36th ALTENBERG WORKSHOP IN THEORETICAL BIOLOGY

Hierarchy and Levels of Organization in the Biological Sciences

organized by

Daniel S. Brooks, James DiFrisco, and William C. Wimsatt

March 8–11, 2018

KLI, Klosterneuburg

Austria

Welcome

to the 36th Altenberg Workshop in Theoretical Biology. The Altenberg Workshops are interdisciplinary meetings organized by the KLI in Klosterneuburg, Austria. The workshop themes are selected for their potential impact on the advancement of biological theory. Leading experts in their fields are asked to invite a group of internationally recognized scientists for three days of open discussion in a relaxed atmosphere. By this procedure the KLI intends to generate new conceptual advances and research initiatives in the biosciences. We are delighted that you are able to participate in this workshop, and we wish you a productive and enjoyable stay.

Gerd B. Müller
President

The topic

The concept of levels of organization features prominently in the sciences and philosophy of science, especially in biology and philosophy of biology. The standard, informal version of the concept, which can be found in the introductory pages of most biology textbooks, pictures the biological world as comprising a number of vertically stratified "levels" of entities, such as the molecular, cellular, tissue, organ, organism, population, and ecosystem levels. The contents of one level "make up" the contents of the next higher level, and this hierarchical structure is supposed to capture a variety of methodological, epistemic, and ontological patterns in science and in nature.

Methodologically, levels are sometimes thought to demarcate areas of scientific inquiry and to organize research practices around clusters of structurally similar phenomena. Epistemologically, levels of organization demarcate classificatory domains where different forms of scientific explanation are deployed (e.g., evolutionary versus molecular explanations). Ontologically, locating an entity at a level is sometimes thought to embed it in fundamental relations to other entities at levels, such as causal relations between intralevel entities or non-causal dependence relations between interlevel entities. Unsurprisingly, the different dimensions of significance surrounding this basic idea have attracted diverse usages by scientists and philosophers of science alike.

Levels of organization can be conceptualized in many ways, and can be recruited for many different tasks. Once we begin to carefully examine how to clearly formulate the concept in order to satisfy the tasks for which it is enlisted, the diversity of conceptual possibilities and empirical applications brings a vast combinatorial landscape into relief. It seems likely, then, that the development of determinate concepts of levels must be guided by specific issues as they arise from within the sciences. We propose to take a new look at levels of organization in the biosciences, with a workshop structured around the problems that can be addressed through work on hierarchical levels.

Format

There will be 15 presentations, with 45 minutes allotted for each—roughly 30 minutes for each talk, followed by 15 minutes for Q&A and discussion. On Friday we kick off with a joint introductory statement by the organizers, addressing the aims and framework of the workshop; on Sunday we end with a general discussion, including publication plans.

To support discussion during the sessions, we encourage all participants to send a rough draft of their presentation and/or some materials that are relevant to their topic to the organizers in advance of the workshop, to be circulated among the participants.

Manuscript preparation and publication

The Altenberg Workshops in Theoretical Biology are fully sponsored by the KLI. In turn, the KLI requests that all participants contribute a paper to a volume edited by the organizers. Altenberg Workshop results are usually published in the *Vienna Series in Theoretical Biology* (MIT Press). The contributors are not necessarily limited to the original participants; they may be complemented by additional experts and co-authors invited at the discretion of the participants.

We expect that participants will revise their drafts as a result of our discussions at the workshop and the ensuing review process. We aim for a September 2018 date for receipt of finished manuscripts for publication. The length of the contributions should be in the range of 8,000 – 10,000 words. The use of figures and photographs is encouraged. All contributions will be edited for style and content, and the figures, tables, and the like will be drafted in a common format. The editors will send specific instructions after the workshop.

Daniel S. Brooks, James DiFrisco, and William C. Wimsatt

Participants

JAN BAEDKE Jan.Baedke@ruhr-uni-bochum.de

Ruhr-Universität Bochum
Institut für Philosophie I
Universitätsstrasse 150
D-44801 Bochum
Germany

ROBERT BATTERMAN rbatterm@pitt.edu

University of Pittsburgh
Department of Philosophy
1001 Cathedral of Learning
4200 Fifth Avenue
Pittsburgh, PA 15260
USA

DANIEL S. BROOKS daniel.stephen.brooks@gmail.com

2267 Chesterfield Lane
Batavia, OH 45103
USA

JAMES DIFRISCO james.difrisco@gmail.com

Konrad Lorenz Institute for Evolution and Cognition Research
Martinstraße 12
3400 Klosterneuburg
Austria

MARKUS I. ERONEN markusillka@gmail.com

Department of History and Theory of Psychology
University of Groningen
Grote Kruisstraat 2/1
9712 TS Groningen
The Netherlands

SARAH GREEN sara.green@ind.ku.dk

Department of Science Education
University of Copenhagen
Øster Voldgade 3
1350 Copenhagen
Denmark

CARL GILLETT cgillett@niu.edu

Department of Philosophy
Northern Illinois University
Zulauf Hall 915
DeKalb, IL 60115
USA

JAMES GRIESEMER jrgriesemer@ucdavis.edu

University of California, Davis
One Shields Avenue
Davis, CA 95616
USA

ALAN LOVE aclove@umn.edu

Department of Philosophy and Minnesota Center for Philosophy of Science
University of Minnesota
831 Heller Hall, 271 19th Ave. S
Minneapolis, MN 55455
USA

ANGELA POTOCHNIK potochaa@ucmail.uc.edu

Department of Philosophy
McMicken Hall ML 0374
University of Cincinnati
Cincinnati, OH 45221-037
USA

THOMAS REYDON reydon@ww.uni-hannover.de

Centre for Ethics and Law in the Life Sciences (CELLS)
Leibniz Universität Hannover
Am Klagesmarkt 14-17
30159 Hannover
Germany

ILYA TËMKIN temkini@si.edu

Smithsonian Institution
PO Box 37012, MRC 163
Washington, DC 20013-7012
USA

JON UMEREZ jon.umerez@ehu.es

EHU-UPV
Department of Logic and Philosophy of Science
Tolosa hiribidea 70, E-20018
Donostia – San Sebastián
Spain

WILLIAM C. WIMSATT wwim@uchicago.edu

Department of Philosophy
University of Chicago
1115 E. 58th St., Chicago, IL, 60637
USA

JAMES WOODWARD jfw@pitt.edu

University of Pittsburgh
Dietrich School of Arts and Sciences
Department of History and Philosophy of Science
1017 Cathedral of Learning
4200 Fifth Avenue
Pittsburgh, PA USA 15260
USA

Hierarchy and Levels of Organization in the Biological Sciences

Thursday 8 March	Evening	
6.00 pm – 9.00 pm		Welcome reception (cold food provided) at the KLI

Friday 9 March	Morning		Chair: DiFrisco
9.45 am – 10.00 am	D.S. Brooks & J. DiFrisco	Welcome address & Introduction	
10.00 am – 10:45 am	William C. Wimsatt	Levels, Perspectives, Causal Thickets Revisited: Cultural Evolution	
10.45 am – 11.00 am	Coffee		
11.00 am – 11.45 am	Carl Gillett	Understanding Levels in the Sciences: Returning to Compositional Explanations and their Backing Relations	
11.45 am – 12:30 pm	Thomas Reydon	Functional Kinds and the Metaphysics of Functional Levels	
12.30 am – 2.30 pm	Lunch	at the KLI	

Friday 9 March	Afternoon		Chair: Baedke
2.30 pm – 3.15 pm	Angela Potochnik	Prizing Apart Levels Concepts	
3.15 pm – 4.00 pm	Markus I. Eronen	The Nature of Hierarchical Organization in Biology	
4.00 pm – 4.30 pm	Coffee		
4.30 pm – 5.15 pm	Daniel S. Brooks	The Levels Doctrine: A Piece of Biology's Edifice	
5.30 pm		Free evening	

Saturday 10 March	Morning		Chair: Brooks
9.45 am – 10.30 am	Sara Green	Defining the "Right" Level or Scale: Lessons from Cancer Biology	
10.30 am – 11.15 am	Robert Batterman	Multiscale Modeling in Inactive and Active Materials	
11.15 am – 11.45 pm	Coffee		
11.45 am – 12.30 pm	James Woodward	Levels, Modeling and Autonomy	
12.30 pm – 2.30 pm	Lunch	at the KLI	

Saturday 10 March	Afternoon		Chair: Eronen
2.30 pm – 3.15 pm	James Griesemer	Scales, Levels, Hierarchies: Toward a Process Ontology for Organization in Biology	
3.15 pm – 4.00 pm	James DiFrisco	Levels of Developmental Evolution: From Composition to Process and Back	
4.00 pm – 4.30 pm	Coffee		
4.30 pm – 5.15 pm	Jan Baedke	Where Do New Levels Come From?	
5.15 pm – 6.00 pm	Alan Love	Manipulating Levels of Organization	
6.30 pm		Departure for Dinner at Griechenbeisl	

Sunday 11 March	Morning		Chair: Green
9.45 am – 10.30 am	Jon Umerez	Autonomous Hierarchies—Pattee's Approach to Function and Control as Time-dependent Constraints	
10.30 am – 11.00 am	Coffee		
11.00 am – 11.45 am	Ilya Tëmkin	Hierarchy Theory of Evolution and the Human Story	
11.45 am – 12.30 pm		General discussion & publication plans	
12.30 pm – 2.15 pm	Lunch	at the KLI	
2.30 pm		Departure for social program	

Abstracts

William C. WIMSATT
University of Chicago & University of Minnesota

Levels, Perspectives, Causal Thickets Revisited: Cultural Evolution

I will review my prior work on levels, showing how it is to be distinguished from other approaches, including particularly the mechanism-based account due to Craver, and how the simplifying idealizations and abstractions proposed by others (usually critics) fail to do justice to what we find in nature. Particularly central to my approach is the fact that it uses multiple partially overlapping criteria, including composition, size and time scales, relaxation times, the action of physical and other forces, including selection, and locus of robust connections. One of the interesting questions is why these criteria should coincide as much as they do. I will then consider factors that lead to breakdown of levels as a useful characterization of modes of organization, where it is most likely to work relatively well, and why we should expect it to break down in systems of increased complexity. I consider complexities that arise in a conceptual geography that includes aspects of organization that fit also perspectives and causal thickets, and when levels fit only a part of the organization that exists in a given domain. I will focus on particular problems that arise when richly interdisciplinary subjects are considered, and how to deal with real and imagined conflicts between them. I will consider in particular, how to characterize cultural evolution. If there is time, I consider how differences between cultural and biological evolution impact modes of organization.

Carl GILLETT

Northern Illinois University

Understanding Levels in the Sciences: Returning to Compositional Explanations and their Backing Relations

The sciences offer a range of compositional explanations, and models, backed by compositional relations that are non-causal in character, where these explanations/models plausibly underlie a number of important scientific notions of a “level”. Unfortunately, providing theoretical accounts of compositional explanations has been neglected by philosophers. And, in fact, many philosophers of science now endorse what I term “neo-Causalism” and claim all explanations of singular facts and/or events are causal. Against this background, perhaps unsurprisingly, the very existence, and coherence, of scientific notions of “level” have been questioned.

However, there are increasingly good reasons to think neo-Causalism is false. And there are emerging alternative accounts of compositional explanation. Elsewhere I have defended just such a theoretical framework for compositional explanations and their relations. In this paper, I deploy my account to illuminate both ontological, and heuristic, conceptions of a “compositional level” that grow out of successful compositional explanations. (I focus on examples spanning human physiology, cell biology and molecular biology to illuminate my account.) I detail how, depending on the maturity of our research, we can have more or less comprehensive arrays of integrated compositional explanations for a certain whole, and hence more or less comprehensive ascriptions of a variety of compositional levels for this whole. I consequently show how recent objections to such “levels” can be rebutted.

Thomas REYDON

Leibniz Universität Hannover

Functional Kinds and the Metaphysics of Functional Levels

This paper explores connections between practices of grouping of entities into kinds and locating those kinds at particular levels of organization, and attempts to formulate a concise concept of levels of organization in terms of kinds. The focus will be on functional kinds and functionally defined levels. Natural kinds are often supposed to be, or at least to correspond to, objective or at least non-arbitrary features of the world. Our best scientific theories tell us that the world consists of various kinds of entities – elementary particles, atoms, molecules, samples of various substances, genes, organisms, and so on – with their own kind-specific properties and behaviors, and these kinds are thought to be aspects of the way the world is in and of itself, independently of human interests and classificatory activities. As natural kinds are located at various levels of organization with things of a particular kind at one level being composed of things of various lower-level kinds, an argument for the non-arbitrariness (Wimsatt, 1994: 225) of such levels seems possible on the basis of the alleged non-arbitrariness of natural kinds. Functionally defined kinds, in contrast, are often thought of as not being real kinds, or at least as being "less real" than natural kinds. Functions are multiply realizable and seem to depend crucially on the way in which we analyze the workings of a system. Functional decompositions of a given system can be done in multiple ways and depend on the investigators' interests. There thus seems to be a non-arbitrariness connected to natural kinds and associated levels of organization that is lacking in the case of functional kinds and functionally defined levels. I want to argue against this strict distinction between natural kinds and levels on the one hand and functional kinds and levels on the other. Both natural and functional kinds perform important epistemic roles in our investigations of the world and are in this sense practice-dependent (Ereshefsky & Reydon, 2015; Reydon, 2016), but in order to be able to perform such roles they must also have some foundation in the world "out there". For both natural and functional kinds, and their associated levels, this foundation is what makes them natural and non-arbitrary. I will explore how this grounding of kinds and levels in nature is realized and present a view of levels as grounded on kinds, which in turn are grounded on connections between epistemic and investigative interests and relevant features of the world.

Ereshefsky, M. & Reydon, T.A.C. (2015): 'Scientific kinds', Philosophical Studies 172: 969-986.

Reydon, T.A.C. (2016): 'From a zooming-in model to a co-creation model: Towards a more dynamic account of classification and kinds', in: Kendig, C.E. (Ed.): Natural Kinds and Classification in Scientific Practice, London & New York: Routledge, pp. 59-73.

Wimsatt, W.C. (1994): 'The ontology of complex systems: Levels of organization, perspectives, and causal thickets', Canadian Journal of Philosophy, Supplementary Volume 20: 207-274.

Angela POTOCHNIK

University of Cincinnati

Prizing Apart Levels Concepts

There are a number of conceptions of levels of organization. Some are commonsense ideas of the hierarchical ordering of our world, like part-whole composition, ordering by spatial and temporal scales, and functional specifications that can be accomplished by different means. Other levels relate to our scientific representations of our world, such as degree of abstractness and field of scientific investigation. Elsewhere I have argued against a universal conception of discrete, stratified levels of organization (Potochnik and McGill, 2012). I believe that many of the problems with such a view trace back to the conflation of different levels concepts.

In this paper, I discuss each of the levels concepts mentioned above, analyzing the accordances and discordances among them. This shows that the concepts are all distinct in important ways: none of the levels concepts can be expected to cohere. But, without coherence among these conceptions of levels, the significance of levels of organization—for our world or our scientific representations of that world—is dramatically reduced. For while none of these levels concepts is inherently problematic, it's also the case that none has, by itself, sweeping significance. Or so I will argue. An obvious consequence of this view is that one should be very clear, if invoking levels, about precisely which concept is intended.

Markus ERONEN

University of Groningen

The Nature of Hierarchical Organization in Biology

The idea of hierarchical levels of organization is deeply rooted into contemporary biology and its philosophy. It refers to layers in nature, where entities at a higher level are composed of entities at the next lower level. Typical levels of organization are the molecular level, the level of cells, the level of organisms, and the level of populations. But are there really such levels in nature? In this talk, I will argue that the hierarchical organization of nature is actually far more complex and messy than has been assumed. Nature does not come in levels in the sense in which they have been traditionally understood. Levels of organization should be seen as heuristic tools, not as ontological features, and biological organization should be analyzed in terms of more well-defined concepts, such as scale and composition. I demonstrate the importance and usefulness of this approach by applying it to the debate on levels of selection.

Daniel S. BROOKS

The Levels Doctrine: A Piece of Biology's Edifice

The concept of 'levels of organization' was originally conceived and deployed as a conceptual tool in biology in order to fulfill two main purposes (Brooks 2014): as a means of preserving a materialistic worldview that extends beyond a mere physico-chemical ontology, and simultaneously to explicate the qualitative distinctness of the things populating this expanded ontology. It was during this original genesis and development that 'levels' acquired two features that remain endemic to its usage as a conceptual tool today. The first of these was its firm establishment as a heuristic tool, endowing the products of its usage with an approximative character (Brooks and Eronen accepted; see also Wimsatt 1994/2007). The second major feature that the term acquired was an epistemic goal motivating its usage: to structure problems in biology (Brooks under review).

In this paper, I will argue that 'levels' moreover possesses a more general character as a major organizing concept in science. More specifically, 'levels of organization' possesses a distinct profile and history that warrants its elevation to the status of a 'doctrine' of biology. Much like the cell theory, the neuron doctrine, or the germ theory of disease, the 'levels doctrine' forms a basis of communication for scientists concerning the study of natural phenomena. In this form, the levels concept renders intelligible what is otherwise a complicated mess in the world. The doctrinal form of 'levels' complements the term's usage as a conceptual tool in scientific practice, which I have articulated elsewhere (Brooks 2017; under review; Brooks and Eronen accepted).

I argue that this leads to a kind of "contingent transcendental" (Chang 2008) argument, building off statements made by Wimsatt of the "Kantian flavor" (Wimsatt 1994/2007, 203) of the levels concept: 'Levels' comprises a loose confluence of ideas and commitments regarding how we take the world to be in order to give structure to scientific problems we pose of nature and the solutions we offer to these problems. What then demarcates 'levels of organization' as a distinct concept is the manner in which it basically posits biological phenomena as objects of inquiry when specific claims using levels are formulated: It assumes, or rather imposes, structure onto phenomena by drawing from a cluster of sub-concepts that together constitute the rational boundaries of the concept's applicability. Among these sub-concepts are hierarchy, complexity, and organization. These lend intelligibility to the levels concept.

This doctrinal character is recognizable in the patterns of usage constituting key applications of the term in scientific contexts, where 'levels' is used in a justificatory manner to defend one or more theses concerning the natural world or how it should be studied, or to prime readers for claims author(s) make using the term.

Brooks, D.S. Under review. "A New Look at Levels of Organization"

Brooks, D.S. 2014. The concept of levels of organization in the biological sciences, Department of Philosophy, Bielefeld University, Ph.D. thesis. https://pub.uni-bielefeld.de/publication/2786539

Brooks, D.S. 2017. "In Defense of Levels: Layer-cakes and Guilt by Association" in Biological Theory. 12 (3): 142–156

Brooks, D.S. and M.I. Eronen. Accepted. "The Significance of 'Levels of Organization' for Scientific Research: A Heuristic Approach" in Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences

Chang, H. 2008. Contingent Transcendental Arguments for Metaphysical Principles. Royal Institute of Philosophy Supplements. 63: 113-133

Wimsatt, W.C. 2007. Re-Engineering Philosophy for Limited Beings: Piecewise Approximations to Reality. Cambridge, MA: Harvard University Press.

Sara GREEN

University of Copenhagen

Defining the "Right" Level or Scale: Lessons from Cancer Biology

Discussions about reductionism versus the autonomy of higher levels of organism are often assumed to be of interest mainly to philosophers. However, the question of whether multi-scale systems can be understood "bottom-up" also has important practical implications. I elaborate on this point by drawing on a scientific controversy in cancer biology. Accounts differ with respect to the delineation of the phenomenon to be explained, and with respect to view on the relevant scale to approach the causal analysis. Many life scientists see tumour-sequencing as a powerful tool to provide a finer-grained classification of cancer types and disease trajectories. Others argue that making sense of the effects of mutations requires a better understanding of - and contextualization within - the higher-level dynamics and organization of tissues. The debate is often polarized between a view of cancer as a genetic disease and an approach defining cancer as a problem of tissue organization. I examine the consequences of the two views by pointing to practical implications pertaining to the design of relevant experiments and evaluation of evidence. Moreover, I discuss the extent to which the views can be reconciled in multi-level models and explanations.

Robert BATTERMAN

University of Pittsburgh

Multiscale Modeling in Inactive and Active Materials

I will first discuss aspects of multi-scale modeling of inactive materials. For example, how can we relate lower scale structures of a steel beam to its upper-scale continuum elastic behavior. I argue that such models can explain the relative autonomy and stability of that upper-scale behavior from lower scale details.

I then turn to modeling of so-called active materials. Active materials involve systems that neither can be considered to be in thermodynamic equilibrium nor in some kind of steady state. Instead, active materials (paradigms of which are composed of interacting living systems or components of living systems) are inherently non-equilibrium and have components that transduce energy. Examples include the metaphase spindle that segregates chromosomes during cell division. Within the spindle there are microtubules and motor proteins that enable the spindle to self-organize.

I investigate the differences between modeling active and inactive materials. One question involves the role, or lack thereof, played by physical boundaries. In many models of inactive materials, physical boundaries are often idealized away by the taking of certain limits. Inactive materials appear to rely on boundaries and these seem, to some extent to be emergent features of self-organizing systems.

General lessons for methodology concern differences in multi-scale models of inactive and active materials.

James WOODWARD
University of Pittsburgh

Levels, Modeling and Autonomy

Discussions of “levels” (of organization, description, modeling, explanation etc.) are ubiquitous in contemporary science and philosophy. On the one hand, level talk seems to do real work in many areas of science, suggesting that it is not a notion that can be dismissed as completely confused. On the other hand, as many philosophers have complained, the notion of level seems multiply ambiguous and unclear in crucial respects. In my contribution, I will try to sort out what is useful in the notion of level and when appeals to different levels are appropriate. My basic picture is this: in many areas of science, there is a set of explananda M (which can be at least partially specified in some compact way—e.g. in terms of considerations linked to spatial, temporal or energy scales) that characterize some behaviors of a system S and an accompanying model or theory E which explains or predicts these M in the sense that one can solve the equations of the model in such a way as to account for these explananda. (That is, one can actually exhibit how the explananda depend on the factors employed in the model by solving the relevant equations.) At the same time, there are other explananda M* characterizing system S which cannot be derived from or accounted for in terms of E. This may be because accounting for M* in terms of E is completely computationally intractable (one can’t solve the relevant equations, either analytically or via some perturbative strategy) and/or because the M* do not depend on the factors E but rather on some other set of factors E*. In such cases, M (and E) and M* (and E*) may be said to be at different levels. For example, (1) the overall behavior of an axon (e.g. in firing) depends on its circuit level structure as described by such models as the Hodgkin-Huxley model. On the other hand, (2) the opening and closing of the individual channels by which ions move through the axon membrane depends on the molecular details of these channels. (1) and (2) are thus at different “levels”. The overall behavior in (1) does not depend on these molecular details in the sense that channels differing in molecular details are compatible with the overall behavior captured by the HH model. Moreover, accounting for this overall behavior at a purely molecular level is a computational impossibility. (See Herz et al., 2006 for discussion and for a catalog of a number or different levels of modeling of neuronal behavior.) At the same time the HH model certainly does not describe factors on which the behavior of the membrane channels depend.

In general when explananda and models are at different levels in the sense described, we think of them as belonging to different "domains" or "protectorates", which are somewhat independent of one another—independent in the sense that M can account for E without at the same time accounting for E* and E* can account for M* without accounting for M. Some degree of independence of this sort seems crucial to doing successful science—if all explananda depend equally on what is going on at some single fundamental level, as some philosophers claim, most science would be impossible. But the independence or autonomy of these different domains or levels is often only partial: often there will also be explananda that can only be accounted for by joining up models at different levels (getting models at different levels "to talk to one another"). Exactly because of the computational limitations described above and because models at different levels are designed to account only for explananda at their level, bringing models at different levels into contact with one another can be difficult and requires considerable ingenuity—figuring out how to do this is a matter of ongoing research (multi-scale modeling) in many areas of science. Somewhat ironically, the difficulty of making these connections suggests that there is something "real" about levels—or at least that talk of levels captures important and non-trivial features of scientific practice.

The importance of levels also suggests the importance of studying strategies and criteria for identifying the right level at which to explain or model phenomena of interest. Time and space permitting, I will discuss some of these strategies.

Herz et al, (2006) "Modeling Single Neuron Dynamics and Computations: A Balance of Detail and Abstraction" Science 314, 80

James GRIESEMER

University of California, Davis

Scales, Levels, Hierarchies: Toward a Process Ontology for Organization in Biology

I explore relations between concepts of scale, level and compositional hierarchy in biology. Biologists have tended to follow physicists' (and mathematicians') lead in thinking about scale and scaling phenomena, but concepts of levels of organization take their own distinctive forms in the biological sciences. It is not at all clear whether concepts of levels at work in various biological specialties are compatible, let alone relate to concepts of scale in coherent ways. My primary aim is to explore what a "process ontology" might contribute to a discussion that has been framed primarily by object/property ontologies suited to physics and chemistry, which biologists often tacitly or informally adopt, but against which some biologists and philosophers have sometimes strained. I plan to revisit Wimsatt's touchstone 1974 paper, "Complexity and Organization," with an eye toward what a biology-centered notion of scale might look like from a process perspective on both the epistemology of measurement and the ontology of process models for eco-devo-evo. I draw inspiration and insight from recent work on concepts of scaffolding interactions in biology to organize reflections on scale and the dynamical emergence of levels of organization.

James DiFRISCO

Konrad Lorenz Institute for Evolution and Cognition Research & KU Leuven

Levels of Developmental Evolution

In Wimsatt's (1994/2007) extensive treatment of the concept of levels of organization, levels are characterized as "local maxima of regularity and predictability in the phase space of alternative modes of organization of matter" (2007, 209). In worlds like ours, entities and properties cluster together in a compositional partial ordering and at certain scales in such a way that they support (some) level-specific generalizations. In this paper, I investigate how we should think about levels as maxima of regularity and predictability in the theory of hierarchical developmental evolution coming from evolutionary developmental biology (evo-devo). This problem has two main components: (1) determining the appropriate units of generalization in comparative evo-devo, and (2) modeling the hierarchical relationships between these units.

(1) The levels that are commonly distinguished in developmental biology include the genetic or molecular level, regulatory network levels, cell and tissue levels, organs and other phenotypic levels, and organisms. Applying Wimsatt's idea, we can think of these standard developmental levels as supporting level-specific generalizations about genes, gene regulatory networks, characters, and so on. These generalizations may contain information about (a) the causal structure of development, or (b) phylogenetic relationships. But we can also take "maxima of regularity and predictability" as a criterion for re-drawing level-boundaries so that we are better capturing regularities and enabling predictions about developmental evolution. I will argue that implementing this criterion encourages moving beyond the dominant gene-centered models (e.g., Erwin and Davidson 2006) and towards developmental processes as privileged units of generalization. Because processes are difficult to fit into the standard composition-based definitions of levels (DiFrisco 2017), this may force us to reconsider how we should conceptualize levels in development.

(2) A central goal of research in evo-devo is to provide causal models of developmental evolution that are generalizable—i.e., that don't have to be repeated anew for each species. The goal is roughly to formulate general correspondences between causal variables at different levels. This goal faces the principled obstacle that there is often significant autonomy between developmental levels. For example, in the widespread phenomenon of developmental system drift, related taxa can maintain the same character even though the genes and/or mechanisms causing the character have drifted apart in evolution (True and Haag 2001). The level at which the developmental causes of the same character in different taxa are most comparable has been called the "causality horizon" (Salazar-Ciudad and Jernvall 2013). Causality horizons are maxima of regularity and predictability that connect a phenotypic level with causes at a lower level. It will remain difficult for researchers to capture "wide" causality horizons in comparative evo-devo due to phenomena like developmental system drift. Nonetheless, I will show why we can expect progress from emerging dynamical systems models of developmental processes.

Davidson, EH, and DH Erwin (2006) Gene regulatory networks and the evolution of animal body plans. Science 311: 796-900.

DiFrisco, J (2017) Time scales and levels of organization. Erkenntnis 82(4): 795-818.

Salazar-Ciudad, I, and J Jernvall (2013) The causality horizon and the developmental bases of morphological evolution. Biological Theory 8(3): 286-292.

True, JR, and Haag, ES (2001) Developmental system drift and flexibility in evolutionary trajectories. Evolution and Development 3(2): 109-119.

Wimsatt, W (2007) Re-engineering philosophy for limited beings. Cambridge, MA: Harvard University Press.

Jan BAEDKE

Ruhr University of Bochum

Where Do New Levels Come From?

Hierarchies including levels of, for example, genes, cells, tissues, organs, organisms, and ecosystems, are ubiquitous in the biosciences. Describing such hierarchies gives order to the complexity of nature. Recently, philosophers of science in the ‘new mechanism movement’ have argued for conceptualizing biological hierarchies by means of the ideas of composition and constitution. What this view usually does not address is how the levels of organization described in hierarchical models originally came into existence. In fact, it is always presupposed that levels of organization already exist and are merely gradually changing over time. This perspective does not consider that levels (i) in multicellular organisms are built-up over developmental time and (ii) evolve to qualitatively novel levels in evolution (i.e. evolutionary novelties). Against this background, this paper, first, discusses the shortcomings and biases of the standard view of biological hierarchies and levels as well as its underlying preformationist assumptions. Second, by drawing on historical and contemporary cases from developmental biology and evolutionary developmental biology, it discusses the different ways in which organization and thus levels can change. Based on this analysis a more dynamic conceptual framework is presented that allows incorporating the creation of new levels during evolution and plastic development.

Alan C. LOVE

University of Minnesota

Manipulating Levels of Organization

Despite their widespread invocation in scientific practice and pedagogy, levels of organization have come under increasing philosophical scrutiny (e.g., Brooks 2017; Craver 2007; DiFrisco 2017; Eronen 2015; Potochnik and McGill 2012; Thalos 2013; Wimsatt 2007). The majority of these analyzes (whether for or against) focus on levels of organization in terms of hierarchical representation. However, another important dimension of scientific practice is manipulation. Scientists not only represent levels of organization, they also manipulate them. In this paper, I examine the manipulation of levels of organization in developmental biology with special attention to the origin of tissue-level organization from cell-level organization during embryogenesis. I use two forms of experimental practice (one historical, one contemporary) for illustration: mixed cellular aggregates (Trinkaus and Groves 1955) and monolayer differentiation (Jackson et al. 2010). These experimental practices help to demonstrate that levels of organization cannot be reduced to principles of composition or scale as some critics have argued. However, they also do not lend credence to abstract "layer-cake" theoretical perspectives about levels that presume they are comprehensive in character, global in scope, and map directly onto the disciplinary structure of the sciences. Manipulation practices emphasize that developmental biologists are not interested primarily in levels per se but in transitions between particular levels, which includes the loss of tissue-level organization in metastatic cancers (Douezan et al. 2011).

Brooks, D.S. 2017. In defense of levels: layer cakes and guilt by association. Biological Theory 12:142-156.

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

DiFrisco, J. 2016. Time scales and levels of organization. Erkenntnis 82:795-818.

Douezan, S., K. Guevorkian, R. Naouar, S. Dufour, D. Cuvelier, and F. Brochard-Wyart. 2011. Spreading dynamics and wetting transition of cellular aggregates. Proceedings of the National Academy of Sciences USA 108:7315–7320.

Eronen, M.I. 2015. Levels of organization: a deflationary account. Biology & Philosophy 30:39–58.

Jackson, M., A.H. Taylor, E.A. Jones, and L.M. Forrester. 2010. The culture of mouse embryonic stem cells and formation of embryoid bodies. In: Mouse Cell Culture: Methods and Protocols, A. Ward and D. Tosh (eds), 1-18. Totowa, NJ: Humana Press.

Potochnik A. and B. McGill. 2012. The limitations of hierarchical organization. Philosophy of Science 79:120–140.

Thalos M (2013) Without Hierarchy: The Scale Freedom of the Universe. Oxford: Oxford University Press.

Trinkaus, J.P., and P.W. Groves. 1955. Differentiation in culture of mixed aggregates of dissociated tissue cells. Proceedings of the National Academy of Sciences USA 41:787–95.

Wimsatt, W.C. 2007. Re-Engineering Philosophy for Limited Beings: Piecewise Approximations to Reality. Cambridge, MA: Harvard University Press.

Jon UMEREZ

University of the Basque Country

Autonomous Hierarchies — Pattee's Spproach to Function and Control as Time-dependent Constraints

The issue of levels of organization or hierarchical organization in biological systems remains a key conceptual predicament for philosophical considerations grounded on strict epistemological principles responsive to scientific knowledge. In particular, the problems about how to understand the origin and nature of control processes in the biological realm (Umerez 1994) and how to account for the specific inter-level relations they give rise to, elicit a good deal of conflicting attempts to elucidation.

In Howard Pattee's work on hierarchy (see, i.e., 1969, 1970, 1971, 1972, 1973a, 1973b), we can find the foundation and potential development of a naturalist(ic) approach to biological hierarchical organization (Umerez 2001). As he himself has stated more than once, his interest in hierarchies stem from the necessity to address those conceptual difficulties found in his research on the origins of life. As a physicist dealing with the "highly unlikely and somehow arbitrary constraints which harness these laws [of Physics] to perform specific and reliable functions" (Pattee 1970, 117), he focused on studying the origin and nature of hierarchical controls in biological systems and limited accordingly his use and analysis of the idea of hierarchy.

In his view, those hierarchical controls, besides being autonomous (producing their own rules, not externally imposed) and a full-fledged part of the physical world, are also characterized by having a specific effect on individual elements of the collection (out of which they have arisen) and by producing some integrated function of the collection as such (Pattee 1969, 162-3).

Out of this basic motivation, Pattee develops an increasingly complex approach grounded on basic concepts and distinctions taken from the language of Physics (law/rule, initial conditions/boundary conditions/constraints, dynamics/record (measurement), rate dependent/rate independent, …) and extending to more general epistemological issues (matter/symbol, observer, epistemic cut, …) in his attempt to give an account of the specificity of fully natural but nontrivial inter-level relations in biological systems, taking the cell as the basic instance and the enzymatic reaction as the paradigmatic process.

Thus, one of his main contributions is to distinguish and characterize to kinds of hierarchical relations, structural and functional, based respectively on two kinds of physical constraints. Holonomic constraints are auxiliary conditions that limit permanently the number of degrees of freedom of a system and are, therefore, the basis for structural hierarchies, while nonholonomic constraints are variable auxiliary conditions that limit in time the number of degrees of freedom of the system, being the basis for the functional hierarchies typical of living systems. The latter are dynamical structures that establish time-dependent relations among degrees of freedom but introduce a different temporal scale (Umerez 2016, Umerez & Mossio 2013).

In this paper I introduce and analyze Pattee's approach, discuss its relevance for current debates and use some of his insights to extract some consequences regarding the nature and interpretation of hierarchical organization and relations in biological systems.

Ilya TËMKIN
Smithsonian Institute
&
Niles ELDREDGE
American Museum of Natural History

Hierarchy Theory of Evolution and the Human Story

Evolution is both the process of change of heritable information and the resulting historical record. An accurate interpretation of life's history, therefore, requires understanding of the forms in which information is stored, and the mechanisms by which it is transmitted and modified. The hierarchy theory of evolution claims that information is distributed and channeled across multiple levels of the nested compositional hierarchy of replicating genealogical systems, extending from the molecular level to that of the species. The emergence of developed culture in humans provided new mechanisms of information acquisition, storage, and transfer, that ultimately defined and continue to shape the history of our species, with profound global consequences for the fate of our planet. Here we attempt to integrate uniquely human modes of cultural transmission distributed across levels of sociocultural hierarchy with the existing body of the hierarchy theory derived for biological replicator-interactor systems to provide a blueprint for an overarching causal theory of human sociocultural evolution. Drawing on recent advances in evolutionary theory, anthropology, archaeology, evolutionary psychology, and general principles that govern behavior of complex systems, we analyze major trends in human evolution and speculate on the origin of religion, music, and art.