosophers; i.e. that there was no real philosophy of biology (see, e.g., Matthen and Stephens 2007, xi).

The historical analysis offered here will develop two arguments in support of the analysis of levels developed in the foregoing chapters, and for philosophical interest in the levels concept in general. First, the integrative account of levels developed by the organicists undermines the status of the layer-cake account offered by Oppenheim and Putnam (1958) as the default conception of levels in philosophy. For one thing, the integrative account of levels was constructed independently from Oppenheim and Putnam's layer-cake account and overall Unity of Science project, and the organicists' principal work on levels even precedes the former's (1958) publication by almost thirty years. In fact, Oppenheim and Putnam do not *seem* to have been aware of the organicists' work on levels, and do not cite any of the writers or papers that contributed to, or actively advertised, the integrative account. Additionally, the integrative account also more accurately reflects how scientists themselves conceptualized levels of organization. The principle reason for this is that the account was by and large constructed by scientists, though some philosophers (most notably Woodger 1929[1967]; 1930 and Feibleman 1954; cf. Abir-Am 1991, 171) also contributed to the articulation of the account. Moreover, a comparison between the organicists' integrative account of levels and the depiction of levels of organization in biological literature reveals far more similarity than with the layer-cake account (Section 1.4; Section 5.5). A direct comparison, conversely, between the integrative account and the mechanistic account is more difficult to execute, due to the mechanistic conception of levels being so thoroughly tied to the (contemporary philosophical) concept of a ‘mechanism’, and more generally with the account of mechanistic explanation offered by New Mechanists such as Craver (2007a) and Bechtel (2008).[103] Hence, this chapter will again focus on the layer-cake account, which, as will be seen, is more impacted by the integrative account anyway.

Second, the analysis offered in this chapter supports the claim that the organicists were responsible for establishing the epistemic goal motivating the usage of the levels concept in biology, which was developed in the last chapter. This epistemic goal, i.e. to structure explanatory problems in biology, manifested itself in the usage of the levels concept by the

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[103] An analysis of the mechanistic account has, furthermore, already been offered by Eronen (2013; 2014) who, in agreement with the analysis given in Chapter 2, has concluded that the mechanistic account of levels “is too limited as a theory of levels” to be of use for a general analysis of the concept. As also argued in Chapter 2, the mechanistic conception of levels is best seen as a contrast point to the layer-cake account.

organicists while defending the main tenets of their program. Initially, the levels concept aided the organicists in articulating their conception of biological phenomena as objects of explanation, and the autonomous status of biology as a legitimate natural science distinct from the physical sciences (Section 5.3). This use of levels was begun by Joseph Woodger in his 1929 book and a follow-up 1930 article. Soon thereafter 'levels of organization' was actively used, and advocated (especially by Joseph Needham), as a means to elucidate the structure of biological phenomena for the purposes of explanation. After doing this, Needham later took the levels concept and began developing the concept into a more encompassing account that transformed the levels concept from a specialized notion used in the construction of the organicist program to a full-fledged account of its own. For these reasons, the organicists' work in developing the levels concept, and its direct uptake into the integrative account of levels by other biologists of the time, not only support the arguments made in foregoing chapters, it also explains the programmatic character that imbued the organicists' own usage of the levels concept (Section 5.3.1).

One tentative bridge between the contemporary and historical usage of ‘levels’ developed in the last chapter and the historical usage of ‘levels’ that will be developed in this chapter is the influence of organicism on the personal philosophy of Peter Mitchell, who, as seen in the last chapter, implemented the levels concept into his chemiosmotic hypothesis. In Section 4.5, the role of the levels concept, and particularly its role in structuring the explanatory problem of ox-phos, was discussed at length. That analysis, it should now be said, was provided with the aid of hindsight; i.e. it now known (i) how ox-phos works, and (ii) that Mitchell’s chemiosmotic hypothesis turned out to be the correct explanation. *Why* Mitchell himself looked to levels-tinged language to develop his chemiosmotic hypothesis can partially be answered by looking to the inspiration that Mitchell himself found in looking at particular organicist writers (especially Joseph Needham and Joseph Woodger) during his doctoral training at Cambridge (Section 5.6)

The movement called organicism (alternatively “organismal” or “organismic” biology) does not designate a clearly-defined group of people, but rather a loosely-knitted group of scientists and philosophers distributed among many disciplines. These included biochemistry and embryology (Needham 1936), genetics (Waddington, 1940), physiology (Woodger 1929 [1966]; Needham 1934; 1936), cell and molecular biology (Novikoff 1945a), ecology (Rowe 1961), and even psychology and sociology (Needham 1943, Redfield 1942). Furthermore, though this "movement" extended approximately from the mid-1910's to (approximately) the early 1960's, with early roots in the late 19th century, it designates only a very rough continuity in the issues that it treated, and the arguments articulated for these issues. During this time, organicist ideas were continuously associated, dissociated, and re-associated with vitalism, the school of thought it was originally explicitly formulated to reject.

For this reason, an implicit distinction will be observed in what follows between different "groups" of organicist thought. Specifically, "organicism" will refer here to a group of researchers based primarily in Cambridge, i.e. *Cambridge organicism*,[104] consisting particularly of C.W. Waddington, Joseph Needham, and Joseph Henry Woodger, who formed the core of the Theoretical Biology Club, a circle of friends and colleagues interested in developing a novel scientific program for the study of biological phenomena (Abir-Am 1987; Senechal 2013, Ch. 12). The work of this small but influential group of scientists and philosophers, and especially that of Needham, will form the basis of the analysis in this chapter. Though other scientists also actively, and independently, contributed to developing organicist thought *writ large* (e.g. Haldane 1916; Ritter 1919; cf. Mayr 1981, 66-67), a comprehensive treatment of organicism's history will be far beyond the scope of this chapter.[105] Some deviations from the Cambridge organicists' vision of organicism will later be considered in connection to contrastive interpretations of certain elements of the organicism program, many of which were problematic for the "movement" at large.

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[104] Unless otherwise noted, 'organicism' will refer to 'Cambridge organicism'. Where the latter *is* explicitly mentioned, it is meant to contextualize the respective passage within the organicist movement *at large*.

[105] Several authors have recently offered summaries of organicism and its main tenets. Gilbert and Sarkar (2000) give a short summary of organicism, and reintroduce its basic tenets as a live program for developmental biology. Allen (2005) offers a historically informed analysis of the organicist program vis-á-vis the New Mechanism.

5.2 The Historical Context of the Levels Concept

By the 1910's an influential debate had emerged concerning the nature of biological phenomena and what comprised their explanation. One side of the debate held that biological phenomena were "nothing over and above" their physico-chemical components; that e.g., the phenomena that comprise life and living things, like physical non-living phenomena, posed no special problems to constructing a scientific explanation for them. In other words, biological phenomena can, in principle, eventually be exhaustively accounted for in only chemical or physical terms. This position, called *mechanism*,[106] hinged strongly on the premise that living phenomena, though complex, are structured in a way fundamentally similar to machines, and that understanding them would be an inevitability of scientific progress (Bechtel and Richardson 1993[2010], 17; Allen 2005, 264; Loeb 1912, 1916; cf. Nicholson 2012, 160). The mechanist approach to conceptualizing and explaining biological phenomena in the early decades of the 20th century can for this reason be seen as being a strongly reductionist position.

The other side of the debate rejected both of these mechanistic claims, i.e. that biological phenomena are "nothing over and above" their physical constituents and the machine analogy between life and non-life. This broadly anti-reductionist position, known as *vitalism*, postulated a qualitative distinctiveness possessed by life and living things. In this endeavor, the vitalists argued that living things and the processes that constitute them are in some way qualitatively distinct from their physico-chemical components, and that new, hitherto unformulated ways of conceptualizing and explaining living things were necessary to account for biological phenomena. The vitalists made two particularly strong claims concerning how to conceptualize the study of biological phenomena. Firstly, and most importantly, they imposed a strong dualistic status to biological phenomena; i.e. that life occupies a completely different ontological category than physical, non-living phenomena. For the vitalists, explaining living phenomena in terms of their constituent parts was incapable, in principle, of

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[106] This use of 'mechanism' differs starkly from that of the New Mechanism philosophy that is responsible for the mechanistic account of levels discussed in Chapter 2. Rather, it will refer here to a program for scientific for scientific research from the early 20th century. For a basic history of this program, see Allen (1975, ch. 4), and Nicholson (2012).

capturing phenomena *as biological* for scientific purposes. Secondly, the vitalists also argued for distinguishing between the proper areas of inquiry constituting, respectively, the physical and the biological sciences. Both of these claims, in significantly modified form, would be taken up as issues by the organicists (see especially Section 5.3).

The mechanist-vitalist dispute comprised several dimensions of disagreement in their respective claims. Broadly speaking, these disagreements can be divided between metaphysical and epistemological issues. Metaphysically, both sides disagreed starkly with the other concerning the ontological status of biological phenomena. The mechanists, in claiming that biological entities and processes were "nothing over and above" physical and chemical entities, defended a *materialist* position, i.e. the thesis that the world consists solely of the fundamental constituents of physical world, e.g., matter and energy. The vitalists, on the other hand, rejected materialism, and held that the physical universe simply does not exhaust the basic ontology of the natural universe (Allen 2008, 51-4). Instead, some kind of "vital force" was said to imbue life with an extra quality, which could account for the distinctness between living and non-living matter. Of these, Henri Bergson's notion of *élan vital* and Hans Driesch's related notion of *entelechy* are perhaps the most famous attempts at articulating this vital force (Allen 2008). The reliance on these notions ultimately doomed vitalism to the status of a speculative, phlogistonal metaphysics (ibid.). These vital forces were widely deemed to be blatantly pseudoscientific concepts that served only to make any vitalist claims empirically unverifiable and scientifically questionable.

The dispute between the mechanists and the vitalists also had an epistemological dimension, which has not been addressed in philosophy as effectively as their metaphysical disagreement. This, upon initial reflection, is not entirely surprising. This disagreement centered on how to propose new approaches to explaining biological phenomena in a way that captured what was distinct about living phenomena.[107] In pursuit of their epistemological claims, vitalist researchers eventually ran into a wall when trying to articulate more concretely what their position amounted to. In particular, vitalists were incapable of coherently expressing the meaning of, or even further developing, key terms in their anti-mechanist position, such as the

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[107] This issue has also received increased attention recently, seen especially in a new and insightful (2015) paper by Doug Russell, and also the recent (2013) anthology on vitalism edited by Normandin and Wolfe.

"qualitatively distinctiveness" of living things from physico-chemical things, and the "autonomy" of biological phenomena from other materialistic phenomena found in the physical sciences. In order to account for these ideas, and the anti-reductionist arguments that they were meant to support, vitalists referred back to their intangible and non-existent "vital forces" to give their program scientific substance. Since neither an account for biological explanation nor a viable research program could be concretely offered by the vitalists, the epistemological disagreement between the mechanists and the vitalists is often quickly passed over or ignored by philosophers. These questions would later be capitalized upon by the organicists (see below).

The decisive reliance of the vitalists on this postulation guaranteed that the dispute would remain by and large a *metaphysical* one. The vitalist movement quickly faded away, as they sought also to demonstrate the inability of the mechanist program to adequately *explain* biological phenomena (Allen 2008). The mechanist program, in stark contrast, survived and proliferated because of the success it demonstrated in producing successful explanations for the phenomena the vitalists claimed were fundamentally impossible for the program (Bechtel and Richardson 1993[2010]; see also Nicholson 2012). The success attributed to the mechanist program (i.e. its robust track record of producing reliable explanation) seems hence to be a result not only of marshaling evidence from a wide array of cases of explanation across biology that demonstrated the explanatory usefulness of the mechanist approach. Rather, with the failure of vitalism as an instructive historical backdrop, the mechanist program also seems to have simply better fit scientist's own thinking about their work as concerns explaining biological phenomena.

Though the popularity of vitalism would not last long into the 20th century, a variety of interrelated successor debates surrounding the issues of the mechanist-vitalist dispute quickly coalesced in the aftermath of the mechanist-vitalist dispute. These debates would go on to strongly influence various areas of philosophical discussion even well into the 21st century. This splintering of debates approximately followed the metaphysical and epistemological lines of disagreement in the original mechanist-vitalist dispute concerning the reducibility of biological phenomena to physical phenomena. One of these debates, that concerning *emergentism*, was taken up by philosophers and focused on the metaphysical issue of the reducibility of "special" phenomena[108] such as certain mental and biological properties, and the physical properties with which they are associated.[109] The emergentists, especially Samuel Alexander (1920), C. Lloyd Morgan (1923), and C. D. Broad (1925), defended the irreducibility of certain mental properties, especially those associated with phenomenal consciousness (McLaughlin 1992; Stephan 1999a). However, unlike the vitalists, who postulated awkward and conceptually problematic vital forces to account for their notion of irreducibility, the emergentists rejected these vital forces (see, e.g., Alexander 1920, 64; Morgan 1923, 35), and introduced the notion of *emergence*, which proved to be more tractable to philosophical analysis than vitalist notions like *entelechy* et al.[110] Emergence was instead articulated as a relation between the non-fundamental properties in question and the physical properties on which they supervene, rather than a question regarding the substances of the world. In its strongest form, emergence refers to properties that are not, even in principle, reducible[111] from the properties of their physical constituents. The opponents of emergentism, who again identified their position as "mechanism", but perhaps better designated here as physicalism or metaphysical reductionism,[112] argued that cases appearing to be non-reducible, i.e. emergent, vis-á-vis their physical components were actually nothing more than unfinished or immature projects of science, which, once properly understood, would comport with the

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[108] Implicit in the choice of the word "special" here is the claim that the emergentists followed the vitalist program in claiming a "special status" for the respective phenomena they chose to analyze. For the vitalists, these included "life" and living processes, while for the emergentists it was the mind and phenomenal consciousness.

[109] The main difference between emergentism and vitalism was that the irreducibility ascribed by emergence concerned the relation between properties or sets of properties, whereas the irreducibility of vital forces concerned the *substances* that nominally competed directly with materialistic (i.e. physical) matter to make up the fabric of the universe.

[110] This does not mean that articulating the notion of emergence is without controversy. In fact, the coherence of emergence in the philosophy of mind is hotly debated even today, with a sprawl of positions ranging from flat denial of its meaningfulness (Kim 1999), affirmation of the concept (Chalmers 2006, in Clayton and Davies 2006), and a slew of intermediate positions that differentiate between many possible forms the concept can take (Stephan 1999b). In the philosophy of science, emergence is also a prominent topic with a rather distinct line of discussion surrounding it (see, *e.g.*, Clayton and Davies 2006; Mitchell 2009). The range of positions that one can take concerning emergence has even led some to denounce emergence and emergentism as vitalism in disguise. (Beckner 1969b).

[111] Of course, understanding strong theses of emergence of this variety depend on which notion of "reduction" one entertains. In the debate surrounding emergentism (particularly in the philosophy of mind), reduction is understood as the ability to deduce the properties of the higher-level phenomenon from the properties of the lower-level phenomenon.

[112] Following modern designations of the mechanist position (see McLaughlin 1992; Beckermann 1992; Kim 1999; 2005)

materialist view of the world. That is, emergent properties, like the biological phenomena that preoccupied the vitalists, would eventually be accounted for by the ontology of physics and chemistry (see, e.g., McLaughlin, 1992).

This debate survives even today as a topic of active research in the philosophy of mind regarding the reducibility of the mind to the physical world, where reductionism and emergentism are still widely analyzed and continue to constitute viable philosophical positions that are actively defended (Beckermann *et al.* 1992; Stephan 1999a; MacDonald and MacDonald 2010). Contemporary literature on emergence and physicalism of the mind indeed continues to cite these historical predecessors that emerged in the aftermath of the mechanism-vitalist dispute (*ibid*). The debate between the emergentists and the mechanists is also particularly noteworthy here because it is where the term "levels" was both coined and first addressed as a significant theoretical concept (Needham 1943, 234; see also Section 5.3.1).

Concurrent to the debate surrounding emergentism, another successor debate to the mechanist-vitalist dispute also began to take shape in the 1920's: that between (once again) the program of mechanism and what came to be known as *organicism*. The mechanist-organicist dispute differed in several important respects from the debates mentioned above. For one thing, this debate, in contrast to those involving vitalism and emergentism, was broadly *epistemological* in that it did not dabble deeply into the metaphysical issues that occupied the other non-mechanist positions like emergentism and vitalism. The metaphysical dimension of disagreement between the mechanists and the emergentists and vitalists was essentially a non-issue for mechanism and organicism, since the organicists were in broad agreement with the mechanist position concerning the materialist status of biological phenomena.[113] Indeed, the outright rejection of vitalism, and affirmation of a materialist ontology, constituted common ground to both organicist and mechanist arguments (Needham 1928a, 34; 1941, 18; Woodger 1930, 6-7; Beckner 1969b, 550). Instead, the issues that the

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[113] Some organicist writers did provoke a metaphysical dispute with the materialist ontology of the mechanists, particularly J.S. Haldane and Alfred North Whitehead, whose respective conceptions of holism directly postulated conceptions of qualitative distinctiveness that were deemed to be obscurantist by their mechanist and organicist contemporaries alike. This issue will be revisited below.

organicists engaged concerned the nature and status of biological phenomena as objects of legitimate scientific study, and how best to investigate them as such. Organicism can for this reason be distinguished from vitalism, *and* emergentism, in virtue of advocating a *non*-reductionist rather than an *anti*-reductionist position. The central criticism of the mechanist program expressed by the organicists was not the categorical failure of the mechanists in capturing the qualitative essence of life, but rather the adequacy of the program for *explaining and conceptualizing* all of life's phenomena (see Section 5.3 below).

More generally, another aspect of the mechanist-organicist dispute was the organicists' interest in establishing the autonomy of the biological sciences from the physical sciences. Interestingly, even here this did not entail demarcating themselves *completely* from the mechanist program with idle criticisms of the ontological inadequacy of their reductionist approach, as occurred with the vitalists. Rather, it entailed the construction of a framework in which a *conception of biological problems* could be constructed, which the organicists deemed to be more adequate explanatory framework for working biologists. For the organicists, the autonomy of the biological sciences from the physical sciences can be seen as a claim made to offer a productive alternative for how to express the tasks that lay before scientists in explaining biological phenomena, which the mechanist program did not adequately appreciate (see Section 5.3). This alternative, the organicists said, was superior to the reductionist option offered by the mechanists in that it complemented the framework laid out by the mechanists (Needham 1928a, 34-35, 39).

A key premise to the organicists' program was their use of the levels concept to articulate their specific claims. The organicists developed the levels-based hierarchical view of the world that had already begun to take shape in the mechanist-vitalist dispute (Hoernlé 1918, 465), and received particular attention in the discussion concerning emergentism (McLaughlin 1992, 50; Alexander 1920, 3; Morgan 1923, 5-6). The organicist program used the levels concept to construct an image of nature in which the major constituents of the natural world could be divided in terms of their *organization.* In particular, this view of the world postulated that the way that the components and processes of a particular phenomenon are arranged captures the differentiation of *kinds* of things (see Section 5.3 "Holism and Organization"). This was then in turn used to (1) articulate the difference between life and non-life, and (2) ascribe an ordered rendering of structure-related behavior in biological phenomena. To accomplish these tasks, the organicists took up the original “levels of reality” concept of the emergentists, and further developed the concept into levels of *organization* (see Section 5.3.1).

Organicism for this reason presents a fertile but largely forgotten historical episode in the philosophy of biology (cf. Gilbert and Sarkar 2000; Nicholson and Gawne 2014). Its program was prescient in the nuance and subtlety with which it expressed its view of the study of biology.[114] Nevertheless, much of the substance that made up organicist thought, expressed through its conception of levels of organization, survives today in contemporary biological thought. The depictions of levels in introductory textbooks and educational commentaries (Section 1.4) often reproduce organicist theses wholesale as now basic knowledge concerning how to conceptualize the study of biological phenomena in general. The initial controversy that spurned both the vitalists and the organicists concerning how to fit biology into the natural sciences has now long since dissipated, and the life sciences are now seen as a complementary partner to the physical sciences in the study of nature.

While the metaphysical dimensions of the debate between vitalism and mechanism is well established and has received wide attention in the philosophical and historical literature, the epistemological issues of the mechanist-vitalist dispute that were addressed by the organicists have received relatively little recognition in the philosophy of biology. In fact, the legacy of organicist thought has been less than well-received by philosophical audiences (cf. Nicholson and Gawne 2014, 246-248). This points holds as well for the organicists' work on the levels concept For this reason, it will be necessary to quickly re-examine the content of the organicists’ scientific program, vis-á-vis it's contrast with mechanism and vitalism, in order to properly reconstruct their impact on contemporary issues in the science and philosophy of biology. Though a comprehensive treatment of this will be impossible here, its relevance to highlighting the importance of the hitherto, and likewise, neglected account of levels of

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[114] The contributions of organicism are more clearly acknowledged in theoretical discussions within biology than in philosophy. In fact, organicist ideas of levels of organization have become so embedded in biology, their intellectual heritage is rarely linked explicitly back to their historical sources. This point was recently emphasized in Nicholson and Gawne's (2014) extended defense of Joseph Woodger's work as a progenitor to contemporary philosophy of biology.

organization that was constructed within the organicist movement will be directly noticeable.

5.3 The Organicist Program and the Levels Concept

The beginnings of organicist thought is generally claimed by later scholars to have been first articulated in the work of William Emerson Ritter, particularly his (1919) book *The Unity of the Organism* (Beckner 1959, 185; 1967, 549; Mayr 1982, 66). The members of the Theoretical Biological Club of the 1930's, who constituted Cambridge organicism, preferred a wider base of historical association, citing in particular J.S. Haldane's (1916) Silliman Memorial lecture *Organism and Environment as Illustrated by the Physiology of Breathing* as their most relevant predecessor (and later contemporary, see Needham 1932b).[115] In order to outline more specifically the content of the organicist program and the role of the levels concept within that program, the first part of this section will articulate the major tenets of the organicist program, while the latter two parts of this section will deal with the use of the levels concept by the organicists to defend these tenets as part of their program.

5.3.1 The Tenets of the Organicist Program

Though vitalism turned out to be an empty promise due to the deficient arguments developed by its proponents (in particular the postulation of the life's phlogistonal vital force), the organicist program would go on to construct a robust alternative to the mechanist program. In stark contrast to the vitalists, the proponents of organicism actively worked to give their ideas a solid basis in scientific practice (see below). Nonetheless, the extent to which the organicists would succeed in their stated goals would later be debated through the middle of the 20th century (Beckner 1959, Ch. 9; Hein 1968; 1969, 1972; Hull 1974, Ch. 5; Roll-Hansen 1984). The organicist program was, in contrast to the vitalist program, largely epistemic in nature

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[115] Needham (1928a) cites even earlier writers as instigating the organicist movement, in particular Yves Delage's (1903) *l'hérédité et les grands problèmes de la biologie générale*.

because of the organicists' broad agreement with the materialist basis of existence.[116] Indeed, the Cambridge organicists were careful to point this out in their arguments, since interpreting these tenets in a *metaphysical* way threatened to place organicism too close to vitalism. The disagreement between the mechanists and the organicists, instead, focused on how to best capture the difficulties of approaching biological phenomena as scientific (and materialistic) objects of inquiry.

In this endeavor the organicist program comprised several tenets that will be of particular interest in this chapter. These tenets present general claims concerning the overall view of the organicists concerning both the nature of biological phenomena and the autonomy of the biological sciences. A centerpiece of the organicist program, as mentioned above, was its surprisingly advanced conception of levels of organization, which they specifically developed in order to effectively articulate the tenets of their program (Section 5.3.1). The major tenets of the organicist program important for this discussion include: holism and organization, autonomy of the biological sciences from the physical sciences, and practical relevance to biological research.

(1) ***Holism and Organization***

Biological phenomena are significantly different from physical phenomena due to the presence of organization in living things, which exhibits a degree of complexity that is unknown to non-living things (Needham 1928b, 79; 1936, viii; 1943, 18; 1945; Woodger 1929 [1966], xviii-xix; Waddington 1940; 1957, 5).**[117]** Due to the presence of organization, the organicists argued, one kind of phenomenon or phenomena (say cells) result in another kind of phenomenon or phenomena that manifest completely different features than those of which

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[116] This commitment is captured by Needham, when he specifies that "[t]he mechanist, after all, never asserted that there was no difference between a stone dog and a real live dog; he only insisted that the processes going on in the living dog were extremely complicated special cases of the processes known to occur in the inorganic world" (Needham 1928a, 34).

[117] The presence of complexity was offered as an important condition with which to distinguish between biological and physical phenomena, as part-whole relationships can be found in both branches of science (Needham 1928a, 35). This contention is supported, at least historically, by Warren Weaver's (1948) use "organized complexity" as an important criterion for distinguishing between the kinds of problems encountered in biology, as opposed to the "unorganized complexity" manifested by problems encountered in physical science.

it is made (for instance, tissue). In effect, the organicists claimed that biological phenomena exhibit *holistic* features that can only be adequately characterized by attributing to them a status of being distinct from the physical and chemical constituents of which they are composed. That is, the wholes to which physical and chemical parts belong designate biological entities that biologists seek to investigate and study. Due to the presence of organization by their parts, these entities exhibit behaviors that their parts cannot. These phenomena are *biological* insofar as the wholes that exhibit these holistic features designate units that biologists typically investigate in their empirical work. Needham summarizes this idea in the following way:

> "Thus, on the organic theory of nature [i.e. organicism], all the universe is seen to consist of wholes, or organisms, whose parts, as Lloyd Morgan would say, go together in substantial unity, or in other words, are only themselves so long as they remain in their natural places within the whole to which they belong. For the constitutive relationships or parts are not entities having an existence in their own right [i.e. they do not manifest the phenomenon to which they belong], but only in virtue of their position and function in the organism [i.e. organized whole] of which they form parts" (Needham 1928a, 34.[118]

The "substantial unity" to which Needham refers here is meant to express the thesis that organized wholes that exhibit behaviors or properties that are not found in their constituent parts necessitate a differentiation of kind between those wholes and their constituent parts. That is, biological phenomena retain their identity, *as scientific objects of study*, only insofar as the problems that they pose to scientists are characterized (at least initially) in terms of the wholes to which they belong: Wholes are not *only* their parts. In this way, the "constitutive relationships" of biological wholes to their parts is, in agreement with mechanism, sufficient to account for their status as material entities (*contra* vitalism). At the same time, *contra*

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[118] This mention of Lloyd Morgan represents an interesting nod to the emergentists by a younger Needham in expressing the difference between biological and physico-chemical phenomena. The exact relationship between emergentism and organicism would allow more insight to be produced regarding the levels concept, which, for considerations of space, cannot be entered into at this time. For one thing, as will be seen below, an older Needham (1943) would later repudiate the contributions of the emergentists' to the understanding of the levels concept as being completely out of contact with scientific practice.

mechanism, the whole was deemed by the organicists to be, at least sometimes, "*quite inadequate for the problems which it [mechanism] was required to answer in biology*" (Needham 1928a, 31; emphasis added).

It should be noted that the holism the Cambridge organicists ascribed to biological phenomena was relatively innocuous in comparison to other meanings that 'holism' can connote. For the Cambridge organicists, the holism they attributed to organized wholes (i.e. "organisms", see Nicholson 2010) merely captured the fact that biological wholes are different from their physical parts, and that, because of this, the way that we characterize the tasks involved in explaining such phenomena should reflect approaches that are appropriate for adequately capturing those features. This stands in stark contrast to not only the vitalist position, but also to stronger notions of differentiating physical and non-physical phenomena associated with, e.g., emergence, and even to other interpretations of holism given by other organicists (like J.S. Haldane and Alfred North Whitehead). Each of these alternative positions attributed a special status to holistic features that went beyond merely postulating an important basic difference between biological and physical phenomena. The holism of the Cambridge organicists is for this reason much closer to what Carl Craver (2007, Ch. 6) defends as part and parcel to "nonfundamental explanation" in the biological sciences today.[119]

Conrad H. Waddington (1957), speaking to the same point as Needham above, includes a similar clarification of the organicist interest in organized wholes, though he avoids problematic terms like "holism" or "emergence", and speaks directly to systemic properties:

> "The problem is therefore the investigation of *systems*, i.e. components related or organised in a specific way. The properties of a system are in fact 'more' than (or different from) the sum of the properties of its components, a fact often overlooked in zealous attempts to demonstrate 'additivity' of certain phenomena. It is with these '*systemic properties*' that we shall be mainly concerned. These only arise as a result of a

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[119] In a nutshell, Craver argues that higher levels of organization are explanatory relevant (against reductionist and causal exclusion arguments to the contrary) due to higher-level properties eliciting *appropriate* or *proportional* explanatory generalizations under causal interventions. This, he claims, demonstrates that "[t]he ability of organization to elicit novel causal powers (that is, nonaggregative behaviors and properties) is unmysterious both in scientific common sense and common sense proper" (Craver 2007, 217).

> particular type of organisation, i.e. particular functional relationships between the components, and these properties, of course, 'disappear' when that organisation is destroyed or altered. *This is the reason why the physical sciences, often dealing with the same components as those in organisms, in many cases fail to say something of relevance to the biologist*" (Kacser, in Waddington 1957,[120] 191, emphasis modified; see also Waddington 1940, 142-143)

Due to the relative innocuous character of the Cambridge organicists' understanding of holism, this tenet of the organicist program has often been criticized as "trivial" (Beckner 1969b, 551) or otherwise unsurprising and exaggerated (Nagel 1961, ch. 12; David Hull 1974, ch. 5).[121] From a contemporary perspective, this tenet of organicism can indeed now be considered basic knowledge in biology (see for instance Reece et al. 2010, 3; Solomon et al. 2010; Section 1.4). However, what *is* interesting about the Cambridge organicists' stance on holistic features in biological phenomena is their emphasis on such features as a means of framing the issue in terms of explanatory adequacy, which was unique for its time (but see Russel 2015). It is hence a testament to the insights produced by the (Cambridge) organicists that the claims underlying this tenet are now considered common knowledge in contemporary biology.

(2) ***The Autonomy of Biology from the Physical Sciences***

The organicists saw at the core of the mechanist-vitalist dispute regarding the distinction between physico-chemical phenomena, and biological phenomena a deeper disagreement regarding the status of biology as a natural science. Specifically, proponents of the mechanist program in biology often defended the (perhaps exaggerated) claim that an adequate description of a biological system was only possible if one examined the parts of that system

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[120] Kacser's essay appears an appendix in Waddington's book, which the latter found necessary to publish with the rest of the book's content.

[121] Conversely, others have criticized organicism as a whole for what is perceived as a dramatic vacillation between different meanings, and interpretations for the significance of, holistic features in biological phenomena presented by different factions of organicists (see especially Hull 1974, 125-127; Gilbert and Sarkar 2000, 4-5).

in isolation of the whole (Hull 1974, 129; Allen 1975, 106). Implicit in these mechanistic claims was the further implication that the physical sciences were in themselves generally *more adequate* for explaining the problems that biological phenomena exhibited to scientists.

Needham identifies this aspect of the debate as the introduction of a "wall of partition" between the respective objects of study in the physical and the biological sciences:

> "At this point no one who has examined the history of biological thought can fail to be impressed by the fact that here[122] in a most striking manner a *wall of partition* has gone down between, not the organic and the inorganic, as might have been said ten years ago, but between the living and the non-living" (Needham 1928a, 34).

For the organicists, the biological sciences did not constitute a homogeneous branch of science seeking centralized unity, but rather a cluster of distinct scientific fields that investigate different aspects of nature, as revealed by the diversity of different kinds of biological phenomena (see especially Abir-Am 1987, 10; Woodger 1929, 273, 288). These aspects of nature are not reducible to, nor reproducible by, other disciplines: Rather, each individual discipline in biology embodies different interests regarding, and different epistemic access to, natural phenomena (Needham 1936, 19-23; cf. Nicholson and Gawne 2014, 260, 273[123]).

It was therefore foolhardy, according to the organicists, to claim that, as a matter of principle, the problems of the biological sciences could be adequately solved by explanatory approaches and resources provided by the physical sciences. Needham (1928a) went on to point out that this disagreement originated neither in the debates of the mechanism-organicism dispute, nor in the mechanist-vitalist dispute, but rather was a reiteration of a debate with deep roots in the history of science. Hence, the mechanist "wall of partition" blocking the acknowledgment of the biological sciences as a legitimate and autonomous branch of natural science was argued

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[122] See the above quote from the same text. By "here" is meant, i.e., the dispute between the demarcation between physical phenomena and proper biological phenomena via the manifestation of holistic properties by the latter.

[123] Nicholson and Gawne (2014) compellingly demonstrate the presence of this conviction in the writings of Joseph Woodger (ibid.).

on the grounds that the physical sciences were explanatorily more fundamental:

> “[I]t would be well to indicate that this question of the *primacy* as between physiology and physics is not so barren as it might at first appear [i.e., as it appeared in the mechanist-vitalist dispute, and in “obstructionist” or obscurantist organicist writers]. It has an importance *for the practice of science as well as in philosophy*. Very little study of the history of scientific thought is required to show that the tacit background of a great experimentalist's mental operations exercises a profound influence on the line of progress which knowledge takes. The instance which here specially concerns us is the difference in opinion between Louis Pasteur and Justus von Liebig over the fermentation question...Pasteur adopted a physiological view, and insisted on looking at the metabolic activity of the yeast-cell as the important factor; but Liebig made every effort to disregard it for fear of a possible surrender to vitalism. To [Liebig], *chemistry was much more fundamental than physiology, and he felt that any explanation which involved living organisms was a backward step*. The effects of this dichotomy of opinion on the history of biology were very far-reaching, and even after the demonstration that the yeast-cell was an essential element in fermentation there remained two trends of though, one considering the yeast-cell only as the carrier of the essential enzyme, and the other thinking it as a physiological entity with a metabolism of its own” (Needham 1928a, 32-33, emphasis added; see also Hein 1969, 239).

Against this claim of the fundamentality of the physical sciences, the organicists once again responded on the grounds of a more nuanced understanding of explanatory adequacy. Woodger speaks to this effect, arguing from the organicist stance on biological phenomena to the autonomy of biology:

> “The laws of mechanics provided by physics do not enable us to predict the course taken by a ball in a game of tennis. This is because a game of tennis involves persons, their aims, temperaments and skills, and all these are completely abstracted from in physics. Chemistry, as such, abstracts from organisms as viewed by biologists, and hence from [problems arising with drug interactions with an unborn fetus during]

> pregnancy. Consequently in the testing of drugs from a chemical standpoint there is a possibility of the pregnancy of the patient being overlooked, together with possible effects on the foetus. Owing to the complexity of organization encountered among living things, and the occurrences between them of parts which are existentially dependent upon other parts, constituting the whole, we have the possibility to be reckoned with of the occurrence of so-called internal relations between such parts...*Similar considerations may apply to the parts of organisms at many different levels, and if this is the case it will mean that the chemical outlook will not always suffice but will require supplementing and checking from the biological standpoint*" (Woodger 1929 [1966], xviii-xix, emphasis added).

These extended quotations not only show how intimately the organicists' understanding of biological phenomena is connected to thinking about the status of biology as an autonomous science, it also introduces for the first time in this discussion the organicists' use of the levels concept as a means to articulate their program.[124]

(3) ***Practical Relevance to Biological Research***

For the organicists, drawing inferences about the structure of both science and nature should follow from case-based studies, and emphasize principles that allow for context-specific details of the particular cases being treated to be filled in (see especially Waddington 1940, 143-144).[125] This complements both of the foregoing tenets in that despite the generalized character of the claims regarding, respectively, biological phenomena and the autonomy of biology, the inferences from which these claims are drawn should be informed by detailed acquaintance with scientific research. This highlights another underlying purpose of the organicist project in offering constructive contributions that were relevant to scientific practice, rather than merely theory (cf. Nicholson and Gawne 2014, 274-275; Russell 2015

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[124] This will be further discussed below in Section 5.3.1.

[125] This is a methodological point regarding the style of argument that the individual organicists employed to construct their arguments. It nonetheless remains true that the organicists were interested in establishing a novel *program* for the whole of biology.

37-40).

This tenet of the organicist program is important to consider in regards to the attempts the program's advocates to distance themselves from vitalism while offering a viable alternative to the mechanist program. Firstly, though the presence of complex organization is something that the organicists took to be widespread in, and even generally designative of, biological phenomena, it was by no means a vague or unanalyzable principle to which biologists should hold themselves accountable. Rather, *discovering* and *characterizing* the organizational features of particular biological phenomena *on a case-to-case basis* constituted the "central problem" of biological explanation for the organicists (Needham 1932, 88-89, 92; 1934; 276; 1936[1973], viii). This cannot be underemphasized as an exegetical point of the organicist program, and would be brought up again and again during the heyday of organicist thought in the 1930's (particularly by Needham) as the ultimate point of contrast between the Cambridge form of (i.e. "legitimate") organicism, and the pseudoscientific extravagances of both vitalism and more obscurantist attempts at articulating the organicist program (see especially Needham 1932, 89; 1932b, 525). These other positions, for the Cambridge organicists, were extremely problematic *precisely because* their specialized notions offered no practical application in biological research. Take for instance the following comments from Needham:

> "If we take biological organisation as axiomatic, that is, as an essential part of the impenetrable alogical core[126], we at once remove it from the realm of experiment. We are adopting a course as fruitless as it would be to take the chemical elements as axiomatic in physics and to make no attempt to go behind the periodic table into the realm of the electronic structure of atoms...The sublime expression 'I am that I am' is well suited to the manifestation of a deity, *but when applied to the immediate problems confronting scientific workers, its use becomes nothing more than the frank confession of intellectual bankruptcy*" (Needham 1936, 16, emphasis added; cf. Needham 1934 and 1943, Ch. 1 for similar comments).

Despite the clarity in which this point was expressed by the Cambridge organicists, the

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[126] By "alogical core", Needham is specifically referring to the "arbitrary" and ultimately unsubstantiated conviction informing vitalism's life force and to Haldane's notion of "organization" in organicism.

emphasis on organization by the organicist movement at large would also become a point of criticism that later commentators would continue heap on the organicist program in general (Beckner 1969a, 1969b; Heine 1969; Roll-Hansen 1984). For now, though, this point is important to note as an important tenet of organicism as it not only presented their program as one oriented towards practical relevance to working scientists (in direct contrast to especially vitalism), it strengthened the two foregoing tenets. Specifically, it gives the first tenet above (holism and organization) a more justifiable grounding; namely, in experiment and practice, rather than theory and principle. Similarly, it also implied that biology, in being an autonomous science, is simply more adequate for *grasping* and *answering* the problems that biological phenomena present to scientific explanation. For, if organization in biological systems is a problem that practicing scientists actively engage in explaining, this in turn vindicates its other claims that biological phenomena are different from physical phenomena, and the acknowledgment of the autonomy of biology.

The organicist program served to both distinguish it from vitalism's virtually non-existent epistemological program, which never progressed beyond *calls* for a dramatic shift in the conception of life and how it was investigated (Allen 2008), and also to improve upon the epistemological issues articulated that, at one time, inspired the anti-mechanist sentiment of a physics- and chemistry-centered conception of science. The resulting program, i.e. organicism, was rather unique for biology at the time (Allen, 1975, ch. 5; Gilbert and Sarkar 2000; cf. Nicholson and Gawne 2014; Russell 2015[127]). The difference between vitalist claims of the qualitative difference between living and non-living phenomena, and organicist postulation of holistic, yet material, features is that the organicists took such organized wholes to not only be wholly consistent with materialism, but most importantly, accessible by experiment. Because of this, to *adequately* identify biological phenomena *as* biological, scientists must characterize the phenomena that they wish to investigate and explain in a way

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[127] Russell's recent (2015) analysis of the exchange between Arthur Lovejoy and Herbert Spencer Jennings from 1909-1914 offers a poignant contrast to this point that the organicists were the first to compile this novel program. Russell argues compellingly that Lovejoy and Jennings constructed an especially potent scientific epistemology that (a) was based on the rejection of the excesses of vitalism, while being simultaneously inspired by the vitalists' call to distinguish between physical and life sciences as very different enterprises, and (b) connects very well with contemporary thinking about scientific knowledge. I readily acknowledge Russell's point, and wish that I had heard of the paper before this dissertation was submitted for review.

that (i) captures the features of the phenomenon in question, such that this characterization (ii) permits empirical investigation without relenting to obscurantist notions like those offered by the vitalists and by some organicist writers (Needham 1928a, 35; 1936, 15-16). It is at this juncture that organicists introduced the concept of levels as a novel theoretical term.

5.3.2 The Organicists' Use of the Levels Concept

The concept of levels of organization was central to the organicist program. In it the Cambridge organicists found a conceptual device that served both to represent their view of the natural world's non-reductionistic-yet-materialist ontology, and also to elaborate the tenets of their program, which detailed the unique explanatory problems facing biologists as an endeavor distinct from those pursued by the physical sciences. The term "levels [of existence]" actually seems to have been introduced into the philosophical literature by the emergentists[128] (cf. McLaughlin 1992, 50-51), but was at the same time widely observed to be an unanalyzed term in need of active development (Conger 1925; Brown 1926).[129] Hence, though the organicists did not *invent* the concept of "levels" or the hierarchical view of the world with which it had already become associated, they were responsible for adding the qualifier "levels *of organization*", and quickly became interested in the problematic task of articulating its meaning and significance for science. As this section will show, the organicists' development of 'levels of organization' imbued the concept with a *programmatic character*, meaning that the levels concept came to be generally expressive for the content of the

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[128] Needham attributes the first use of the "levels" concept to Samuel Alexander (1920), and also acknowledges Auguste Comte's thoughts on the hierarchical view of scientific disciplines (Needham 1943; 234, 269 respectively). The specific term that Alexander coined was "level of existence" (Alexander 1920, 3). Other references to the term "level", with and without a particular "of" qualifier, were also intermittently used by the various mechanist, vitalist, and organicist publications. Haldane used the term without further qualifier in his rejection of the "reduction of the organic to the *level* of the inorganic" (1919, 105, emphasis added), while the philosopher R.F.A. Hoernlé actually mentioned the term "levels of organization" in a (1918) conference report regarding the mechanist-vitalist dispute. However, neither Hoernlé nor the authors summarized in the report exhibited any commitment to the term or its development.

[129] George P. Conger was forthcoming in an astute observation of the challenges posed by the trend towards the "doctrine of levels" in philosophy at the time, saying: "Phrases denoting differences of level are familiar, and I think are becoming increasingly frequent, in the literature of several sciences...As used in metaphysics, *it is evident that such phrases have the fascination of great generalizations, but also the dangers of loose metaphors*" (Conger 1925, 309, emphasis added).

organicist program.

The members of the Cambridge organicist group, the Theoretical Biological Club (TBC), applied the levels concept both in their individual writings and privately.[130] The analysis of the concept "levels of organization" by the organicists was catalyzed by Joseph Woodger, who modified the term from Alexander's original term "levels of existence" (Woodger 1929 [1966], xvii; 298-299; 321; cf. Roll-Hansen 1984, 404).[131] In particular, Woodger's (1929) book *Biological Principles*, along with a follow-up (1930) paper, introduces the term as a concept of substantial significance, and should therefore be recognized as the historical sources most responsible for initially injecting the term into scientific thought, and into philosophical analysis of scientific thought. In these sources, one can see that Woodger's primary interest in the levels concept was directed towards offering a more clear and unambiguous explication of what organized wholes (i.e. "organisms") in biology are (Woodger 1930, 8-10). These organized wholes, as seen above, were a central element for the new emerging approach to explaining biological phenomena offered by the organicist program. Woodger also promoted the levels concept as a means of arguing for the autonomy of biology, the second major tenet discussed above (see especially the extended quote by Woodger given above in Section 5.3).

Joseph Needham, in his (1930) review of *Biological Principles*,[132] quickly picked up on the concept, and identified Woodger's discussion of levels of organization as "the major innovation of Woodger's book" (Abir-Am 1991, 171; see also Needham 1930, 222-223).[133]

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[130] The collaborative efforts of the Theoretical Biological Club are more visible in the personal correspondence of its members, which Pnina Abir-Am (1987) details at impressive depth and length.

[131] ##Woodger eventually shifted his focus away from the levels concept as his overall philosophical approach moved towards a more formalized approach focusing on analyzing the language used to articulate biological claims (Nicholson and Gawne 2014, 262-269).

[132] Needham's review, coincidentally, appeared one month after the publication of Woodger's (1930) paper on the "organism" concept, and re-sparked a flurry of exchanges between the two that had begun earlier that year (Abir-Am 1991; 169-172).

[133] Indeed, his encounter with the levels concept in Woodger's work led Needham to quickly take up the concept. In Needham's earlier, pre-1930 writings on organicism, one can see the difficulty with which he fumbled to balance his defense of organicist ideas against both mechanism and vitalism. In his (1928b) paper, for instance, Needham grasps towards something like the levels concept when he writes: "Thus to the scientific mind the living and the non-living form one continuous series of systems of differing degrees of complexity, all of which consist of parts that can be understood as parts when separated from their wholes and are therefore interpretable in terms of '*metrical macroscopic mechanism*'" (Needham 1928b, 79, emphasis added). Needham's excited endorsement for the levels concept becomes apparent when one notes Needham's

Simultaneously, though, he did express reservations about the relevance of Woodger's formal approach for practicing scientists, saying:

> ##“But it is perhaps rather characteristic of his book that immediately following his section which deals with the hierarchies of levels in the animal body, there is not a section devoted to the practical applications of this (new?) mode of thought...Research workers, therefore, get little help from Mr. Woodger here, and this holds true throughout the book” (Needham 1930, 223).[134]

Needham himself would nonetheless take up the levels concept as a central motif in his own writings, and would frequently use the term to propagate organicism's ideas concerning explanation in biology. The emphasis of his approach, as will be seen below, focused on a more open-ended, empirical characterization of levels. The reason for this lies in Needham's interest in analyzing biological phenomena in a more case-based manner.

As it turns out, the organicist conception of levels was a product of intense negotiations among the members of the TBC, in particular Needham and Woodger. These negotiations occurred in both academic and personal settings in the form of publications and letters, respectively, and concerned the philosophical platform that their group would represent. The discussions between Woodger and Needham directly resulted in the creation of the Cambridge organicists' philosophical and scientific program, the tenets of which were discussed above (cf. Abir-Am 1987, 10-11).

It was during these negotiations, Pnina Abir-Am (1987) reports, that the levels concept acquired its distinct importance for the organicists, as it specifically emerged as a product of compromise made between the philosophical differences held respectively by Needham and Woodger. The two differed from each other on a range of issues, including who would

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enthusiastic, and frequent, use of the concept in his post-1930 works.

[134] This review, it would turn out, would begin a cascade of interactions between Needham and Woodger that resulted in the construction of the Theoretical Biology Club (Abir-Am 1987, 11). Abir-Am (1991) goes into exceptional detail regarding the process of rapprochement between Woodger and Needham and its significance for the development of Needham's own thought specifically, and more generally for the development of the Theoretical Biological Club. The role of the levels concept for these exchanges will be considered below.

participate in the TBC discussions (ibid. 12-13), the topics that the group should dedicate their time analyzing (ibid. 13-14), and how to balance the interests and goals of the other members they chose to include in the group (ibid. 14-15). However, the principle difference between Needham and Woodger concerned the nature of how to analyze, and propose solutions to, the problems in biology that both were interested in engaging. Woodger, who had recently become interested in formalized methods reminiscent of the logical positivists, emphasized focusing the group's efforts towards "exploring the potential of a new symbolic logic" (ibid. 14)[135]. Needham, on the other hand, was more interested in an empirically-informed approach that sought to analyze the interconnections of knowledge between different disciplines in biology, especially discipline-bound concepts (ibid. 13).

The compromises hammered out in the organization of the Cambridge organicists' group by Needham and Woodger was directly subsidized by their shared interest in Woodger's (1929; 1930) introduction of the levels concept:

> "The rapprochement between Woodger and Needham pertained to their complementary strategies in a theoretical biology revolving around the *non-classical concept of levels of organization*. While Woodger remained primarily concerned with erecting a logical skeleton for embryological facts, the latter to be supplied by experimental scientists, *Needham's preoccupation with the synthesis between presumably contradictory systems of knowledge such as biochemistry and embryology required access to philosophical bridging devices.*" (Abir-Am 1987, 12, emphasis added)

The members of the Theoretical Biology Club at Cambridge thus resolved to undertake in their organicist program an analysis of the concept to elucidate what was scientifically viable in the collection of intuitions that were being expressed in the increasingly frequent references to the levels notion. These efforts, and particularly those of Needham, resulted in a general account of levels that was surprisingly sophisticated for its time. This account came to be

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[135] This corresponds to what Nicholson and Gawne (2014, 262-269) refer to as Woodger's "Formal Period", in which Woodger became interested in constructing an axiomatized system that would offer "a rigorous means of expressing and relating propositions of the kind afforded by propositional logic" (ibid, 262-263). It should be noted though, that Woodger himself was not a logical positivist (ibid.).

known as the "integrative levels" account, which also received its namesake from Needham in his later writings (see Section 5.4).

Looking at this point in more detail, the organicists' use of the levels concept focused initially on effectively expressing the tenets of their program. Consider first how the levels concept was used to articulate the tenet of holistic features exhibited by biological phenomena (due to the complexity of the organization of their parts). Here, the levels concept conferred a means by which holism and organization in biological phenomena could be expressed without the "spooky" connotations that haunted the vitalists, emergentists, and even other organicists. Woodger (1930) elaborates:

> "The concept of organism [i.e. organized whole] requires a number of subsidiary notions such as 'organic whole,' 'organic part,' and 'organic relation.' Also an organism exhibits what I call '*hierarchical order*.' It is easy enough to see 'intuitively' what is meant by these terms; there has been a good deal of vague talk from time to time about 'the whole being more than the sum of its parts,' etc.; the difficulty is to make these notions precise *in order to enable us to see how we can use them for scientific purposes*...In hierarchical order we begin with a single individual which will be symbolized by *W*. This is analysable into individuals called members (*m* or *M*) which fall into classes of two kinds called *levels* (*L*), and *assemblages* (*A*). There is also a fundamental relation (R_h) in which the members stand to one another, and upon which the whole hierarchical type of order depends" (Woodger 1930, 8, emphasis modified).

The formal perspective of Woodger can already be clearly seen taking its shape in this passage. In fact, Woodger's attempt to clarify the term "levels" closely follows the definition of a formal hierarchy, which was discussed in Chapter 1:

> "We proceed to the following definitions:
> *Level*: A level is a class of members of *W* and is such that no member of the class stands in the relation R_h to another member of the class. In any hierarchy there are at least two levels.

> *Highest Level*: One level is such that none of its members stand in relation R_h to any other member, but each stands in the relation R_h to *W*. This may be called the highest level.
>
> *Lowest Level:* if there is any level which is such that its members are incapable of further analysis this constitutes the lowest level.
>
> *Next Highest Level:* if *m* is any member of a given level *L* then there is one and only one level (other than *L*) containing one and only one member *M* such that *m* stands in the relation R_h to *M*. This is the next highest level above *L*" (ibid., see also Woodger 1952 for a restatement and refinement of Woodger's thinking on levels)

Needham's use of the levels concept deviated from this formalized approach,[136] and instead emphasized the ability of the concept to aid in (i) producing an accurate depiction of the relations between particular wholes and their parts for specific empirical cases and (ii) how to understand relations between the knowledge produced by different scientific disciplines.[137] Abir-Am also acknowledges this difference in the two researchers' understanding of levels, saying that "[i]n contrast [to Woodger], Needham exemplified what Woodger called 'thinking for use', a thinking affected by the pragmatic aspect of laboratory life, or rather by the need to account for concrete facts rather than for abstract patterns of logic" (Abir-Am 1987, 60 fn. 39).

The concept of levels of organization hence presented a significant notion by which the organicists could effectively express the program regarding how to frame the impact of the organicists' new philosophy of biological explanation. The final part of this section will demonstrate that the organicists' use of the levels concept was also motivated by the same epistemic goal that informs the levels concept today.

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[136] At the same time, Needham frequently referenced Woodger as the one most responsible for drawing attention to the issue of articulating the specific details of organization within a particular system, and in particular those designative of biology (see, e.g., Needham 1934, 275; 1936, 7, 18, 107-111; 1943, 182-183, 192, 242-243).

[137] Needham's use of levels will be looked at in more detail in Section 5.3.3, as his use of the levels concept is more prudently examined in connection to the epistemic goal of the levels concept, which Needham actively worked to build into the concept.

5.3.3 The Epistemic Goal behind the Organicists' Use of Levels

As the rest of this section will show, the use of the levels concept by the Cambridge organicists to express the particular claims of their program was unambiguously motivated towards *structuring the problems* facing biologists in constructing explanations for biological phenomena. This is a significant observation, as it offers a major justification for the ideas developed in the foregoing chapters. For one thing, it establishes an historical precedent for the epistemic goal of the levels concept discussed at length in Chapter 4: In effect, it was the organicists that conceived, and applied, the epistemic goal motivating the use of the levels concept in biology. Moreover, this observation will serve as an additional point of justification in drawing parallels between the organicist conception of levels and the pluralistic treatment of levels also given in the foregoing chapter. These parallels will be discussed further in the next section (5.4), where the organicists' initial development of the levels concept attracted the attention of other biologists, and was further developed into its own full-fledged account.

Recall from Chapter 4 that the epistemic goal of the levels concept is recognizable in two kinds of claims, i.e. descriptive level claims and hypothetical level claims. In descriptive level claims, the levels concept appears as a descriptive term applied to provide a characterization of a phenomenon for which an explanation is sought, while in hypothetical level claims the levels concept appears as an operationalized term with which to direct research efforts in solving a particular explanatory problem.

The epistemic goal of the levels concept, in both of these forms, is especially identifiable in Needham's advocacy of the tenets of organicism. In the opening sentence of a (1934) paper in *Nature*, Needham again makes it clear that the ultimate target of the organicist program is to come to grips with the nature of biological problems: “Those who are accustomed to ponder the *ultimate problems of biology* are aware that though the need for a comprehensive [understanding of] biological science is great, the *difficulties in obtaining it* are equally considerable” (1934, 275). This statement comprises two parts. The first part concerns the explanatory problems of biology, which, not surprisingly now, center around the discovery and characterization of organization in biological phenomena. This, as seen in other quotes from Needham above, proceeds in a contextualized manner, as the different explanatory problems that are treated in biology vary from case to case.[138] The second part of this statement concerns the difficulties in solving these particular problems (i.e. constructing explanations) in an adequate manner. Interestingly, Needham states that the "main difficulty" (ibid.) hindering scientists from accomplishing this concerns figuring out how to relate knowledge associated with one discipline, treating one object of study, to the knowledge of another discipline that treats another object of study, both of which are related by a part-whole relation (the examples he discusses, plainly seen in the paper's title, stem from "Morphology and Biochemistry"). In other writings, Needham was even more explicit in his use of the levels concept, saying:

> "Whatever the nature of [organizing] relations may be, they form the *central enigma* of biology, and biology will only be fruitful in the future if this is recognized...*The hierarchy of relationships, from the molecular structure of the carbon compounds to the equilibrium of species in ecological wholes at the other,* will probably be the *guiding idea of the future*" (Needham 1932, 92).

As was typical of Needham, he did not prescribe a generalized account with which to go about dealing with this difficulty. Rather, it is his diagnosis of the issues facing biology that is noteworthy. Specifically: The explanatory problems of biology can be adequately characterized only when it is acknowledged that biological phenomena are often distributed across different levels of organization. This is significant in that Needham was effectively claiming that the hierarchical descriptions made possible by descriptive level claims allow for the features or behaviors exhibited by biological phenomena (for which an explanation is sought) to be captured in a manner that is amenable to scientific investigation. This exemplifies the descriptive goal motivating the levels concept in constructing adequate descriptions of nature.

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[138] This is visible in the text of this (1934) paper. Specifically, Needham develops this point of the importance of organization by discussing *particular* experimental findings, and also *particular* methods, in biochemistry made by contemporary scientists of the time on, e.g., the study of protein structure in biological systems, such as the echinoderm egg, or muscle and yeast extractions (ibid.).

At the same time, Needham and the other organicists also drew consequences for constructing biological explanations from hypothetical claims involving the levels concept. This followed as a corollary to the above thesis concerning descriptive level claims in biology. Particularly, Needham claimed that once we acknowledge that nature is structured hierarchically into levels of organization (and that many biological phenomena are often distributed across several levels), we also see that different scientific disciplines often treat different aspects of a particular problem for which they are best suited, i.e. by investigating the entities that follow part-whole distinctions given by the levels at which they located. Given this, solving biological problems often involve suggestions to move to a different level, where not only the relevant entity, but also the relevant investigative means for adequately grasping that phenomenon in the first place are located. The ability of such an *open* levels concept to structure the explanatory problems of biology, rather than a particular analytic definition of the levels concept, is what Needham identifies as biology's “guiding idea of the future” (ibid.).

The organicist use of levels hence also became an operationalized term under Needham's development, and became a means by which biologists of different disciplinary perspectives could gain insight into a particular explanatory problem: To wit, by suggesting where to find insight for how a given biological phenomenon should be studied in order to construct an adequate explanation for that phenomenon. This way of using the levels concept added a distinct element of “heuristic push and go” (Needham 1932, 88) to the organicist program that gave it a decisive legitimacy over vitalism and obscurantist organicism as an alternative to the reductionist-mechanist program. In his discussion of the “hierarchical continuity of biological order”, Needham (1936) discusses the several case studies (particularly metabolic activity in muscles) as exemplars of phenomena with features that can only be accounted for explanatorily in an interplay between several levels of organization. This interplay is mediated, furthermore, by distinct scientific disciplines. Beginning generally, Needham details the implicit descriptive hierarchical layout in which he discusses this case, and the status of the ontological and epistemic items at the distinctive levels therein as possible sources of explanatory insight to which one can turn. At the same time, he prepared the hypothetical form of particular level claims that arise out of this backdrop, saying:

> “The term 'living' applies to all the components [of a multi-level system] in their organising relations. If this is so, then we *should expect to find* that at levels which are well within the sphere of physico-chemical analysis, there are phenomena which give us glimpses of the rudiments of wholeness. And *it should follow* that a contribution to the unification of biochemistry and morphology can be made *by a study of such phenomena*” (Needham 1936, 117-118, emphasis added).

In effect, Needham claimed that different levels of organization, and the epistemic resources associated with these levels, are not only important for adequately describing biological phenomena, but also represent sources of insight to which scientists may turn their efforts when confronted with specific obstacles to explaining the phenomenon in question (cf. Section 4.4.1.2). Speaking to the investigation of metabolic activity in muscle cells, he discusses at length the role of both biochemical entities and their morphological (higher-level) context, saying that:

> “In elucidating the finer [i.e. lower] levels of biological organisation it is important to discover precisely how much of the normal working of the cell's metabolic changes goes on when the organisation [imposed by higher levels] is to a greater or lesser extent destroyed...[On the one hand,] [t]he more work is done of muscle chemistry, especially in the study of extracts, the more it appears that the phosphate esters of carbohydrates found in the extracts may not be physiological...[At the same time, however,] [i]t is difficult to picture an integrative mechanism *except in the distinctively morphological terms of contiguous situation of the two enzymes at an intracellular surface*” (Needham 1936, 120-121; emphasis added).

Needham reiterated the use of the levels concept as a validation of organicism's program many times in his career, citing specifically the level concept's ability to guide scientists in structuring the explanatory problems of biology, both as a descriptive term in descriptive claims, and as an operationalized term in hypothetical claims. In a retrospective of the mechanist-vitalist dispute, he again directly cites the levels concept in this capacity:

> “This deadlock [between mechanism and vitalism], which in various forms had run through the whole history of human thought, was overcome when it was realised that *every level of organisation has its own regularities and principles*, *not reducible to those appropriate to lower levels of organisation, nor applicable to higher levels, but at* the same time in no way inscrutable or immune from scientific analysis and comprehension. *Thus the rules which are followed in experimental morphology or genetics are perfectly valid in their own right, but comprehension will never be complete until what is going on at the other levels, both above and below, is analysed and compared with the level in question.* Biological organisation is the basic problem of biology; it is not an axiom from which biology must start.” (Needham 1943, 18; emphasis added)

The epistemic goal of the levels concept is also identifiable in the organicists' advocacy of the autonomy of biology. This comprises a more general context of usage for the levels concept, and more particularly the organicists' overall conception of biological explanation, namely in the institutional organization of biological research.[139] The organicists used the levels concept to promote their program as the basis for redistribution of scientific authority in biological research. This redistribution concerned which researchers could be considered competent in characterizing the problems of biology (see especially Abir-Am 1987, 9-10, 18-28; but cf. Roll-Hansen 1984).

After Needham had abandoned active research in the biological sciences for his studies of the history of science and technology in China (the career for which he is best known), he later reiterated his support for organicist program by once again directly citing 'levels of organization' in an updated (1967) forward to his book *Order and Life*:

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[139] The identity of the Cambridge organicist movement in an *institutional* context of science, rather than research and philosophical contexts, is one dimension of significance of the organicist movement that, due to space considerations, cannot be entered into here. A summary of this context, and specifically the organicists efforts to more establish their program in an institutional setting, can be found in Abir-Am's (1987) analysis of the TBC. The role of the levels concept in this endeavor is analyzed in more depth in Mertens and Brooks (*in preparation*).

> “I still think that the organizational patterns and relations in living things, *integrative hierarchies* never exhibited in non-living material collocations, are the proper subject-matter of biological enquiry, and that the recognition of their existence is in no sense a disguised form of vitalism. I still think biological order and organization are not just axiomatic either, but constitute *a fundamental challenge to scientific explanation*, and that meaning can only be brought into the natural world *when we understand how the successive 'envelopes' or 'integrative levels' are connected together*, not 'reducing' the coarser to the fine, the higher to the lower, nor resorting to unscientific quasi-philosophical concepts” (Needham 1936[1967], viii, emphasis added)

Thus, the usefulness of 'levels of organization' for the organicists is that it aids scientists to structure the unique kinds of problems faced by biological researchers. These problems, furthermore, though similar in kind insofar as they are 'biological', necessitate a contextualized treatment for their particular solution, i.e. their explanation. The value that informs this epistemic goal that the organicists infused into their use of the levels concept pertains, like the use of the levels concept today, to explanatory adequacy.

To be clear, the other Cambridge organicists also advocated the value of the levels concept in imposing structure onto a biological phenomenon delivered by descriptive and hypothetical level claims. For instance, Waddington (1940) also used the levels concept in this regard, saying that:

> “When we speak of the dependence of the parts on the whole we must always have in mind *some particular context*; thus the parts of an entity can be said to be dependent on the whole, in a particular context, if, in order to express the properties of the parts in that context, some reference to the whole is necessary...This is often expressed by saying that the tissue *can no longer be adequately regarded* as a mere mass of cells, but has attained a higher level of organization, in which the relevance of the whole organ to the constituent cells can *no longer be disregarded*....The statement made earlier that organisation must be defined with reference to some context provides the clue [to

> explaining what is meant by 'level of organization']. *A new level of organisation is in fact nothing more than*[140] *a new relevant context*. When it is said that an organ rudiment has a higher level of organisation, as a developing entity, than a mere mass of cells, what is meant is that some organ is relevant to the former, while the latter has nothing to do with an organ, either because it is not yet competent [i.e. viable] or because it has passed the regulative stage and reached a point at which its development is completely mosaic, each fragment differentiating on its own without any reference to the whole." (Waddington 1940, 143-144, emphasis added)

This passage is noteworthy for two reasons. First, Waddington's use of the levels concept here reflects both forms that the epistemic goal of the levels concept can exhibit. The descriptive use of levels is visible in Waddington's statement that an entity under investigation, described at one (here the lower) level can at times "no longer be adequately regarded", i.e. adequately characterized, at that level. Instead, adequately characterizing that entity necessitates being characterized at other levels, i.e. as another kind of entity possessing new, holistic features. The hypothetical use of levels as an operationalized term informing scientists 'where to go' is also visible here, specifically in that (new) levels of organization are, in relation to a particular phenomenon, a "new relevant context" in which an aspect of that phenomenon needs to be considered in order for its explanation to be constructed.

Secondly, this passage is also noteworthy in that it contains an important footnote (appearing at the end of the sentence "...can no longer be disregarded") that directly cites two texts support of the claim made about levels in that sentence. These two texts were Woodger's (1929) book and Needham's (1937) Herbert Spencer Lecture called "Integrative Levels: A Revaluation of Idea of Progress". The importance of Woodger's (1929) book has already been discussed. Needham's (1937) lecture, however, marks a significant change in the development of the organicists' conception of levels into a general account, which became known as the integrative account of levels.

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[140] The phrase "nothing more than" here seems to be a prophylactic expression meant to avoid any connection back to, e.g., vitalism.

5.4 The Integrative Account of Levels of Organization

Beginning at the end of the 1930's, the organicist conception of levels transitioned into a more generalized account that came to be known as “integrative levels of organization” (Needham 1937[1943]; Novikoff 1945a). The 'integrative account', as it will be called here, was a direct descendant of the organicists' work on levels, though its development *as an account of levels* was perpetrated rather outside of the Cambridge organicist milieu. Instead, it was actively developed and used by a small number of scientists (and at least one philosopher) who claimed affinity with a number of organicist theses, and who saw promise in the organicist conception of levels as, in itself, a major contribution to biology (Novikoff 1945a, 1945b; Feibleman 1954, 1965; Rowe 1961). The main thesis that the integrative account is meant to support is that the natural world is divided into successive orders of complexity and increasingly integrated organization (Novikoff 1945, 209; Feibleman 1954, 60), meaning that the holistic features that scientific phenomena acquire (as a result of the complexity of their organization) allows quasi-systematic differences between kinds of phenomena to become apparent (Novikoff 1945, ibid.; Rowe 1961, 421). This account of levels has received only minimal attention from contemporary philosophical analysis (e.g. Blitz 1992), and even where the account or its developers are mentioned it is almost invariably cited in connection to different ideas such as emergence or emergent evolution.[141] For this reason, and unlike the layer-cake account of levels, the integrative account is virtually unencumbered by the complications that plague the former, at least as concerns the account's presence in the philosophical literature.

Before moving to the characteristic features that make up the integrative account, one further note concerning the account's inception is necessary. The transition of the organicist conception of levels to the integrative levels account was instigated by Needham, who

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[141] Though Potochnik and McGill (2012) do refer to one of the central texts that articulated a number of the accounts features (i.e. Feibleman 1954), their analysis of levels will not be counted as having acknowledged the existence of the integrative levels account. The reason for this is that they identify Feibleman (1954) as exemplifying everything that is wrong with the levels concept in contemporary philosophy of science (see Chapter 3). This is a mistake, as the integrative account of levels, including Feibleman's attempt to articulate the account's central features, is markedly different from the layer-cake account of levels that, as argued in earlier chapters, currently claims the status of the default conception of levels of organization in philosophy.

simultaneously bestowed the account its namesake in the title of his 1937 Herbert Spencer Lecture “Integrative Levels: A Revaluation of the Idea of Progress” (Needham 1937[1943], 233).[142] The integrative account proved to be a motley creation during its inception, as can be seen in Needham's inceptive (1937[1943]) articulation of the account. In particular, the integrative account was originally meant by Needham to extend far beyond the biological and theoretical biological work he devoted to the concept of levels of organization in the early- to mid-1930's. Instead of dealing primarily with the nature of biological phenomena and their explanation, the account of “Integrative Levels” was initially meant to encompass a grand overarching theory of the nature of the world and the evolutionary processes that led to its creation (Needham 1937[1943], 233). In this regard Needham (1937[1943]) was keen to manufacture a connection between the physical world and the biological world with the socio-cultural world of human society, and in doing so introduced a number of questionable elements into the Needham's understanding of levels of organization.[143] Nonetheless, despite these questionable elements, the basic thesis expressed by the account remained focused on the concept of levels of organization, and the usefulness of the concept as more than simply a technical term connected to expressing the tenets of the organicist program. For, although the target of “Integrative Levels” comprised “no less than the whole nature of the world, and the

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[142] Historically speaking, this marked the end of the Cambridge organicists' (and specifically Needham's) active development of the levels concept. The period between which the levels concept emerged as a substantive concept and eventually transitioned into a general account of how to organize nature can be marked with the respective publications of Woodger (1929) and Needham (1937[1943]). The passage cited above from Waddington (1940) above offers indirect support for this. Needham (1937[1943]) is hence important as an impetus for further interest in the organicist conception of levels, which, as will be seen in this section, was taken up by other scientists interested in this contribution of the organicists to theoretical biology.

[143] Specifically, Needham intended the account to become a model with which to analyze trends in 1930's world politics in a cultural evolutionary framework. Two features of Needham's initial articulation of the integrative levels account are noteworthy here, as they comprise wild, unsubstantiated claims that depart from his previous work in biology and philosophy. These features include (i) a vulgar extrapolation from the organizational patterns in nature to human society as a means of establishing a continuity between the physical, biological, and cultural, and (ii) the attribution of an innate drive towards perfection to evolutionary processes in nature as a means of justifying explanations of society. Both of these features are expressed in the lecture as an extension of Herbert Spencer's analogy of society-as-an-organism (ibid. 235-237). Needham's (1937[1943]) lecture hence exhibits a dramatic break from the organicist work he had engaged in during the 1920's and 1930's. The difference between Needham's earlier (pre-China) career is markedly noticeable in both tone and substance in the lecture, in particular because of the radical Marxist undertones that crudely intrude into the lecture's content, e.g., in claiming that the inevitability of a socialist paradise is guaranteed because of the “authority of evolution” (ibid. 272) driving change in human society. The line of thought here begun by Needham was later taken up and further advocated in a symposium at the University of Chicago organized by the anthropologist Robert Redfield (later published in Redfield 1942). This (1942) collection of essays (and particularly the contributed papers of two scientists, Gerard and Emerson, respectively) instigated Novikoff's (1945a) defense of the account of integrative levels against this frivolity.

way in which it has come into being" (ibid.), Needham was quick to specify that "[t]he subject, then, to which our attention is to be given is *the existence of levels of organisation* in the universe, *successive forms of order in a scale of complexity and organisation*" (ibid. 233-234, emphasis added).

Isolating the characteristic features of the integrative account of levels therefore is a doubly delicate matter, as the account (1) is divided into two very separate theses regarding the structure of the world and its significance for science (i.e. one following the sense of 'levels of organization' developed above by the Cambridge organicists, and another sense introduced by Needham 1937[1943] concerning trends in evolutionary processes extending from biology to human society[144]), and more importantly (2) the account never reached a critical boundary of attention, particularly by the philosophical community, where the account's characteristic features would be critically analyzed and expressed authoritatively. The analysis of the account given here will be a product of analyzing in particular three texts in which the integrative account received treatment as a "programmatic call" (Allchin 2008, 284) to reorient biological research in a manner strongly influenced by the organicist program of the 1930's.[145] From these sources, the following characteristic features can be identified for the integrative account of levels:

1.) <u>Global scope and contextual character</u>

The scope of the integrative account is global, at least in its ultimate aspiration, but is not comprehensive in its character. Instead, the character of particular level claims exhibit a

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[144] The latter of these will not be relevant for the discussion here, and is only mentioned here an exegetical point with which to better demarcate the contribution of the integrative account to an understanding of levels of organization being pursued in this dissertation.

[145] These texts include an (1945a) article in *Science* by the cell biologist Alexander Novikoff, a (1954) paper by the philosopher James K. Feibleman, and another (1961) article by the ecologist James. S. Rowe. Each one of these texts contained slightly different emphases in regards to their articulation of the integrative levels account. For instance, Novikoff (1945a; 1945b) focuses on recouping some of the damage done to the reputation of the integrative account done by Needham (1937[1943]) and the authors in Redfield (1942), and sought to return attention to the levels concept back to understanding how it could be used for aiding biological research. His advocacy of levels strongly resembled the uses of the levels concept originally developed by Needham and the organicists in the early- to mid-1930's. Feibleman (1954; 1965), on the other hand, sought to summarize what levels of organization are according to the integrative account in a more systematic manner, detailing a number of features of defines a "level", and how levels are generally used to aid in constructing explanations. Rowe (1961), finally, focuses on the complementary uses of the levels concept in ordering epistemic resources of disciplinary perspectives in the investigation of different phenomena as well as the more ontological ordering of entities in nature that are used in those perspectives.

contextual approach. That is, the account only claims that different levels of organization (globally) exist, but insists at the same time that the character of different particular level claims is an open question that should be investigated contextually.

2.) ‘Incomplete’ epistemic continuity

Like other conceptions of levels, the integrative account claims that there is a material continuity between the things that make up the natural world, wherein those objects are connected via part-whole relations. The integrative account, however, is completely open as to the precise character of this continuity, instead preferring to emphasize that exactly this issue designates something to be discovered in the process of scientific research (hence the label “incomplete”). Studying these parts and wholes can proceed by means of different criteria by which to separate levels, to wit: compositional relations and distinctions of scale. For this reason, there is no single, uniformly describable continuity between all the objects of the natural world, because levels-based descriptions of a given system or phenomenon will be given contextually by the scientists directly involved in its investigation.

3.) Weak association between levels and scientific disciplines

The integrative account also postulates a weak, but definite, association between scientific disciplines and the things that populate the natural world. Though a broad trend in the partitioning of the natural objects according to particular scientific disciplines is mentioned by the account's authors (e.g., cells-cell biology; molecules-molecular biology), the account readily admits for many different disciplines, and especially different disciplinary perspectives, having their own working definitions or conceptions of a particular entity in nature (molecular biology also investigates cells; physical chemistry also investigates ecosystems). As such, no rigid ordering of sciences follows from the ordering of natural entities, though local reconstructions of what scientific disciplines are involved in the investigation of what are parts of a particular phenomenon are possible.

5.4.1 Global Scope and Contextualized Character

The scope of the integrative account, at least initially, appears to be unabashedly global, i.e. it expresses levels of organization as extending through the entirety of the natural world, and all of the entities within it (Needham 1937[1943], 233; Novikoff 1945, 209). In application, however, levels of organization in the integrative account are characterized in a contextualized fashion. That is, levels are used for specific systems studied by scientists interested in explaining a particular phenomenon. The reason for this is that uncovering the specific details of the part-whole relations that compose a *particular* phenomenon is one of the major tasks that scientists face in their construction of explanations (see also the comments on "context sensitivity" in Section 5.3). Making claims about the entirety of the world does not fall under pressing issues engaged in the explanatory work of typical scientists.

This dual interpretation of levels (global yet contextualized) in the integrative account as global in scope but contextual in application results in a quandary regarding how many levels of organization are postulated to exist. The proponents of the integrative account indeed offer simultaneous but distinct answers to this question. Whenever 'global' levels are the topic of discussion, only an exceedingly small number of 'levels' are enumerated, which are extremely coarse grained concerning their particular membership (i.e. what *particular* entities belong to them) yet designative of vastly different categories of entity-types. More specifically, 'levels of organization' in this sense include the *physical*, *chemical*, *biological*, *psychological* or *mental*, and *sociological* levels (Novikoff 1945, 209, Rowe 1961, 421; see also Needham 1937[1943], 233-235).[146] At the same time, advocates of the integrative account also consciously point out that a more relevant series of levels are what exhibit relevance to biological research. Novikoff, for instance, clearly states that the foregoing coarse-grained 'super-levels' do not exhaust the descriptive layout of biology, saying that "[w]ithin the biological level, there are a series of other integrative levels[:] In multicellular organisms[147] there is a hierarchy of levels – cells, tissues, organs, organ-systems and organism" (Novikoff 1945, 210). James K. Feibleman (1954) echoes these comments, admitting that:

"We have been talking about the integrative levels of the scientific fields as if only five

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[146] Sometimes even the *cosmological* level is also mentioned in the interest of completeness (see Needham (ibid. 234) and Novikoff (ibid.).

[147] This use of the term "organism" refers to the standard biological entity, rather than the specialized organicist term that interested Woodger and Needham.

> [i.e. the 'super-levels' given above] were involved. This was necessary in order to see clearly some of the relations [between different levels and scientific disciplines]. But the situation is more complex than that. For each [super-]level is the name for a considerable group of sub-levels. As our investigations continue, the complexity of the levels is increasingly revealed. The picture will therefore have to undergo continual improvement (Feibleman 1954, 64-65).

Rowe (1961) goes even further, pointing out the inherent difficulty in giving an exhaustive, or even precise, list of levels of organization. “That there are differences in opinion”, Rowe writes, “as to how different levels of organization are constituted, and inconsistencies in within many of the proposed hierarchies of levels, is apparent from [surveying different authors' attempts to construct different lists]” (Rowe 1961, 421). Rowe goes on to cite several authors' lists of levels (including Novikoff's, (ibid.)), and eventually proposes “population”, “community”, and “ecosystem” as relatively stable levels whose exact status and qualities also deserve attention.[148]

One motivation for the distinct interpretations of levels given by the proponents of the integrative account is that they expected the account to offer solutions to distinct theoretical questions in biology. The global scope in which the integrative account is initially advertised is meant to reiterate support for the thesis that the different main branches of science (physics, chemistry, biology, etc.) designate distinct natural sciences that do not reduce to one another. Support for this interpretation is found in various references to the organicists' earlier contributions to the mechanist-vitalist dispute, and specifically the organicist tenet that biology is an autonomous science. Novikoff cites the organicists’ efforts in this regard when contrasting the levels concept in biology and in physics:

> “[L]iving cells present problems not to be encountered in the test tube or the flask...It has been a great contribution of the 'organicists' that they have demonstrated the error of

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[148] Notably, combining Novikoff's and Rowe's respective level layouts results in the list of organizational levels (molecular, cellular, tissue, organ, organ-system, organism, population, community, ecosystem) that are now ubiquitously seen in biological texts (Section 1.4). These 'super levels' are closer to what the British emergentists of the 1920's postulated with their notion of 'levels of being'-

> the mechanistic reduction of the biological organism to the physico-chemical...No matter how complete our knowledge of living systems becomes in the future, living substance must still be recognized as matter on a higher level, with new, unique properties which have emerged on [sic] combination of the lower-level units" (Novikoff 1945a, 210; similar comments can also be found in Feibleman 1954, 64 and Rowe 1961, 421, 426).

Correspondingly, the localized interpretation of levels sees the layout given by global 'super-levels' is not adequate for scientists' investigations of biological phenomena. This agrees with the organicists' earlier development of the levels concept in their own usage, and can also be seen in the advocates of the integrative account. For instance, Novikoff again presents another major motivation for the levels concept, which strongly resembles earlier advocates of 'levels of organization' like Needham et al:

> "A full understanding of the organism is [e.g.] not possible without complete knowledge of the activities of its cells. But knowledge of 'the individual cells' does not exhaust the problems of organism physiology; the activity of the individual cell is greatly influenced by the products of activity of other cells in tissue, organ, organ-system and organism...Just as cells do not exist in isolation in the organism, neither do organs or organ-systems" (Novikoff 1945a, 210-211).

So, the dual interpretation of levels of organization given by the integrative account is consciously postulated by its advocates as a means of serving distinct theoretical purposes, both of which were imported from the organicists' development of the levels concept, and the original debates for which the concept was developed. The global interpretation is a broad thesis concerning the nature of the world, which serves as a means of understanding the autonomy of biology as a natural science. The local interpretation is a thesis concerning the how biological phenomena are best treated with the levels concept.

5.4.2 Incomplete Epistemic Continuity in Levels of Organization

Following its global scope, the integrative account postulates a *compositional continuity* extending through the natural phenomena of the world. The way in which this continuity is understood differs starkly from that of the layer-cake account. For one thing, the integrative account offers no general answer to how this continuity is structured; i.e., the account does not offer an analysis of inter-level relations or a precise articulation of the criterion by which levels are identified or differentiated. In other words, here there is no stepwise condition. Instead, the integrative account describes this continuity in a neutral fashion, and posits simply "part-whole relations" as the relation connecting different levels. The precise nature of these relations are treated on a case-by-case basis by different authors, who describe the way that different levels become related to each other by referring to specific experimental results done on different level-bound structures.

Looking at the passages where particular, case-based relations between distinct levels are discussed, proponents of the integrative account move between criteria of scale and composition to clarify what is meant by "part whole relations" in the case being discussed. Needham, for instance, introduces the basic idea of levels of organization as "successive forms of order *in a scale of complexity and organization*" (1937[1943], 234, emphasis added), but then quickly shifts to a compositional criterion of differentiating levels when applying the levels concept to particular cases, saying: "A *sharp change* in organisational level *often* means that *what were wholes* on the lower level *become parts* on the new, e.g. protein crystals in cells, cells in metazoan organisms, and metazoan organisms in social units" (ibid. emphasis added; see also Feibleman 1954, 59-63;). The highlighted terms in this statement emphasize an openness to how levels of organization are related, one which falls drastically short of prescribing a universal or comprehensive characterization of the material continuity of the world.

Like the dual interpretations of the account's scope, the open manner in which levels are distinguished by the integrative account is a resulting consequence of the account serving as an answer to a still open discussion in biology occurring at that time. In this case, the discussion concerns the organicist thesis that phenomena in biology, in general, exhibit properties that are distinct not only from those in the physical sciences, but also those in other biological disciplines. This distinctiveness is a result of the role that complexity and organization play in determining how the behaviors of biological entities manifest as phenomena to explain (see above Section 5.3 “Holism and Organization”). However, recall also that establishing this thesis was an issue of considerable debate during the time of the Cambridge organicists. In the context of their articulation of this tenet to their program, the “qualitative distinctiveness” of biological phenomena was a buzzword largely because of the efforts of the vitalists (and other, more obscurantist organicists). The familiarity of the scientific and philosophical community with this idea at that time was largely the result of the rejection of the pseudoscientific efforts of, e.g., the vitalists in elucidating what exactly this distinctiveness could entail. Since the manner in which biological phenomena are characterized by levels is bound to the explanatory problems that are posed, and investigated, by scientists, the specific way in which levels are related to one another in a given case will also be bound to what is deemed effective for constructing an explanation.

This understanding of the material continuity of levels in the world results in three consequences of note concerning how levels are conceptualized by the integrative account. Firstly, it preserves the spirit of the organicists' original understanding of levels, which emphasized that the organizing relations in biological phenomena (something designative of them as scientific objects of study, see Section 5.3) are not given *a priori* (Novikoff 1945, 209). Rather these relations themselves must be discovered and characterized by scientists on a case-to-case basis in the explanations of particular phenomena. Novikoff explains:

> “By stressing the material interrelationships of parts and whole and the qualitative uniqueness of each level of integration, the [levels] concept is of genuine help to biologists. Its dialectical approach avoids 'organicism,' 'fatalism' [i.e. vitalism] and mechanical 'atomism,' and helps attain a fuller understanding of such problems as the interrelations of cellular structures and metabolism [etc.]...By avoiding teleology, the

concept aids the search for causes of biological phenomena" (Novikoff 1945, 215).[149]

This directly reflects the insight Needham attempted to infuse into the levels concept's role in dealing with organizing relations as "the central problem of biology" (see Section 5.3 "Context Sensitivity"; and Section 5.4). Hence, though the integrative account takes upon itself the commitment to a material continuity extending through the entirety of nature, the precise character of this continuity is highly *incomplete*, and designates a feature of levels as things waiting to be discovered.

Secondly, the "stepwise" fashion in which the layer-cake account structures compositional continuity is lacking in the integrative account. Instead, the things located at a given level can be related to one *or more* levels below or above them (see especially Feibleman 1954, 59; Novikoff 1945, 214-215 and Rowe 1961, 422, 423-424 make similar points). This, again, makes sense in light of the context-sensitive way in which biological phenomena are treated by the integrative account. To wit: The levels of organization that are considered relevant for best investigating or explaining a given phenomenon is often decided with a pragmatic element to it, because the (contextually-chosen) criteria by which levels are understood, and what stands in need of explanation will be selected on the basis of how the phenomenon itself is characterized. Rowe (1961), for instance, observes that the objects that are included in a layout of levels connected to a given phenomenon are actually dependent on what objects are "perceived" to be of use to studying that phenomenon, and that these "perceptions" (see Section 5.4.3) may quickly change. He says that "[e]ach successive level is not formed by aggregation *of only one kind of lower level organization*; the relation between successive levels is not symmetrical. The object [of study] at each level is *heterogeneous*; it organizes *a variety* of spatially located systems" (Rowe 1961, 421, emphasis added).

In other words, adjacently located levels (higher *or* lower) do not carry any inherent primacy in describing hierarchical layouts for biological phenomena. This, Rowe continues, is

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[149] Novikoff's dismissal of "organicism" here is not directed at *Cambridge* organicism, rather at the obscurantist variants of organicism mentioned above. It is also conceivable that Novikoff mentioned "organicism" here as an observation of the differences between his and Needham's (1937[1943]) and Redfield's (1942) original biologistic presentation of the integrative account.

especially the case with the study of ecosystems, saying:

> “Recognition of the pragmatic element in the definition of ecosystems is a healthy reminder that there may be merit in various approaches to their selection [as objects of study]...The terrestrial ecosystem is not always presented in so neat a package; usually it must be *carved out of the living landscape by use of the appropriate criteria*. To some people this subjectivity of boundary delineation is a stumbling block to acceptance of the ecosystem as an object of study, yet it need not be...The criteria by means of which ecosystems can be defined and bounded are many...[I]n the context of an hierarchy of organizations, ecology becomes [the] study of the *contingencies of objects at any level* on the more inclusive [i.e. lower] levels of organization” (ibid. 423) (Rowe 1961, 422-3, emphasis added).

Finally, a third consequence of the incomplete material continuity postulated by the integrative account is that levels are not necessarily clearly demarcated from one another. Though the identity of some general, relatively stable levels of organization may be agreed upon among scientists (such as molecule-cell-tissue-organ-organism-population-community-ecosystem series), the integrative account explicitly acknowledges that boundaries between even the most widely accepted levels can be vague. Needham (1937[1943], 255) was the first to make this observation, citing the existence of “mesoforms” that do not clearly belong at any one particular level. Novikoff imports this observation into the integrative account of levels, saying: “The different levels of matter, while distinct, are not completely delimited from each other. *No boundary in nature is fixed and no category air-tight*. 'Mesoforms' are found at the transition point of one level of organization to the next.” (Novikoff 1945, 209). Significant examples of mesoforms include things such as viruses, which possess properties of both living and non-living matter (Needham, ibid. Novikoff, ibid.), and even the different notions of biological 'organisms', which may appear in single-cell, colonial, and multicellular varieties (Novikoff, ibid.). “Yet”, Novikoff continues, “the absence of rigid demarcation between [different levels] does not make the difference between them any less clear or fundamental. Mesoforms, 'the more clearly we understand them, will all the more clearly serve to bring out the essentially new elements of (the) higher order'” (Novikoff, ibid.).

5.4.3 Weak Association Between Science and Nature

The integrative account also postulates that *some* connection exists between different levels of organization and the scientific disciplines that investigate the entities populating those levels. In stark contrast to the correspondence thesis of the layer-cake account (see Section 2.2.4), however, the integrative account postulates only a *weak association* between science and nature. Using the distinction established in Section 5.4.1, understanding this weak association is best understood in terms of the shift between global and local scopes with which the account conceptualizes levels.

Rowe (1961) envisioned the typical, global levels of organization (molecule-cell-...-ecosystem)[150] as increasingly inclusive sets of “objects of study” composed of the entities that typify each respective level (see also Feibleman 1954, 62). The designation of these “objects of study”, however, does not belong to some static “universe of discourse”, but rather are constructed from discipline-bound “points of view” (Rowe 1961, 423). This is illustrated in Figure 5.1.

Here nature and science already become decoupled from any strict correspondence in the integrative account. The reason for this is that scientific “objects of study” (ibid. 421) located at different levels are only identified as such in terms of the manner in which they are “perceived” (ibid.) by scientists. In other words, scientific characterizations of its explanatory phenomena are in fact a consequence of the disciplinary training that one receives in becoming a scientist. In his words: “Perception is not simply a registry by a receptive mind of

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[150] Here the reader will notice a switch in what is considered “global” levels given by the integrative level (above, the five “super-levels” were given as the stand-in series for 'global levels'). The difference is merely expository, for, as was seen in the discussions of locality in Section 2.3 and Section 4.2, the local character of levels in actual scientific application are contrasted with both of the foregoing candidates for understanding levels as global in scope.

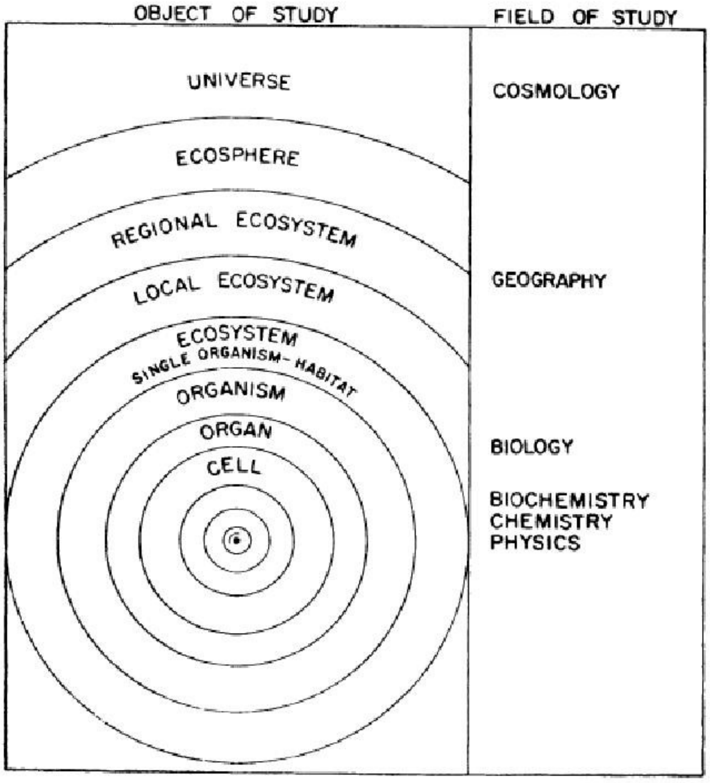

FIG. 1. Diagrammatic representation of objects of study at increasingly inclusive levels of organization; some corresponding fields of study are also shown.

Figure 5.1 Rowe's depiction of the association between science and nature, according to the integrative account. Rowe envisioned the general relation between science and nature as one that could only be vaguely captured, as this image makes clear (Rowe's expression of "corresponding" here notwithstanding). The column "objects of study" represents the entities of the world, ordered into levels of organization depicted as increasingly inclusive sets. The size of these sets, however, are meant to depict the relative number of different perspectives that can be constructed regarding the phenomena that are perched at a given level, which may include reference to any number of other entities perched at the same or different levels. The column "fields of study" are strategically placed to *not* correspond directly to any *one* level, but rather to show association with what kinds of entities certain branches of science *typically* investigate. Image taken from Rowe 1961, 422).

what lies 'out there'; rather it is an active intellectual process which provides consciousness with 'objects' as vehicles of meaning for the world as sensed"[151] (ibid.; cf. Section 5.4.1). The context of perceiving scientific objects of study in this way constitutes a disciplinary-bound

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[151] One interesting topic for further analysis here is whether the 'levels of organization' concept expresses purely abstract, rational things or objective, real structure of reality. Here is not the place for such an analysis. For now, though, it is important to note that Rowe's position on this question is a deeply dialectical one that postulates levels of organization as both an ontological reality (albeit hidden from direct, simple observation) of which the human intellect actively works to interpret and refine its understanding.

perspective that informs a particular scientist on how to differentiate a particular phenomenon from nature. These perspectives, furthermore, attain a downward- or upward-looking orientation in the context of explaining a particular phenomenon, depending on what level is being investigated, and whether other disciplinary perspectives are involved in constructing that explanation (see especially Figure 5.2 below). This in itself is yet another surprising feature of the integrative account levels, as it specifically allows multiple disciplines to be brought to bear on a particular phenomenon.[152]

At the same time, Rowe argues that it is a grievous error to conflate a scientific discipline ("field of study") with a particular perspective ("point of view") (ibid. 424). Though the perspective from which one will approach the study of a particular phenomenon will be grounded from the particular disciplinary embedding in which one works, this in itself is not sufficient for knowing (i) what criteria this perspective utilizes to identify the phenomenon in question and characterize the task of explaining it, and (ii) how this perspective relates to other perspectives (both within and between disciplines) that investigate the same phenomenon. Both of these aspects of a given perspective will be specified locally for the case at hand. Consequently, "[a]s points of view that can be focussed on various objects or levels of organization, neither [e.g.] physiology nor ecology need imply a field of study" (ibid. 423). This extended layout of the association between science and nature is illustrated in Figure 5.2.

Importantly, the integrative account regarded such opportunities for multi-disciplinary investigations as an important condition for constructing adequate explanations for biological phenomena. The interspersal of different disciplinary perspectives that can be brought to bear on a particular explanatory endeavor for this reason exploits the weak association between levels of organization and scientific disciplines to create a better means of grasping the phenomenon for which an explanation is sought, or, as Rowe calls it, "catching the rabbit" (Rowe 1961, 425). Moreover, this occurs not only because there are *more* perspectives (both

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[152] Rowe explicitly endorses this as a valuable feature of the integrative account of levels, which is implied in the following quote: "If the two modes of comprehension – the inward [i.e. downward-]looking and the outward [upward-]looking – are applied to the objects in an hierarchy of integrative levels, an overlapping of viewpoints must result" (ibid. 423).

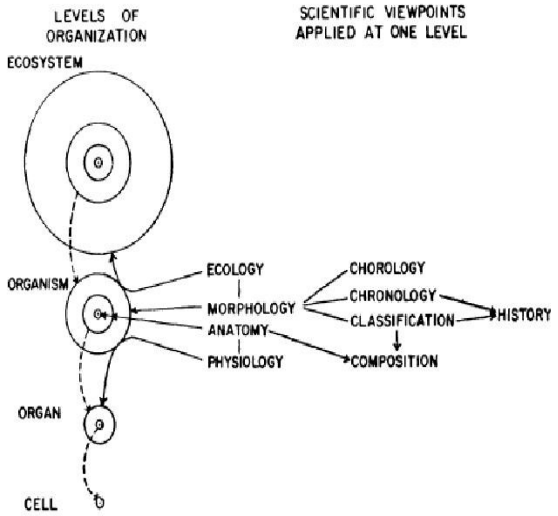

FIG. 3. Related objects (levels of organization), and scientific viewpoints as applied at one level. Note that the viewpoints, anatomy, composition and physiology are applied in descending the levels while morphology and ecology are applied in ascending.

Figure 5.2 Rowe's pluralistic conception of disciplinary-bound perspectives and levels of organization. This image clearly exhibits the *weak* association between scientific disciplines and the entities of nature ordered by the levels concept under the integrative account. In particular, any ordering of scientific disciplines is mediated through a particular perspective from within that discipline, which is in turn contextualized in terms of the explanatory interests of that perspective and the criteria with which the object of study in question is investigated. Rowe summarizes this thusly: “All the viewpoints are inter-related through the objects on which they are focussed; they bring mutual support to scientific studies, particularly within a level-of-organization scheme” (ibid. 424). Figure taken from Rowe (1961, 425).

within and between disciplines) that could be brought to bear on a particular phenomenon. Rather, the more different kinds of discipline-bound perspectives are able to investigate a single level of organization, the more likely it is that the resulting scientific work produced in that constellation will be able to provide knowledge about other level-bound parts of that system (see Figure 5.2).

One of the main stumbling blocks of the layer-cake account of levels was the rigid correspondence it postulated between scientific disciplines and levels of organization. Recall from Chapter 2 that Oppenheim and Putnam (1958) postulated that a *branch* of science “*essentially corresponds*” to a *universe of discourse* representing the total set of entities investigated by that science (Oppenheim and Putnam 1958, 6; see Section 2.2.4). This levels-mediated understanding of the relation between nature and science served their reductionist vision of the Unity of Science. This, as seen in Chapter 3, is extremely problematic. In fact, the proponents of the integrative account condemn just such simplistic characterizations of the relation between science and nature. Rowe (1961) warns against just such strong correspondence when he says: “However, there has been a tendency for physiologists to *arrogate the individual organism as their own field*, calling...their study 'environmental physiology'” (Rowe 1961, 423). The approach of the integrative account, hence, effectively avoids the stultifying layer-cake understanding of the relation between science and nature.

5.5 Integrative Levels & Layer-cake Levels

The integrative account represents a prescient conception of levels of organization that has received little to no attention in contemporary philosophy of science. The reasons for this lack of attention can at this time only be speculated, but two plausible initial explanations offer themselves. Firstly, it is conceivable that the integrative account failed to achieve notoriety because of its affinity with organicism. Beyond the efforts of the Cambridge organicists, the organicist movement at large was largely met with skepticism that often comprised flat dismissal of its program (Beckner 1969b; Hein 1967; 1969; Hull 1974, Ch. 5; Roll-Hansen 1984). Consequently, any grievances that were brought against organicism would hold, *mutatis mutandis*, for the integrative account. Secondly, it is also possible that the general skepticism surrounding the levels concept (Ch. 3) insulates the integrative account from attracting philosophical interest. More particularly, the status of the layer-cake account of levels as *the* default conception of levels of organization in philosophy, which is the root cause of this levels skepticism, may have simply grabbed the spotlight and never let go.

As the analysis in Chapter 3 showed, the status of the layer-cake is highly questionable, if only because it imposes a highly problematic conception of levels onto philosophical discussion that critically misses the fragmentary character of the levels concept in scientific usage. The rest of this section will contrast the integrative account with the layer-cake account. As will be seen, the former account avoids almost all of the pitfalls for which the latter has now become notorious.

One principle difference between the integrative and the layer-cake accounts is the philosophical discussions in which they were embedded. The layer-cake account, to recall, was originally conceived as part of Oppenheim and Putnam's overall Unity of Science project. This project was reductionist in character, and aimed to reduce the sciences down to one fundamental branch, namely physics. Later, the account acquired an association with the debate surrounding theoretical reductionism and anti-reductionism during the latter half of the twentieth century, which, at least in the case of philosophy of biology, has largely run its course (Brigandt and Love 2010; Waters 2010; see also Chapter 3).

The integrative account, on the other hand, was conceived and developed in the context of organicist biology of the 1920's-1940's, and remains a largely underappreciated, yet relevant area of study for contemporary philosophy of biology. In particular, as the discussion in this chapter has broached, the organicist program exhibits a strong affinity to pluralistic approaches to understanding scientific explanation and the entities of nature[153]. This agrees with Abir-Am's characterization of the Cambridge organicists, who had the following to say about their program:

> “The Biotheoretical Gathering...became a vehicle for transforming personal alienation from both the social and scientific orders into a springboard for collective creativity...They viewed isomorphism between organized entities in all disciplines, pluralistic lawfulness and epistemological parity as the new themes of scientific unity, to supplant the classical, atomistic and reductionistic view which had been discredited at that time by the combined impact of the relativity and quantum theories [of theoretical physics]” (Abir-Am 1987, 10).

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[153] If the integrative account is associated with a contemporary philosophical account of explanation, it is with the “New Mechanism” account. However, it was already seen that the (New) mechanists actively defend a different conception of levels, which was discussed in Chapter 2.

One consequence of this affinity is that the organicists' conception of levels of organization was unabashedly applied to both the disciplinary structure of science, especially biology, as well as the hierarchical layout of biological phenomena. Unlike the layer-cake model, however, the association between the ontological objects of biological study and the disciplines that constitute biology were not related by anything like the strict correspondence that Oppenheim and Putnam's account envisaged. One of the reasons for this was that levels, to the organicist, were not conceptualized as a monolithic scaffolding with which to blueprint the ultimate unification of science and nature, respectively, but rather a theoretical device that expressed the complexity of a world in which such a grand unified, and reductionist, image of the world was impossible. Instead, the organicists' view of levels supports a fractured view of biology wherein its constituent disciplines could orient themselves toward each other while preserving their individual disciplinary identity.

Interestingly, this also resulted in a conception of levels that had both global *and* local applications (see Section 5.4.1). On the one hand, the organicists needed the levels concept to express a global image of the world in which the biological sciences, i.e. the disciplines constituting biology, could be represented as independent disciplines, non-reducible to one another, and engaged in perfectly legitimate, and parallel, scientific pursuits. On the other hand, the levels concept was only empirically useful if it was capable of supplying specific contributions to particular explanatory problems, which are identified, investigated, and solved in a local manner.

Finally, the organicist conception of levels imported into the integrative account also preserved the epistemic goal of the levels concept (see Chapter 4). This is not surprising, as the organicists appear to be the ones who are responsible for constructing this epistemic goal during their original development of the levels concept. Later proponents of the integrative account appreciated both the usefulness of the epistemic goal of levels, and the fragmentary character that it carries with it. Indeed, this was ultimately one of the most attractive features of the organicist levels concept, as Novikoff makes clear:

> “The concept of integrative levels *indicates to research biologists the crucial aspects of*

> *their problems*, the solution of which puts the known facts into perspective by revealing the decisive element, the element imparting the uniqueness to the phenomena under study...As biologists become more familiar with the concept, a greater number will recognize *its value both as an aid in the understanding of biological data already accumulated and as a reliable guide for research*" (Novikoff 1945a, 215, emphasis added).

The existence of the integrative account of levels now puts the entrenched status of the layer-cake account as the default conception of levels directly into question. The efforts of the organicists in developing the concept of levels of organization introduces wholly new dimensions to the philosophical understanding of the concept that promises to be fertile material for a discussion that, until now, has not yet occurred.

5.6 Organicist Influence on Mitchell's Chemiosmotic Hypothesis

One final thought will serve to better connect the fragmentary account of levels developed in the last chapter with the historical analysis given in this chapter. Though the organicists' development on the levels concept, and the subsequent (integrative) account that was constructed out of the organicists' work, have largely escaped explicit attention in philosophy, it has continued to influence biological research even to today. One important bridge between the historical context of the development of the levels concept in the organicist movement and in the biological textbooks of today (see again Section 1.4, Section 4.4-5) can be seen by looking again at the construction of the explanation of ox-phos. This point was quickly touched upon in Section 4.5.2, in the analysis of Mitchell's exemplification of the levels concept, and in particular its epistemic goal, in his construction of the chemiosmotic hypothesis.

Recall that Mitchell privately developed his own philosophical notions with which to conceptualize problems in biology (Section 4.5.2). These notions, i.e. fluctoids, statids, and fluctids, represent qualitatively different types of things that can be manifested by different phenomena. Of particular interest is Mitchell's notion of a "fluctoid", which, as was seen above, constituted a stand-in term for a kind of *organized whole* whose workings could not be explained solely with reference to the processes (fluctids) or objects (statids) of which it is composed. A "fluctoid", in other words, bears resemblance to a phenomenon that manifests holistic features of the kind discussed in Section 5.3.1. As it turns out, this aspect Mitchell's private philosophy was directly influenced by the Cambridge organicists and their levels-inspired program. Prebble (2001) makes this connection explicit, saying that: "With the intention of defining and developing his philosophy, Mitchell identified the fluctoid idea in the writing of such early twentieth century biological thinkers as D'Arcy Thompson, Rudolph Höber, *Joseph Needham* and particularly *Joseph Woodger*. A number of the characteristics of the fluctoid were illustrated in this way" (2001, 444, emphasis added).

Though the manner, and precise depth, in which Mitchell became influenced by the organicists is, for now, an open question,[154] *that* Mitchell was influenced by their program is at least arguable, even if not yet compelling. Isolating the *precise* influence on Mitchell of the organicists' advocacy of the *levels concept* is also tentative, but it appears at least initially plausible that his levels-mediated treatment of the problem of ox-phos was at least *indirectly* inspired by the organicists' ideas involving levels. Prebble (2001) again provides a bit of substantiation for this point when he writes that:

> "A further characteristic of [Mitchell's] fluctoid philosophy is its dynamic aspect and its reference to physical forces. Mitchell found various comments on the nature of life which he enlisted to elaborate the fluctoid concept. The structural and flowing elements are combined in a single entity. In Joseph Needham's work he found a quotation from Woodger. "It is to be noted that a molecule, an atom, or an electron, *if it belongs to the spatial hierarchy of a living organism, will be just as much 'alive' as a cell*, and one which does not belong to such a spatial hierarchy will be 'dead'… The

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[154] One initial, but for now speculative, hypothesis that could substantiate this influence is the fact that Mitchell pursued his PhD studies at Cambridge University, which coincided with the final years of Needham's tenure at Cambridge before moving to China. If Mitchell did not have direct contact with Needham himself, the geographical and disciplinary proximity of the two surely warrants closer analysis. This question presents itself as an excellent issue for further research, but for now is far beyond the scope of the present analysis.

> ideas discussed here give a view of Mitchell's approach to cell structure in the late 1940s and give some meaning to the concept of the fluctoid." (ibid. 444-446, emphasis added).

The quote from Woodger that Prebble here cites as an impetus for his fluctoid philosophy is actually embedded in Needham's (1936) book, where Needham presented his ideas of the "hierarchical continuity of biological order". As seen above in Section 5.3, Needham's *Order and Life* represented one of the most mature expressions by Needham's work on the levels concept (particularly via the epistemic goal that he developed into the concept) and its usefulness for treating explanatory problems in biological research. Further allusion to the influence of the organicists' work on levels on Mitchell can be seen in a passage that Needham provides, which strongly recalls the two ways that Mitchell's chemiosmotic hypothesis was said to implement the levels concept into the explanation of ox-phos:

> "The ordinary division of a living organism into parts of cells, cells themselves, and atoms, has been brought by Woodger under the notion of 'hierarchical order.' From the present point of view we are mainly interested in 'spatial hierarchy.' The higher or coarser levels correspond of course to the domain of morphology and anatomy as ordinarily understood, the intermediate levels to histology and cytology, the lower levels to biochemistry. *On this view, structure, even, if you like, morphology, should be found fully within the sphere of biochemistry,* and that this is so, the whole realm of permutations and combinations of the carbon atom illustrates…*The contribution of biochemistry to biology is too often thought of as it were primarily concerned with the reactions of simple substances in homogeneous media, and the complexity of chemical structure is forgotten*. Unfortunately, not only do we have to deal with them in extremely complicated molecules, *we also have to deal with them in extremely complicated situations, that is to say, in the colloidal milieu of the living cell.*" (Needham 1936, 110)

The three highlighted parts of this passage line up remarkably to the contributions of Mitchell's level-mediated contributions to the explanation of ox-phos in Section 4.5. The first highlighted part concerning morphology being “within the sphere of biochemistry” resembles the conviction described in Section 4.5.2 concerning the shift of ox-phos from a chemical to a biological problem. This resemblance finds justification in the rest of the passage, where something like the attitude observed in the biochemistry community’s expectation the phlogistonal ‘chemical intermediate’ is criticized. It was, to recall, exactly Mitchell’s proof that ox-phos does *not* occur in a “homogeneous” medium (i.e. in the mitochondrial matrix). Rather, the “milieu of the living cell”, i.e. the role of the mitochondrial matrix and ATP synthase (both higher-level, ‘living’ features of the cell) were central to uncovering the explanation for ox-phos. If, as Prebble (2001) claims, Mitchell was directly influenced by the organicist program (and particularly Needham and Woodger), *and* one locus of this influence was Needham’s (1936) book[155], the idea that Mitchell’s work on chemiosmosis can serve as a bridge between the historical and contemporary uses of the levels concept in biological research has earned the status of *working hypothesis*.

All the same, these allusions must remain tentative for now, but this hypothesized connection between history and contemporary usage of levels centering on the work of Mitchell’s research shows there is still much work to be done on the impact of organicism, and especially its development of the levels concept, on contemporary biology.

5.7 Conclusion

The centrality of the levels concept to the organicist program was a byproduct of compromise between the members of the BTC. The group's members came from highly diverse backgrounds, and this diversity was exhibited in the particular interests pursued within the group. Though the “integrative” account of levels would receive its namesake late in the organicist movement,[156] the enduring ideas it would come to represent were developed much

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[155] Especially, in particular, the foregoing passages above, which just happen to be one of the main sources of the organicists’ development of the levels concept)

[156] By 1943 the organicist movement, at least in its Cambridge form, had largely dissipated. The Theoretical Biology Club that constituted Cambridge organicism had by that time disbanded and its members had gone their own ways after their application for funding was rejected by the Rockefeller Foundation (Senechal

earlier in the late 1920's and early 1930's. Though not then known under the moniker "integrative levels", the initial work on "levels of organization" by Needham and Woodger would be the most substantial contributions of the Cambridge organicists of the TBC to the account, before bequeathing the account to later thinkers and scientists upon the dissolution of the organicist movement.

Almost a century later, the task of elucidating the levels concept remains unfinished in both philosophy and science, particularly as the term "levels of organization" appears to be an unavoidably fragmentary scientific concept (see Chapter 4). It has already been seen that the fragmentary character of the levels concept in biology does not detract from the term's usefulness or validity, and rather weakly unites a plurality of possible meanings the term can have in a particular instance of usage.

The roots of this usefulness are present in the organicists' integrative account. The "integrative" account of levels developed out of the Cambridge organicist work on the levels concept is, arguably, the direct historical predecessor of the concept of levels of organization as it is used in biology today. This is particularly visible in the 'package deal' of modes in which the levels concept was applied by the organicists themselves (cf. Section 4.2.1), which imported many of the insights of organicist thought into a single framework. This simultaneously led to the creation of the epistemic goal of the levels concept discussed in Chapter 4, which guides how scientists view, investigate, and explain biological phenomena. For this reason, the integrative account of levels exhibited a strongly *programmatic* character.

The programmatic character of the levels concept, as it was developed by the Cambridge organicists, is still visible in contemporary biology. Firstly, the organicist account of integrative levels strongly resembles the view of levels depicted in contemporary textbooks in biology. This resemblance is much more than passing: the account of integrative levels arguably *is* the levels concept used in contemporary biological sciences. Supplementary literature in biology on the levels concept often cite directly some of the key organicist and post-organicist texts in which the main ideas expressed by the integrative levels account were

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2013, 131-2).

originally articulated (see, e.g., Lobo 2008). Secondly, the allusions in Section 5.6 to the work of Peter Mitchell as (possibly) being able to serve as a bridge between the historical usage of the levels concept by the organicists and the use of the levels concept in contemporary biology also serves as a significant hypothesis, and deserves more attention in future research.

The concept of levels of organization is nowadays so embedded in the biological sciences, its significance is largely presumed in virtue of the legitimacy of the myriad ideas it is expected to depict. This significance, until now purchased on intuitive appeal, now has a solid basis in contemporary *and* historical biological research.

General Conclusion

This dissertation has provided an analysis of the *character* and *significance* of the concept of 'levels of organization' in biological research. It was found that despite the fact that 'levels' possesses a fragmentary character, i.e. that there many distinct possible yet legitimate meanings for the concept, the concept is nonetheless minimally unified due a general significance attributed to the concept across its instances of usage. This significance was substantiated by the presence of a remarkably conserved epistemic goal that motivates the usage of the levels concept. Furthermore, this analysis traced the historical development of the levels concept back to the work of the organicist movement, under the auspices of the Theoretical Biological Club who worked together at Cambridge during the 1930's. The organicist development of the levels concept still strongly resembles the way that the concept is used today in contemporary biology.

This analysis began in the first chapter with an elucidation of the ubiquity of the levels concept in biological science. For this, a survey of how the concept is depicted in well-known textbooks in biology was provided. This survey revealed that 'levels of organization' is presented in an exceedingly *open* fashion in biology, with many different possible meanings, and facets of importance, possible to attribute to the concept. Additionally, it was noted that although all conceptions of 'levels of organization' probably share a basic hierarchical structure, the formal notion of a 'hierarchy' was not sufficient to exhaustively account for these different elements comprising the usage of levels in biological science. The analysis of 'levels' continued in the second chapter with an exegetical analysis of the two most prominent accounts of levels in philosophy, namely the layer-cake account and the mechanistic account. The first of these, the layer-cake account, designates the default conception of levels in philosophy, and was first constructed by Oppenheim and Putnam in 1958 as part of a larger project arguing for a reductionistic unity of science. As such, many of the features of the account were seen to be tailored to expressing a number of components to their overall argument for this project, in particular the microreduction relations they took to hold between different branches of science. Moreover, this association of ‘levels’ with theoretical reductionism and anti-reductionism was seen to persist even after interest in the ‘unity of science’ declined in philosophy. The second philosophical account of levels, the mechanistic account, is a recent attempt to explicate the meaning of ‘levels’. The features of this account of levels, it was seen, were largely postulated as an antipodal reaction to the layer-cake account. Moreover, the mechanistic conception of levels is deeply embedded in the project of elucidating what a ‘mechanism’ is, as well as what a ‘mechanistic explanation’ is, and eschewed any generalizations regarding the levels concept from particular instances of the concept’s usage. For these reasons, the mechanistic account was found lacking as a viable approach to analyzing the character and significance of levels.

Next, the analysis of this dissertation turned in the third chapter to the recent development of a ‘levels skepticism’, which has argued for the elimination, or at least minimization, of usage of the levels concept. The reasoning for this was that the levels concept apparently is only capable of producing false or misleading statements about nature and science. Moreover, it was also argued by levels skeptics that the levels concept is in fact irrelevant to biological research, owing to its exaggerated importance attributed to it by philosophers. This skepticism was found to be guilty of attacking a straw man, as the conception of levels against which their skeptical arguments were applied is actually one or another variant of the layer-cake conception of levels. This was substantiated with an analysis of the influence of the layer-cake account’s status as the default conception of levels in philosophy, which has unjustifiably associated the levels concept with a number of questionable and unpopular ideas.

In the fourth chapter, a pluralistic account of the levels concept was offered. This account argued that the levels concept exhibits a fragmentary character due to the presence of a strong semantic incommensurability between different instances of the concept’s usage. That is, different instances of use of the levels concept manifest different fragments of semantic content, which draw from a plethora of possible particular meanings pertaining to the referents, scope, definitional criteria, and mode of application that comprise any particular use of the levels concept. The account was for this reason pluralistic, because the different possible meanings of different instances, though legitimate in isolation, were irreconcilable with one another. Though the levels account is not unifiable via its semantic content, it was also found that different instances of the levels concept nonetheless instantiate the same epistemic goal, which is to structure explanatory problems in biology. This was substantiated with an elaborate case study focusing on the construction of the explanation for ox-phos by Peter Mitchell's chemiosmotic hypothesis. The chemiosmotic hypothesis instantiated the epistemic goal of levels in both a descriptive way and a hypothetical way, which complemented each other in regards to constructing the final details of the mechanism by which ox-phos is now known to work.

The final, fifth chapter turned to the historical roots of the levels concept, which were found in the organicist movement in biology during the first decades of the 20th century. It was seen that the Cambridge organicists, and particularly Joseph Needham and Joseph Woodger, were responsible for constructing and developing the levels concept as it is seen nowadays in contemporary biology. Needham was especially interested in the concept after encountering it in the work of Woodger, and developed the concept into the form in which it is now recognizable by implementing both an open context-dependent character, and the epistemic goal of structuring explanatory problems, into usage of the concept. Moreover, it was seen that the organicists' efforts were later taken up by a small number of biologists and further developed into a proper account of levels, called the integrative account. Though the integrative account of levels has received little attention in philosophy, its features were largely in agreement with the survey of levels given in the first chapter. The integrative account, represents a direct historical counterpoint to the layer-cake account, and even preceded the latter's existence by almost thirty years.

The purpose of this analysis has been to instigate new interest in the concept of 'levels of organization' in scientific usage by, as it were, presenting a case for a 're-boot' in the way that the concept is seen and treated in philosophy. For too long, the concept of levels has been associated with questionable ideas of theses that have only served to hide its tangible influence in biological research. This influence is only beginning to be appreciated.

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