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Typology Reconfigured: From the Metaphysics of Essentialism to the Epistemology of Representation

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Abstract The goal of this paper is to encourage a reconfiguration of the discussion about typology in biology away from the metaphysics of essentialism and toward the epistemology of classifying natural phenomena for the purposes of empirical inquiry. First, I briefly review arguments concerning 'typological thinking', essentialism, species, and natural kinds, highlighting their predominantly metaphysical nature. Second, I use a distinction between the aims, strategies, and tactics of science to suggest how a shift from metaphysics to epistemology might be accomplished. Typological thinking can be understood as a scientific tactic that involves representing natural phenomena using idealizations and approximations, which facilitates explanation, investigation, and theorizing via abstraction and generalization. Third, a variety of typologies from different areas of biology are introduced to emphasize the diversity of this representational reasoning. One particular example is used to examine how there can be epistemological conflict between typology and evolutionary analysis. This demonstrates that alternative strategies of typological thinking arise due to the divergent explanatory goals of researchers working in different disciplines with disparate methodologies. I conclude with several research questions that emerge from an epistemological reconfiguration of typology.

Keywords Classification · Epistemology · Essentialism · Methodology · Natural kinds · Realism · Typology

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1 Typology Again?

'Typological thinking' is not something you want to get caught doing in evolutionary biology. It involves committing the cardinal sin of ignoring variation and a tacit appeal to essentialism, which is metaphysically incompatible with population thinking, the very foundation of understanding life from an evolutionary perspective (Mayr 1959; cf. Ghiselin 1997). Or so one version of the story goes. Although Mayr was a bit rough with the history of philosophy, the problems with essentialism in evolutionary biology have been more explicitly articulated with care and precision (e.g., Sober 1980). And since nothing makes sense in biology except in the light of evolution (Dobzhansky 1973), typological thinking may be off limits in all life science inquiry. Why return to typology again?

Mayr's demonization of 'typological thinking' was put to use in many contexts after its initial introduction (cf. Chung 2003). One use that crystallized in the 1970s was the rejection of a role for developmental biology in the reformulation or augmentation of evolutionary theory (Mayr 1980). In contrast, some philosophers interested in how evolution and development might be synthesizing in evolutionary developmental biology (Evo-devo) perceived that typology could be an important dimension of reasoning to reconsider (Amundson 1998, 2001, 2005; Brigandt 2007; Love 2003). Others have even argued in favor of an 'evolutionary essentialism' based on recent findings in developmental biology (Walsh 2006). But Evo-devo researchers have raised anew the concern over typological thinking (Budd 2001; Jenner 2006; Minelli 2003; Richardson et al. 1999). The status of typology remains contested and problematic, but something about the intersection of evolution and development provokes reconsideration.

What is the nature of this provocation? At least one aspect pertains to the multiple disciplinary contributors prevalent in studies that tackle different problems at the juncture of evolution and development (Love forthcoming). These disciplines (including embryology, morphology, and paleontology) have been explicitly maligned for the presence of typology in their explanatory reasoning (Love 2003, 2006, 2007). The styles of reasoning within these disciplines, especially within the broad domain of comparative biology, are quite distinct from those found in population and quantitative genetics at the center of evolutionary theory (cf. Winther 2006). Evolutionary genetics appears to exhibit suitable versions of population thinking that fulfill Mayr's anti-essentialist metaphysical strictures. Therefore, if evolution and development are to be blended into some kind of new synthesis, then the issue of typology and its purported opposition to the necessary perspective of population thinking will have to be addressed (by biologists as well as philosophers).

The primary goal of this paper is to encourage a reconfiguration of the discussion about typology away from metaphysical questions about essentialism and toward the scientific practice (or epistemology) of classifying natural phenomena for the purposes of empirical inquiry. This is germane not only to synthesizing evolutionary and developmental biology but also to a greater philosophical comprehension of all aspects of biology. Epistemological issues, such as styles of explanatory reasoning, modes of representation, and methodological preferences, must move to the center of our attention, rather than metaphysical issues, such as essentialism, natural kinds, and realism.[1] Typology needs to be understood as a form of *thinking* or reasoning, as conceptual behavior—typological thinking involves representing and categorizing natural phenomena, including both grouping and distinguishing these phenomena according to different characteristics, as well as ignoring particular kinds of variation. This needs to be observed and explicated in situ, within different areas of biological investigation, prior to passing judgment on its inevitable conflict with evolutionary approaches to living phenomena. Historical investigations of typology have already shown the existence of different notions of type (Farber 1976; cf. Amundson 2005). Philosophical analyses have been executed with respect to typological thinking in social science and medicine, quite disconnected from metaphysical questions (e.g., Hempel 1965 [1952], 1965 [1961]). Relevant issues include the methodological roles these types play in description, explanation, or hypothesis testing, and how other cognitive strategies, such as idealization and abstraction, are involved in the formation and functioning of these types (cf. Hempel 1952, Section III).[2]

Only once an epistemological reconfiguration is accomplished can the status of typological thinking in Evo-devo, or elsewhere in the life sciences, be evaluated appropriately.[3] Reconsidering typology is justified in part because there are epistemological issues that have not yet received adequate attention, such as the different kinds of types that might be operating in different areas of biology or the roles they play in various aspects of scientific inquiry. In order to accomplish this reconfiguration, I begin with a brief review of the discussion about typology, essentialism, species, and natural kinds that highlights its predominantly metaphysical nature. Then I use a distinction between the aims, strategies, and tactics of science to suggest how a shift from metaphysics to epistemology can be accomplished. Typological thinking can be understood as a scientific tactic that involves representing natural phenomena using idealization and approximation (and thereby involves far more than what has sometimes been referred to as 'typology'). These representations facilitate explanation, investigation, and theorizing via increased abstraction and generalization. Section 4 details a variety of typologies

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[1] 'Epistemology' is construed broadly, referring to a multiplicity of epistemic activities associated with scientific inquiry (Giere et al. 2006). It is not intended to capture distinctions between areas of epistemology discussed in philosophical literatures (e.g., the status of causes versus reasons or the origin versus justification of propositions; see Steup 2008 for discussion). The contrast is with 'metaphysical' in a similarly broad sense, which includes issues like the nature of properties, modality, or physicalism (see van Inwagen 2007 for discussion). Although there are connections between epistemology and metaphysics, the reconfiguration argued for here is a shift from frequently treated metaphysical questions to neglected epistemological ones.

[2] Hempel distinguished three kinds of type concepts (classificatory, comparative, and quantitative) and attempted to isolate their appropriateness to different epistemological tasks undertaken by scientists, recognizing that their use is guided by epistemic values such as fecundity. These analyses are found in the work of logical empiricists prior to the explosive philosophical discussion about essentialism and systematics in biology (cf. Hull 1965).

[3] The same applies for population *thinking*, though it is not the focus herein. It may be that specific forms of typological thinking are fundamentally opposed (epistemologically) to population thinking, even in the area where Mayr first forged the distinction (i.e., species). But this would be an outcome of analyzing how these kinds of thinking (epistemology) operate in very specific arenas of investigation, not something that falls out of a general metaphysical claim about evolution.

from different areas of biology to illustrate the diversity of this representational reasoning. One of these examples, normal stages in developmental biology, is used to illustrate how there can be genuine *epistemological* conflict between a particular typology and evolutionary analysis. This begins to show how typology might be both a necessity and an obstacle to evolutionary reasoning. Alternative, potentially incompatible typologies arise due to the divergent explanatory goals of researchers working in different disciplines with disparate methodologies. In closing I touch on several research questions that become visible once an epistemological reconfiguration of typology has occurred.

2 Reconfiguring Typology: From Metaphysics to Epistemology

The main battleground regarding typological thinking and essentialism has been the nature of biological species (Ghiselin 1997; Hull 1978; Sober 1980, 2000, chap. 6), as was the complex origin of Mayr's original distinction (Chung 2003). Typological approaches were supposedly implicit or explicit forms of essentialism that understood species membership in terms of sharing a common essence or set of essential features.[4] Biological species were natural kinds and "essentialism is a standard philosophical view about natural kinds" (Sober 2000, p. 148).[5] But sets of essential properties for species membership do not change over time and species do; species are historical entities, individuals linked together by a genealogical nexus, and natural kinds are not; species are spatio-temporally restricted, whereas natural kinds are not. Typology led us astray because species are not natural kinds but individuals (Ghiselin 1997; cf. Hull 1978).

Putting aside whether these arguments are successful (cf. Brigandt, this issue; Griffiths 1999; LaPorte 2004; Sober 2000, Sect. 6.1), they illustrate the distinction between population and typological thinking that animates the ongoing controversy surrounding typology. 'Population thinking' refers to the *metaphysical* claim that the statistical terms used to describe organisms collectively are 'abstractions' (i.e., not objective features of the world), and the variation exhibited by individual organisms is a concrete feature of the world that has primacy in biological theorizing. Population thinking about species treats them as 'real' individuals (rather than as collectives) and takes seriously the variation of the component members (or parts) of this species individual. 'Typological thinking' is supposed to represent a contrary metaphysical position, whereby the 'types' used to collectively describe organisms are objectively 'real' (often equated with 'essences') and, in some sense, downplay the reality of variations exhibited by individuals. Typological thinking about species uses unchanging essences (i.e., natural kinds) to categorize individual species, ignoring variation or treating it as accidental. This leads to an

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[4] It is not clear that earlier systematists held this view (Amundson 2005; Winsor 2003, 2006), although this is a continuing subject of debate (Stamos 2005).

[5] A natural kind can be understood as a grouping of objects (or properties) that is based on 'the way things really are' (i.e., metaphysics), as opposed to being grouped merely for our own practical purposes ('artificial kinds'). It is often thought that our scientific concepts (i.e., epistemology) should be based on natural rather than artificial kinds.

artificial categorization of individuals into species by forcing them to conform to a type, denying their individuality and, by implication, their variation: “no two individuals or biological events are exactly the same and processes in biology can be understood only by a study of variation” (Mayr 1976 [1955], p. 301; cf. Chung 2003, Sect. 3.4). If species are conceptualized metaphysically as individuals rather than natural kinds, these ill-fated effects of typology can be expunged from biology (Ghiselin 1997).

This *metaphysical* solution has been challenged by reconceptualizing the nature of the connection between natural kinds, essences, and species (Ereshefsky forthcoming). One strand of thought argues that natural kinds do not require unchanging essences but rather can be based on homeostatic property clusters (Boyd 1991, 1999). These clusters of causally efficacious properties underlie the natural kind but any one property is not necessary for membership in the kind (cf. Rieppel 2006; Wilson 1999). The nature of the cluster itself can evolve, albeit slowly otherwise the stability of the natural kind (and thus its *raison d’être*) is lost. A related strategy is to rethink the essences underlying natural kinds. Essences do not need to be micro-structural in character but can be relationally defined (‘extrinsic’), as long as they exhibit detectable counterfactual force in explanations (Griffiths 1999; cf. Boyd 1999).[6] Options similar to this include ‘common evolutionary origin’ as an essential property underlying a natural kind (Brigandt, this issue; LaPorte 2004).

The motivations for these alternative approaches to natural kinds share in the spirit of a reconfiguration of typology because the attempt to reconceptualize natural kinds is motivated and guided by the explanatory practice of scientists (i.e., epistemology). For example, Boyd introduces the idea of ‘accommodation’ to describe how categorization and causal structure are harmonized to produce successful inductive generalization and explanation (Boyd 1999; Griffiths 1999; Wilson 1999, 2005). Thus, the homeostatic property clusters that underlie different natural kinds are highly variable (disciplinarily relative) and not susceptible to a completely general characterization that abstracts from the details of the causal mechanisms that any particular cluster tracks. But the goal of this type of inquiry is an account of natural kinds (alongside of homeostatic *property* clusters and *causal* mechanisms), not one of the diversity of explanatory practices and occurrences of accommodation in disparate life science disciplines.[7] Instead of concentrating on the causal structure that classificatory practice accommodates to (thereby generating natural kinds), there are independent questions about these explanatory practices that may be asked apart from any commitment to homeostatic property cluster

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[6] This strategy is congruent with the initial determination of homologies in comparative anatomy. “The structure of the system is determined by the relations that prevail between its parts, or, in other words, the parts are individuated not on the basis of their intrinsic properties … but strictly by their relational properties” (Rieppel 2006, p. 530).

[7] “Questions about the accommodation of representational and inferential practices to real causal structures in the world are at issue, and these questions are paradigmatically metaphysical” (Boyd 1999, p. 159). Boyd focuses on species but his analysis does not dissect the actual practices of investigators working in systematics.

kinds: “after all, not every useful category in science is a natural kind” (Wilson 1999, p. 194). These epistemological questions are quite complementary to these alternative analyses of natural kinds, not least because of the recognition that questions of accommodation are relative to disciplinary matrices, even when they are dealing with the same natural phenomena (Boyd 1999, pp. 148–150).[8]

One outcome of this conversation (perhaps unsurprising) is that there is no trivial or obviously necessary link between typology and essentialism (cf. Amundson 1998). For example, typological thinking using homeostatic property clusters can be understood as explicitly non-essentialist (e.g., Rieppel 2006).[9] But it is also necessary to recognize that this conversation is implicitly or explicitly metaphysical in nature. Regardless of whether it is Mayr’s original distinction, Ghiselin’s defense of the individuality thesis, or Boyd’s homeostatic property clusters, the issue of essentialism—either how to characterize it or how to avoid it—keeps the discussion in a metaphysical vein.[10] The existence or reality of types is also a central focus because defenders of typology insist that its rejection is rooted in an empiricist (as opposed to realist) philosophy of science, whose avoidance of metaphysics was adhered to by architects of the Modern Synthesis (Rieppel 2006; cf. Boyd 1999). This stress on essentialism, realism, and natural kinds has meant that the epistemological roles of typology have not received proper attention, either by biologists or philosophers.[11]

Ron Amundson is one of the few authors to have asked how type concepts, such as ‘the tetrapod limb’, are used for epistemological purposes in evolutionary explanations (Amundson 1998, 2001, 2005). ‘The tetrapod limb’ can be understood as a scientific idealization, defined by patterns of relations that obtain among the relevant components and processes (Amundson 2001). This example is helpful in focusing our attention on typology as a form of representational reasoning. First, it is

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[8] Boyd goes so far as to say questions about the reality of natural kinds must be addressed at the level of the classificatory practices relative to a particular discipline rather than with respect to the kind itself abstracted out of this local context (Boyd 1999, p. 158ff; Dupré 1993).

[9] Or, the resulting ‘essentialism’ is substantially different. Mayr was concerned with ignoring variation of phenotypic properties in establishing species boundaries (i.e., taxonomic essentialism). Boyd’s ‘essentialism’ is about the causal mechanisms used to collect objects together into a natural kind, which includes Mayr’s account of species in terms of the ability to interbreed (Boyd 1999, p. 164ff; cf. Walsh 2006). Philosophically, it seems most accurate to describe Rieppel’s view as essentialist in a different sense rather than non-essentialist, but the label ‘essentialism’ still carries negative connotations so ‘non-essentialist’ might be rhetorically preferable.

[10] This is also is the case for more general discussions of essentialism and natural kinds (Ellis 2001).

[11] A similar conclusion has been reached by philosophers interested in the epistemological roles of idealization and approximation in physical science: “The focus of the debate about realism has centered on developing ways of articulating exactly how these [idealized] models retain a degree of abstraction while bearing on reality in some significant way. …However … it is apparent that the successful use of models does not involve refinements to a unique idealized representation of some phenomenon or group of properties, but rather a proliferation of structures, each of which his used for different purposes. Indeed in many cases we do not have the requisite information to determine the degree of approximation that the model bears to the real system. … [the] problem of approximation and idealization is not only a philosophical problem but … also a difficulty that exists *within* scientific practice. …the question of whether a model corresponds accurately to reality must be recast in a way that is more appropriate to the way in which models actually function within the practice that we, as philosophers, are trying to model” (Morrison 2005, pp. 169–171).

not about classifying organisms into species but rather taxonomizing parts or aspects of organisms into units. This typological thinking is not for or about species.[12] Second, the type can 'evolve'; i.e., the features used to classify limbs into the unit 'tetrapod limb' are subject to change. (The classification is generated comparatively by looking across different taxa with divergent evolutionary trajectories.) The unit of evolution (or 'trait') is not equivalent to the unit of formal classification from systematics, 'species' (cf. Dupré 2001). Third, 'the tetrapod limb' is an *idealized* type, which is constructed from ample and acknowledged variation. It is useful because it captures shared structural features but variation within and among these features is also of interest to evolutionary researchers. No one thinks a whale flipper, bat wing, and human arm are identical in all respects.

We can extend and generalize Amundson's analysis by investigating what roles different kinds of typologies play in explanatory reasoning. One area of focus is the prerequisite that any explanation requires a representation of the phenomena to be explained (Sarkar 1998). This allows us to recover etymological roots of 'typology' as "the study of symbolic representation" or "the study of classes with common characteristics; classification,…according to type; the comparative analysis of structural and other characteristics" (OED). Typologies are the product of classificatory representation involved in the formulation of an explanation of natural phenomena. The diversity of typological thinking used in representational reasoning reflects the diversity of explanatory goals (i.e., epistemology) in biology and involves far more than the question of biological species in systematics.[13] This invites further scrutiny of how these idealized types are formed and operate in different arenas of inquiry. Before viewing some examples and highlighting the issues at stake, we need a philosophical rationale for an excursion into the messy details of scientific representation.

3 Aims, Strategies, and Tactics of Science

The methodological reconfiguration at the heart of this paper involves shifting away from metaphysical questions about essentialism and natural kinds to the epistemology of typology as a form of representational reasoning. In order to facilitate this shift it is useful to distinguish between the aims, strategies, and tactics of science. The *aims* of science concern what scientific investigation intends to achieve. Two main options swirl around in debates about scientific realism: truth and empirical adequacy. For a scientific realist, the aim of science is ever-increasing truth (or an approximation thereof) with respect to the categorization and operation

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[12] "The basic goal of comparative anatomy is to determine regularities of structural organization that enable a classification and understanding of the ordered diversity of form" (Shubin and Alberch 1986, 377). Rob Wilson discusses taxonomies of parts in his account of homeostatic property cluster natural kinds (Wilson 1999, 2005). Biologists and philosophers have long discussed the epistemology of decomposing systems into parts (Kauffman 1971; Wagner and Laubichler 2001; Wimsatt 1974; Winther 2006). I return to this below in Sect. 7.

[13] These considerations can naturally lead beyond biology into other domains, such as particle typologies in physics and differences in how various kinds of physical entities are represented.

of natural phenomena (Psillos 1999). For an anti-realist, the aim of science is empirical adequacy (van Fraassen 1980). Cast in terms of the debate about the nature of kinds, the scientific realist seeks to establish natural kinds (natural because they provide a true or approximately true basis for our classification), whereas the anti-realist strives for useful or appropriate kinds (appropriate because they are empirically adequate with respect to phenomena we attempt to classify and our classification goals).[14]

The *strategies* of science are those general plans of action designed to achieve the aims of science. There are multiple strategies in operation within scientific inquiry including experimental design, modeling, and classification, as well as sociological mechanisms such as mentoring and peer review.[15] These strategies do not prima facie favor any interpretation of the aims of science. Realists and anti-realists alike will emphasize the need for good experimental design, classification, and peer review. The difference will be in how these strategies are interpreted. Realism and anti-realism are interpretations of the epistemic activities of science addressed to metaphysical questions.[16] But this is not required to understand how the strategies themselves work. Epistemological aspects of these strategies can be investigated apart from these interpretations.[17]

The *tactics* of science are the specific actions taken in the attempt to successfully accomplish the strategies, and by implication, the aims of science. These are the actual experimental set-ups and data gathering methodologies, the web-interface for blind peer review at a journal, or the pictorial representation of a molecular model at the end of scientific paper. If the strategy is to execute a double-blind randomized experimental design, then the tactics involve the choice of relevant causal factors and populations from which samples will be drawn. Tactical aspects of science are the details of scientific representation, experimentation, and modeling that often must be viewed quite closely to comprehend their operation. The tactics of science are encountered alongside highly specialized terminology, equations, and diagrams. Tactics are specific to different disciplines and often correspond to technical concepts and methodologies that are not necessarily in wide use. They are more difficult to convey across disciplinary boundaries than strategies, such as explanation or peer review.

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[14] I am running roughshod over nuances in discussions about scientific realism (e.g., different forms of anti-realism like instrumentalism and constructive empiricism), but these are not necessary for the present discussion.

[15] The sociological mechanisms might be seen as a means to the end of pursuing the classification, explanation, etc.

[16] Although different versions of anti-realism are not making a metaphysical claim by holding that the aim of science is empirical adequacy, the denial of any necessary metaphysical consequences of scientific theorizing is addressed to metaphysical questions about realism. If one adopts a purely pragmatic approach to the aims of science (e.g., successful manipulation of nature), then the metaphysical questions can be skirted (but in a contentious way). Approaching scientific reasoning through strategies or tactics does not commit one in advance to some version of a realist, anti-realist, or purely pragmatic understanding of the aims of science.

[17] I am not making the claim that all discussion of aims in science is metaphysical. Rather, the aims of science are the locus for debates about metaphysical questions surrounding scientific realism.

This distinction between aims, strategies, and tactics is not meant to be controversial. Although other philosophers may not have attached this significance to the terminology as I have done here, the distinction can be mapped onto other philosophical accounts.[18] Its import for philosophical analyses of science (whether done by biologists or philosophers) arises from the fact that different questions and issues are in the foreground depending on how you look at the phenomena of scientific activity. Many philosophers interested in typology commence their analysis by focusing on metaphysical questions relevant to the aims of science, which means answering questions about realism and the status of natural kinds across all of science. Others might begin their study concentrating on strategies, trying to analyze these at a relatively general level (e.g., the nature of typologies in biological explanation). A third point of departure is tactics, those specific actions adopted by scientists in attempting to carry out particular strategies in their investigations (e.g., the use of particular types of characters in reconstructing a phylogeny of bat species). Once one has begun an analysis at one aspect of the distinction, trafficking back and forth between them can be viewed as a standard (and maybe even necessary) subsequent activity. But where you choose to philosophically access the phenomena of science makes a difference. It encourages one to answer particular questions first (should types be given a realist interpretation or understood as natural kinds?) before proceeding to address questions that are more salient when you begin elsewhere (should a different character type be used in the bat phylogeny?). Answers to questions emphasized for one aspect of the distinction do not necessarily illuminate questions emphasized at another. Arguments about the notion of approximate truth relevant to metaphysical questions about realism ('aims') only have an indirect bearing on whether bat biologists should choose a particular character typology in phylogeny reconstruction ('tactics').

In order to reconfigure typology we need to approach it first and foremost in terms of tactics, rather than aims or even strategies. Concentrating on tactics foregrounds the specific goals of researchers within their local investigative context, which are critical for comprehending the reasons why typologies are present and how they are utilized. Typologies are elements of particular methodological approaches; typological thinking is a form of scientific reasoning utilized for the purpose of understanding a specific aspect of living phenomena (in the case of biology). The aims of science and its strategies keep these particularities in the background. Questions about the reality of the types or whether they are underlain by causal mechanisms characterized as homeostatic property clusters, or even

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[18] Brigandt (this issue) discusses how 'epistemic goals/aims/purposes/demands' can differ across biological disciplines even when focused on similar phenomena (e.g., species). Because of his emphasis on disciplinary and methodological differences, Brigandt's terminology correlates best with my 'tactics' (and to a lesser degree with 'strategies'), in part because the "aim" of science I am examining is supposed to hold across different disciplines and different areas of science. In general, metaphysical questions about aims focus on 'science' as a unit inclusive of all areas of science, whereas epistemological questions about aims zero in on specific areas of science and their distinctive practices, thereby being more relevant to 'strategies' and 'tactics', as articulated above. Another example would be 'heuristics', which most naturally map to my strategies because they are often applicable across multiple areas of science (e.g., reductive research heuristics—see Wimsatt 1980). The details of how these heuristics are applied in a particular disciplinary context would then move us into the domain of tactics.

whether biological explanation is primarily causal explanation, do not get at the details of typological *thinking*. Before making judgments about whether the tactics of scientific representation instantiate an explanatory strategy inimical to the metaphysics of evolution, the tactics themselves should be analyzed. Subsequently, an inquiry that moves from these tactics to the strategies they are meant to accomplish, as well as to their impact on questions of aims, has the potential to illuminate aspects of biological reasoning that have been hitherto overlooked.

This is the most preferable methodology for understanding typological thinking in biology while fully recognizing that 'nothing makes sense in biology except in the light of evolution'. Metaphysical approaches to kind individuation lead to a flattening of representational reasoning in biology; i.e., they treat it as a relatively homogeneous endeavor, ignoring the particularities of disciplinary contexts where empirical inquiry occurs. For example, philosophers explicitly motivated by scientific reasoning (Ellis 2001; Gillett 2002, 2003) presume kinds are individuated by particular properties that contribute causal powers to individuals. The exemplars below indicate that causal powers are not always what motivate typological distinctions nor do they refer only to individuals. These typologies also violate ontological requirements put on natural kinds such as categorical distinctness (no grading into one another) or a hierarchy requirement (no cross-cutting kind membership) (Ellis 2001, chap. 1). The epistemology of scientific individuation is more heterogeneous than some philosophers perceive.[19]

4 Exemplars and Aspects of Representational Typology in Biology

One reason to find the received wisdom about typological thinking problematic is the frequency with which typologies are built in biological investigation and explanation. Observing these widespread tactics should make us wary of sweeping metaphysical conclusions. This does not grant *a priori* justification to every particular representational category, but it does suggest we should be hesitant in concluding that the majority of reasoning in the life sciences is an obstacle to an evolutionary perspective on the history of life. These typologies are often constructed with the specific goal of understanding evolutionary processes. The tactics of scientific inquiry are phenomena worthy of investigation, regardless of whether categorizations turn out to be 'not natural enough'. Although it is impossible to be comprehensive in the space of this paper, I illustrate the variety of typologies in life science through a short tour of examples from different disciplines and methodological approaches.

4.1 Protein Domains (Molecular/Structural Biology)

Protein domains are parts of a polypeptide chain that form a semi-autonomous substructure or fold within a larger functional protein. How these units are defined is

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[19] It should be stressed again that my epistemological reconfiguration of typology is compatible with metaphysical inquiry into science. Some questions, such as the 'objectivity' of typologies, are fruitful points of intersection for coordinated epistemological and metaphysical inquiry.

quite open-ended: "*domain* corresponds to a broad concept for an intermediate level of organization of the structure, function, and evolution of proteins" (Garel 1999, p. 407). Domain types can be identified as (a) stabile units that can be manipulated and retain some activity or structure (immunoglobulin domains); (b) structural units that are observable in X-ray crystallography or determined by other methods (e.g., combinations of protein secondary structure [α-helices and β-sheets]; β/α barrels, β-hairpins; α/α hairpins; $\beta/\alpha/\beta$ units); (c) genetic units that are based on the linear sequence comparisons between DNA and polypeptides; (d) functional units that exhibit a particular activity such as catalysis or ligand binding (e.g., leucine zippers, zinc fingers, and cadherin repeats); (e) evolutionary units that include complexities of genomic structure such as introns, which demarcate protein domains; and (f) thermodynamic units that unfold and refold independently of other aspects of the overall protein (cf. Garel 1999; Denton et al. 2002 on protein folds).[20] These different characterizations are not mutually exclusive and are used in different contexts depending on the local investigative goals of researchers.

4.2 Selection Processes (Evolutionary Ecology/Genetics)

Selection processes have been broken down into a variety of kinds or 'subprocesses'. The most familiar is the distinction between natural and sexual selection. These can be differentiated further, such as sexual selection in terms of mate choice or male–male competition. Natural selection can pertain to mortality, fertilizing ability, fertility, and fecundity (Endler 1986, 1992). It can also be typologized in terms of its different effects on populations (e.g., habitat choice or trait covariance) and trait frequency distributions (directional, disruptive, and stabilizing), which may be continuously varying, discontinuously varying, or have quantitative thresholds (Endler 1986, chap. 1). Philosophers of biology have worried that this diversity means that any generalization about the principle of natural selection sufficiently abstract to include these different categorizations is largely devoid of empirical content (e.g., Brandon 1990, pp. 140–142).

4.3 Modes of Locomotion (Functional Morphology)

Despite the fact that many animals use multiple modes of locomotion (e.g., the ability of some pinnipeds to traverse terrain with flippers adapted for swimming), functional morphologists routinely use a typology for how animals (especially vertebrates) get around in their environment. These include ambulatory (generalized), cursorial (speed running), saltatory (jumping), scansorial (jumping), fossorial (digging), natatorial (swimming), graviportal (large body mass), and bipedal (Polly 2007). The distinctions are observed even when the special labels are not in use (Alexander 2003; Biewener 2003). Modes of locomotion can be broken down into sub-types (gliding, soaring, and powered flight; swimming via undulation or jet propulsion) and treated as facultative versus obligate behavioral strategies (cf. Alexander 2003). Related typologies include plantigrade, digitigrade, and

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[20] Similar domain categorizations can also be utilized for RNA molecules (Stadler et al. 2001).

unguligrade 'stances' (the interaction between distal limb skeletal elements and a contact surface—Polly 2007) and walking, running/trotting, and galloping 'gaits' (Biewener 2003, Sect. 3.4). These are understood to be violable categories that can grade into one another; i.e., distinctions within a typology are used with full knowledge of the blurry lines dividing them. "These categories form a continuum, especially between plantigrade and digitigrade, and some mammals have multiple stances depending on the situation" (Polly 2007, p. 247).

4.4 Characters and Character States (Systematics)

Every phylogenetic reconstruction of evolutionary relationships requires a delineation of the characters that will be analyzed and character states to be scored. For example, a study of larval evolution in echinoids (Wray 1996) used 63 different characters, usually with two or three states each, including egg diameter (<200 μm; 200–350 μm; >350 μm), number of primary mesenchyme cells (<30; 30–100; >100), initiation of skeletogenesis (before gastrulation; during gastrulation; after gastrulation), skeleton 'weight' (gracile versus robust), and color of ectoderm (nearly transparent, lacking distinct color versus opaque, colored). These are classifications that involve commitments to particular kinds of representation. 'Egg diameter' is a representation of a feature of sea urchins that is measurable and can be divided into three states (akin to small, medium, and large). Why were these particular characters and states chosen? Some of the choice is constrained by earlier studies to which this one must be comparable, even if it generates a different phylogenetic hypothesis. But additional decisions were made: "The character set was modified by adding ten new characters representing morphological features found in larvae with derived developmental modes, by adding one new character state to two characters for the same purpose, and by removing seven characters with transformation not represented by the species in the data matrix" (Wray 1996, p. 321). Thus, even if species are not types, the analytical framework used to assess the relationships among species depends on a form of typology.[21]

4.5 Forms of Chromatin (Molecular Genetics)

Chromatin refers to fibers consisting of multiple nucleosomes, which themselves are a complex array of DNA wound around histone proteins. It is divided into two basic types: euchromatin and heterochromatin. Several characteristics are used to distinguish these: degree of condensation, location on chromosome, types of sequences that it contains, number of genes, time of replication during the cell cycle, and whether they undergo recombination (Grewal and Elgin 2007). Euchromatin is less condensed, gene-rich, on the chromosome arms, contains unique DNA sequences, replicated throughout S-phase of the cell cycle, and undergoes recombination during meiosis. Heterochromatin is highly condensed, gene-poor,

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[21] This epistemological claim is weaker than the metaphysical claim that characters should be understood as homeostatic property cluster natural kinds (Rieppel 2006; Rieppel and Kearney 2007). Here the emphasis is on classifying a continuous range of phenomena into distinct categories.

at the extremes of chromosomes (near centromeres and telomeres), contains repetitive DNA sequences, replicated only in late S-phase, and experiences no meiotic recombination. Despite this robust typology, which is routinely used to describe different areas of the genome, researchers have found that exceptions are plentiful. “Trying to define heterochromatin is like trying to define life itself: a cluster of important properties can be specified, but there are exceptions in every instance” (Grewal and Elgin 2007, p. 400). These exceptions and the variation that introduces them is a current focus of research but the typology remains a part of reasoning about genomic structure and its characteristics.

4.6 Normal Stages (Developmental Biology)

The process of development from a fertilized zygote to fully formed adult organism has been studied by breaking down the process into temporal periods or stages (Minelli 2003, chap. 4). ‘Typological thinking’ is manifested as a consequence of conceptualizing a continuous ontogeny in terms of discrete periods that are applicable to all members of a species, as well as to the embryos of other taxa. These can take different forms, from the standardized numerically designated stages of chick or *Xenopus* ontogeny (Hamburger and Hamilton 1951; Nieuwkoop and Faber 1956), to typologies using key development events (e.g., fertilization, gastrulation, neurulation, or metamorphosis). Normal stages involve assessments of ‘typicality’ because of enormous variation in the absolute chronology of different developmental processes.[22] “We have tried to establish average or “standard” types by comparing a considerable number of embryos in each stage, and we have selected for illustrations those embryos which appeared typical” (Hamburger and Hamilton 1951, p. 52). They also involve assumptions about the causal connection between different processes across sequences of stages, which are tricky to assess from a comparative standpoint (Alberch 1985; Minelli 2003, chap. 4). Periodizations or ‘temporal framework choices’ are a fundamental feature of many different biological sciences, especially historically oriented ones (Griesemer 1996).

4.7 Discussion of Typology Exemplars

It should be clear from these examples (and many others that could have been selected) that the basis for typological categorization differs, sometimes dramatically. The typology is structural in some cases, whereas in others it is functional (modes of locomotion), and what counts as ‘structural’ and ‘functional’ also varies across disciplines. In some cases structural and functional considerations are mixed (chromatin),[23] whereas others use either structure or function (protein domains). The typology can also be built out of effects (disruptive selection). What is grouped together is heterogeneous, including entities, activities, properties (size, weight,

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[22] “The shortcomings of a classification based on chronological age are obvious to every worker in this field, for enormous variations may occur in embryos even though all eggs in a setting are place in the incubator at the same time” (Hamburger and Hamilton 1951, p. 49).

[23] Waters (2000) has argued that gene individuation in molecular genetics involves a mixture of structure (features of the DNA molecule) and function (what the translated protein does).

color), processes (selection), mechanisms, and time (normal stages). Sometimes the typology is binary, but in most cases it is not. Exceptions that do not fit neatly are explicitly recognized but do not serve as a basis for abrogating a typology. The typologies are used both to set-up things in need of explanation and contribute to explanations. As a consequence, typologies are often layered or hierarchical and used in conjunction with one another (e.g., the unguligrade stance of the cursorial horse during a galloping gait)—distinct typologies are not presumed to be mutually exclusive. This diversity reflects divergent explanatory goals in the different disciplinary approaches and emphasizes how typologies are often connected with specific methodologies (e.g., X-ray crystallography). Focusing on the tactics of science demonstrates the necessity of examining different local contexts with specific goals for empirical inquiry that guide typology formation and utilization.

These typologies are idealized representations of natural phenomena based on the observational features and measurement techniques used to access them. The representations are constructed according to a number of ‘virtues’ that taxonomic schemes strive for: comprehensiveness, suitably sized groups, reasonably homogeneous groups, reasonably sharp boundaries between groups, and stability (Dupré 2001, Sect. 3). The above exemplars accomplish these goals through a willingness to treat particular forms of variation as less relevant to explanation in order to generate the taxonomy. ‘Reasonably’ homogeneous groups and boundaries are consequences of isolating typicality with respect to certain features. These types are idealized in the sense of intentionally excluding particular forms of variation for explanatory purposes and are useful precisely because researchers knowingly do so (cf. Jones 2005).[24]

Idealization operates alongside of another representational tactic in typologies: approximation. Approximation involves representing phenomena as close to accurately as possible while knowing that the representation is not fully accurate. Idealization and approximation can go together, as when one only has an approximate measure of features whose variation you decide to ignore, or they can function independently, as when one idealizes features with variation that could be accurately captured (i.e., approximation is not inherently demanded). To varying degrees, approximations can be explicit or implicit, capable of being corrected (corrigible) or not, and, context dependent or independent (Sarkar 1998, pp. 48–52). Often approximations within local disciplinary contexts are implicit because they are part of a standardized methodology. Corrigibility with respect to representation often depends on the features in view. Two dimensional pictures of cellular environments that leave out all constituents to highlight a particular process (e.g., vesicle transport) can often be corrected to include these constituents but not to show the dynamics of Brownian motion inside the cell. The effects of the approximations may be estimable or not and involve procedures justified from particular disciplinary perspectives. Some aspects of approximation (lack of corrigibility and lack of estimability) can be assessed ‘in practice’ versus ‘in

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[24] Nersessian describes ‘generic modeling’ in the process of concept formation in terms of the “representation express[ing] what is common to many systems” (Nersessian 2005, p. 139). Typologies are formed out of features common to many systems with explicit knowledge that these systems differ in a variety of other features.

principle', further highlighting the complexity of approximation in scientific reasoning. For example, normal stages involve initially explicit approximations that subsequently become implicit once standardized. They are corrigible, in that any particular period can be decomposed or fused, as well as being context dependent in multiple senses: (a) the environmental context (e.g., temperature) is controlled in their establishment; and, (b) the investigative context of their use determines how these periods are understood and utilized in explanation.

More broadly, idealizations and approximations allow for increased abstraction (the exclusion of concrete particulars in order to comprehend the significance of claims over different degrees of exclusion) and generalization (the extension of claims over a wider scope or range of application).[25] Often abstraction is a vehicle for generalization in that omitting details facilitates generalization across diverse organismal contexts. But since abstraction and generalization are logically distinct (abstraction can be accomplished without generalization and vice versa), the contribution of idealizations and approximations to each of them must be carefully explored. For example, abstraction via idealization in the service of generalization involves a trade off between the scope of a principle and amount of empirical content (see above, Sect. 4.2). Both abstraction and generalization are intimately connected with the counterfactual force of 'laws' or invariances thought to ground explanation (Mitchell 2000; Woodward 2003), as well as facilitating theorizing and suggesting methods of investigation. They are also critical for accounts of concept formation (Hempel 1952; Nersessian 2005), and arguably all forms of scientific reasoning (Cartwright 1989, 1999).

Representational typologies are constructed for the purpose of investigation, explanation, and theorizing. Thus, the virtues and limits of strategies used to create these typologies can be assessed on the basis of how well they contribute to these explanatory goals. The appropriateness of an idealization that ignores variation of a particular kind to achieve a more abstract typology depends on the explanatory goals of the disciplinary context in which it is accomplished. Similarly, whether incorrigible approximations, the effects of which are only in principle estimable, should be used to produce a more general typology is a function of the goals of empirical inquiry for a specific methodological approach. Typologies constructed in one context may be unsuitable for others, or a new context may demand revisions to the typology (i.e., different idealizations or approximations) based on new explanatory goals. Another consideration arising from the scrutiny of reasons for utilizing a particular typology in a specific disciplinary context is the nature of its explanatory role. A typology can be what is explained or, alternatively, used for explaining other aspects of biological phenomena, or both (cf. Brigandt this issue).

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[25] My use of idealization and abstraction differs slightly from the detailed framework put forward by Martin Jones (Jones 2005). For Jones idealization is a form of misrepresentation whereas abstraction is a form of omission and the two are seen as contrasting strategies used in formulating models and laws. Although there is clearly something right about this characterization (that is also reflected in my usage), here I am using idealization and approximation as *local* forms of reasoning used in particular investigative contexts that contribute to more *global* forms, abstraction and generalization, which span across multiple investigative contexts (e.g., in theory formation). The extent of congruence between our perspectives remains a question for further study, but it should be noted that Jones's analysis is very much in the spirit required for an epistemological reconfiguration of typology in biology.

Most importantly for the present discussion, the explanatory interests underlying the formation of these biological typologies are often evolutionary. Whether protein domains, selection processes, modes of locomotion, or characters, these typologies are deployed in the service of comprehending evolution. It is for this reason that we should be suspicious of broadsides against the very idea of typological thinking—specific typologies are another matter.

5 Genuine Conflict Between Typological Representation and Evolutionary Research

Once we adopt an epistemological vantage point on typology, seeing it as an instantiation of representational reasoning relevant to explanation, we can revisit the question of whether typological representation is a stumbling block (albeit not a metaphysical one) to evolutionary investigation. It turns out that the answer is 'yes'. In a recent paper on the evolution of development in arthropods, it has been argued that the standardized periodization for later ontogeny in arthropods constitutes a barrier to proper evolutionary analysis.

> The traditional framework for the description of arthropod development takes the molt-to-molt interval as the fundamental unit of periodization … while a firm subdivision of development in stages is useful for describing arthropod ontogeny, this is limiting as a starting point for studying its evolution. Evolutionary change affects the association between different developmental processes, some of which are continuous in time whereas others are linked to the molting cycle. Events occurring once in life (hatching; first achieving sexual maturity) are traditionally used to establish boundaries between major units of arthropod developmental time, but these boundaries are quite labile (Minelli et al. 2006, p. 373).

Here is an explicit case where a typology from developmental biology appears to obstruct the study of evolution. But notice the contrast with blanket condemnations of typology; it is not typological thinking per se that is the problem but a particular typology. The conventional periodization of later ontogeny is in terms of molt-to-molt intervals (e.g., instars) subsequent to hatching, which are then grouped into stages (e.g., larva, pupa, and imago for insects). But this periodization does have a legitimate function in describing the ontogeny of particular arthropod taxa. This is reinforced by the fact that the periodization of embryonic development (earlier ontogeny) prior to molting is not being criticized. A molt–molt periodization is only problematic when used for a different explanatory purpose, namely investigating evolutionary changes in the very events utilized to construct the typology. The distinctness of periodizations encourages more precise explanations within particular disciplinary approaches and alternative periodizations can be utilized as a methodological tool across disciplinary approaches for dissecting complex biological phenomena (Griesemer 1996).

In addition to the fact that typological thinking per se is not the problem, it is also significant that the problematic aspects of this periodization are not due to essentialism but the lability of the characters used to define the intervals. The authors leave open whether defining the intervals with stable characters is legitimate (they may not be available) and their implicit endorsement of the periodization of embryonic development is in accord with this. Typology using molt–molt intervals is an obstacle because these authors want to explain evolutionary processes that hinge on the temporal variability of molting intervals and their correlated developmental events. The source of epistemological conflict between typology and evolutionary analysis is clear: the shared features used to establish a representational typology cannot be analyzed evolutionarily because they are intentionally being stabilized around a type for other explanatory reasons. Molt–molt intervals are a problematic temporal typology only because of an illicit transference of this typology into a new explanatory context (the evolutionary origin of postembryonic novelties), which arises from a distinct methodological approach. In short, typologies exhibit explanatory relativity. Therefore, a key issue for multidisciplinary syntheses that are aimed at answering evolutionary questions (e.g., Evo-devo) is how these typologies (periodizations, as well as others) can be integrated across disciplinary approaches. The problem is not the removal of typologies but rather their coordination (cf. Collins et al. 2007).[26]

6 Changing the Subject and Other Worries

There are a variety of objections that can be raised against the foregoing attempt to reconfigure typology. Maybe the most natural objection is that I have changed the subject. The issue of typological thinking versus population thinking seems to be a much more focused question about metaphysical commitments and my epistemological characterization of typological thinking casts too wide of a net. The reconfiguration only succeeds by trading in this specific, traditional worry about typology (or one type concept) discussed in evolutionary biology for some general aspects of scientific reasoning. There is a grain of truth in this objection but it actually reinforces the import of my argument. Typological thinking construed epistemologically is much more broad than the metaphysically malfeasant typology of concern to Mayr and others. But the point is that this broader domain, which *includes* epistemological issues relevant to the more famous, problematic 'typological thinking', has been ignored precisely because of an overly narrow focus on the purported metaphysical conflict. Nothing in my account prevents one from drawing the metaphysical conclusion that a form of typology is inherently at odds with an evolutionary understanding of living phenomena. The difficulty is that we have not paid enough attention to the diversity of typological thinking as modes of scientific reasoning within multiple disciplinary contexts. And this is quite

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[26] This does not mean that typologies cannot eventually be jettisoned as inappropriate. In the context of using developmental sequences for reconstructing phylogeny, Alberch (1985) argued that developmental sequences understood as temporal stages were inadequate and needed to be replaced with an understanding of developmental sequences as causally connected events. The task of coordinating typologies may involve the rejection or modification of existing typologies, as well as the creation of new ones.

germane to the original worry since Mayr's condemnations of typological thinking are clearly tied to distinct disciplinary approaches (cf. Love 2003).

Another potential objection concerns whether the attempt to segregate metaphysical and epistemological issues can be accomplished. As discussed in Sect. 3, the point is not to advocate for a removal of metaphysical questions related to typology but rather to shift attention to epistemological questions bearing on typological thinking in terms of representing natural phenomena in biology. But the worry may linger: what do typologies represent or what do they refer to as representations? Don't we need a causal basis of shared properties (metaphysics) in order for a typology to be legitimately used in explanations (epistemology) because this is what gives the typology counterfactual force (cf. Griffiths 1999)? Unless characters are genuinely shared across species (metaphysics) then the epistemological distinction between characters and their states is illegitimate (Sect. 4.5). While not wanting to deny these claims, this worry simply needs to be methodologically impounded. To ask questions of reference is to return to issues centered on natural kinds, which need input from an analysis of how the typological representations are made and what considerations govern their use. Consider again the character of egg diameter and its three character states (<200 μm; 200–350 μm; >350 μm). Prior to assessing whether or not egg diameter is a genuinely shared character, we can ask why echinoid systematists routinely use it (and the corresponding tripartite character state distinction) when constructing phylogenies.[27] It may turn out that there is a genuinely shared character that is correlated with what we term egg diameter, such that egg diameter is not a genuine character. But our understanding of this particular typology is not fundamentally dependent on this assessment. In fact, it is more plausible that we might determine that egg diameter and its three character states are not genuine only after paying attention to how and why the typology was constructed in the first place (i.e., epistemology). Because accounts of natural kinds are related to the scientific practice of constructing and using concepts for explanation and prediction, our method should be one of proceeding from the actual details of the formation and functioning of these typologies to their significance for the reference of theoretical terms (e.g., is egg diameter a genuine character?) and questions of scientific realism (i.e., metaphysics).

A very different worry is that my survey of different disciplines is idiosyncratic or that my implicit individuation of them is artificial. If this was true then the heterogeneity of typological thinking in these different investigative contexts might be exaggerated or misconstrued by not being representative. For example, my discussion of characters and character states in systematics clearly leaves untouched many aspects of taxonomic practice relevant to biological classification. Alternatively, it might be possible to subordinate this seeming heterogeneity underneath an overarching account of typology formation. Although this latter possibility cannot be ruled out at this time (simply because the investigative details necessary to make this assessment are not yet available), it is critical to recognize that the import of my exemplars is not

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[27] More generally, why are most character states bipartite or tripartite? A plausible answer is in terms of the pragmatic need of systematists to routinely and reliably score characters for phylogenetic analyses (epistemology), not that nature usually divides itself in dichotomies and trichotomies (metaphysics).

tied to any contentious account of disciplinary individuation. If the boundaries were drawn differently so as to include two or more of the above exemplars within a single disciplinary nexus, then their original function in the argument is untouched. They are meant to highlight the *diversity* of typological thinking (*qua* representational reasoning) in biological science; diversity within a discipline makes this point in many respects just as well as diversity between disciplines. A description of this typology diversity is independent of whether it should be governed by some set of comprehensive principles applicable to all representational reasoning (a possibility that is *prima facie* implausible in my estimation.)

A final concern related to disciplinary individuation is that the exemplars I highlighted have not been dealt with in sufficient detail. I am quite aware of this but hold that it merely reinforces the reconfiguration I am suggesting. That is, we do not yet know enough about the details of the epistemology of typological thinking utilized in these different areas of biology, whether to better understand typology in life science inquiry or to evaluate whether there are fundamental conflicts with population thinking and the metaphysics of evolutionary processes. Although several philosophers have made contributions relevant to the reconfiguration I am suggesting (see below), my hope is that these exemplars within the context of my argument for a reconfiguration of typology in biology will spur further investigation of these epistemic practices and shed light on their construction and utilization.

7 Questions for an Epistemological Research Program

If the argument in this paper is successful, it suggests a research program related to typological representation for both biologists and philosophers that concentrates on epistemological issues. It foregrounds the explanatory interests of different fields in biology and is sensitive to the heterogeneity of typological reasoning in life science disciplines. These divergent interests drive the formation of typologies through idealization and approximation with respect to particular details for the purposes of investigation and explanation. For example, how do typologies work in scientific modeling? Harré's taxonomy of models is sensitive to idealization and approximation (Harré 1970; Ellis 2001), but these accounts are driven by metaphysical questions regarding the existence and nature of the objects represented, including the status of essentialism. From the distinct perspective of epistemology, several research questions pertaining to typology as representational reasoning relevant to models stand in need of analysis (Jones 2005; Morrison 2005; Weisberg forthcoming). The scientists themselves recognize these issues.[28]

A historical question that emerges from this reconfiguration is whether it usefully captures the way typological thinking operated in earlier chapters of biological research. A cursory glance indicates an affirmative answer. For example, in responding to Mayr's distinction and its concomitant disparagement of morphology,

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[28] "The proper model description of a complex system depends on both the context of the problem and the question one wants to ask. … The art of modeling is to choose the proper degree of detail" (Schuster 2005, pp. 12–13).

Everett Olson explicitly highlights the role of representational reasoning in the context of evolutionary explanation.

> The attention of the morphologist tends to be centered upon form and involves to some extent a typological aspect—typological in that there is some rather concrete, visual *image* involved. Students with this point of view are not quite the unreconstructed villains of the field of evolution as those described by Mayr (1959). But there is the strong tendency to *think* in terms of morphology as *characteristic* of an animal, that there is a form *representative* of a species and metric characters *characteristic* of a genus. What often may appear to be a purely typological view *is not, in fact, based on a disregard or ignorance of population concepts and variability* but upon initial concern with stages in evolution *represented* by some genus or species, or even a *representative* of some higher category (Olson 1960, p. 535; my emphasis).

Related to this are the different styles of representational reasoning associated with typology that were adopted by past researchers (cf. Elwick 2007). But these historical questions also bear on contemporary philosophical analysis. Analyzing the origin of particular typologies that have now become standardized becomes a necessary part of the philosophical reconstruction of their epistemological roles (cf. Lennox 2001). For example, the history of normal stages has recently been examined and shows a variety of conflicting social and epistemological issues feeding into decisions about temporal typologies (Hopwood 2005, 2007), including an intense concern about how individual variation is dealt with in visual representations.

Another question of critical philosophical interest is whether typological representation is substantially different across biological disciplines. One aspect of this concerns whether any prevalent patterns of idealization and approximation are evident in diverse biological typologies. Rasmus Winther's recent discussion of styles of reasoning in 'compositional biology' is explicitly based on the representational tactics used by investigators and identifies patterns of individuation across different disciplines pertinent to the epistemology of typology (Winther 2006). Through a careful examination of exemplars from comparative anatomy, functional morphology, and developmental biology, he demonstrates how they adopt distinct 'partitioning frames' by using structure oriented or process oriented theoretical perspectives.[29] This is one of the few available frameworks that is

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[29] Comparative anatomy uses structural partitioning frames to produce anatomical parts, functional morphology classifies parts in terms of their activities (process partitioning), and developmental biology's concern with causation during ontogeny leads to partitioning 'cause-parts' from 'outcome-parts' (process partitioning) (For full details, see Winther 2006, pp. 479–494). This analysis could be applied to several of above-mentioned typology exemplars. Winther also discusses temporal periodization, although I think normal stages are not best understood as 'cause-parts' and 'outcome parts'. Winther holds that 'compositional biology' uses part/whole units in a way different from 'formal biology', which use mathematics to model quantitative relations among terms that represent relevant biological variables. This distinction is congruent with the recognition that the formation of typologies (understood as a form of representational reasoning) includes the strategy of decomposing a system into parts (as often seen in 'compositional biology') but is not exhausted by it. Further questions include whether typologies are formed from single or multiple partitioning frames and how the use of different kinds of partitioning frames can be both a necessity and an obstacle for multi-disciplinary explanations.

sensitive to the tactics of representation and germane to epistemological issues about typology in several of the reviewed disciplines. It also exhibits a fruitful trafficking between scientific strategies and tactics.

A second aspect is whether these representations cross-classify systematically or haphazardly. Dupré has argued that cross-classification generates incommensurability across biological disciplines (Dupré 1993), although it is possible that upon further investigation translations between typologies could be accomplished (cf. Winther 2006). Another pressing question is whether biological disciplines need commensurable typologies. The most likely realm of adjudication is multi-disciplinary research, where empirically adequate explanations require the input of more than one research perspective (Love forthcoming). This is what is at stake in the question about whether typological thinking is necessary or merely a hindrance to Evo-devo research. If the problems Evo-devo tackles are inherently multi-disciplinary, then typologies from multiple, contributing disciplines will be necessary. But as the case of arthropod molts indicates, they can also be an obstacle if not modified in appropriate ways. This generates a third aspect of philosophical inquiry regarding how to integrate or synthesize typologies (cf. Griesemer 1996), which is necessary to directly address the possibility and/or necessity of typological thinking in the context of Evo-devo, something of interest both to its practitioners and philosophical observers.[30]

A final set of philosophical questions relates representational reasoning from biology to that of other sciences, especially physics. For example, van Fraassen has argued that, "science is a representation of the observable phenomena, by means of mathematical models…the book of science is written in the language of mathematics, and mathematics represents structure alone" (van Fraassen 2006, pp. 13–14). But many of the typologies discussed above do not require mathematics and achieve their representation other than via structure (cf. Winther 2006). How does the representation of physical phenomena relate to representation of biological phenomena? Studies of idealization in physics highlight features of interest in biology, such as isolating objects of inquiry from their environment (either physically or theoretically) or simplifying through approximation (e.g., Hüttemann 2001; cf. Jones 2005). The pictorial dimension of representation in biology seems to touch on issues distinct from those attaching to mathematical representation (cf. Luisi and Thomas 1990), but it might be argued that a different kind of mathematics needs to be utilized or is yet to be fully developed (cf. Stadler et al. 2001). All of these facets lead back to more general issues about the diversity of concepts (i.e., epistemic units of representation) and their formation in different biological and physical science disciplines (cf. Hempel 1952, p. 50ff; Nersessian 2005).

An epistemological reconfiguration of typology does not constitute an argument for or against claims about essentialism. It is a recommendation to discuss typology apart from essentialism or natural kinds. Focus on how classification occurs without dwelling upon its naturalness; analyze the idealizations and approximations that are

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[30] This is a less pessimistic conclusion about the synthesis of evolution and development than that offered by Amundson (2005), but it is based on a more expansive (and epistemological) conception of typological thinking. Amundson construes typology more metaphysically than epistemologically (e.g., Amundson 2005, chap. 11).

the tactics of scientific representation. Although the heterogeneity of representational typology could be seen as support for metaphysical pluralism about biological kinds (Dupré 1993, 2002; Hacking 1991), the argument about typology *qua* representational reasoning should resonate with diverse perspectives on essentialism because many agree that natural kinds other than species may exist in biology. A reconfiguration of typological thinking in biology away from the metaphysics of essentialism to the epistemology of representation has the potential to aid philosophers and biologists in comprehending heterogeneous reasoning strategies in the life sciences, where they potentially conflict, and how they must be synthesized in order to adequately account for complex biological phenomena.

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References

Alberch P (1985) Problems with the interpretation of developmental sequences. Syst Zool 34:46–58. doi:10.2307/2413344

Alexander RM (2003) Principles of animal locomotion. Princeton University Press, Princeton and Oxford

Amundson R (1998) Typology reconsidered: two doctrines on the history of evolutionary biology. Biol Philos 13:153–177. doi:10.1023/A:1006599002775

Amundson R (2001) Adaptation and development: on the lack of common ground. In: Orzack SH, Sober E (eds) Adaptationism and optimality. Cambridge University Press, New York, pp 303–334

Amundson R (2005) The changing role of the embryo in evolutionary thought: structure and synthesis. Cambridge University Press, New York

Biewener AA (2003) Animal locomotion. Oxford University Press, New York

Boyd R (1991) Realism, anti-foundationalism and the enthusiasm for natural kinds. Philos Stud 61:127–148. doi:10.1007/BF00385837

Boyd R (1999) Homeostasis, species and higher taxa. In: Wilson RA (ed) Species: new interdisciplinary essays. MIT, Cambridge, pp 141–185

Brandon R (1990) Adaptation and environment. Princeton University Press, Princeton

Brigandt I (2007) Typology now: homology and developmental constraints explain evolvability. Biol Philos 22:709–725. doi:10.1007/s10539-007-9089-3

Budd GE (2001) Why are arthropods segmented? Evol Dev 3:332–342. doi:10.1046/j.1525-142X.2001.01041.x

Cartwright N (1989) Nature's capacities and their measurement. Clarendon, Oxford

Cartwright N (1999) The dappled world: a study of the boundaries of science. Cambridge University Press, New York

Chung C (2003) On the origin of the typological/population distinction in Ernst Mayr's changing views of species, 1942–1959. Stud Hist Philos Biol Biomed Sci 34:277–296. doi:10.1016/S1369-8486(03)00026-8

Collins JP, Gilbert SF, Laubichler MD, Müller GB (2007) Modeling in EvoDevo: how to integrate development, evolution, and ecology. In: Laubichler MD, Müller GB (eds) Modeling biology. MIT, Cambridge, pp 355–378

Denton MJ, Marshall CJ, Legge M (2002) The protein folds as platonic forms: new support for the pre-Darwinian conception of evolution by natural law. J Theor Biol 219:325–342. doi:10.1006/jtbi.2002.3128

Dobzhansky T (1973) Nothing in biology makes sense except in the light of evolution. Am Biol Teach 35:125–129

Dupré J (1993) The disorder of things: metaphysical foundations of the disunity of science. Harvard University Press, Cambridge, MA

Dupré J (2001) In defence of classification. Stud Hist Philos Biol Biomed Sci 32:203–219. doi:10.1016/S1369-8486(01)00003-6

Dupré J (2002) Humans and other animals. Oxford University Press, New York

Ellis B (2001) Scientific essentialism. Cambridge University Press, New York

Elwick J (2007) Styles of reasoning in early to mid-Victorian life research: analysis:synthesis and palaetiology. J Hist Biol 40:35–69. doi:10.1007/s10739-006-9106-4

Endler JA (1986) Natural selection in the wild. Princeton University Press, Princeton

Endler JA (1992) Natural selection: current usages. In: Keller EF, Lloyd EA (eds) Keywords in evolutionary biology. Harvard University Press, Cambridge, MA, pp 220–224

Ereshefsky M Natural kinds in biology. In Routledge encyclopedia of philosophy (forthcoming)

Farber PF (1976) The type-concept in zoology during the first half of the nineteenth century. J Hist Biol 9:93–119. doi:10.1007/BF00129174

Garel J-R (1999) Folding of large proteins: multidomain and multisubunit proteins. In: Creighton TE (ed) Protein folding. WH Freeman and Co, New York, pp 405–454

Ghiselin MT (1997) Metaphysics and the origin of species. SUNY, Albany

Giere R, Bickle J, Maudlin RF (2006) Understanding scientific reasoning, 5th edn. Wadsworth/Thomson Learning, Belmont

Gillett C (2002) The dimensions of realization: a critique of the standard view. Analysis 62:316–323. doi:10.1111/1467-8284.00377

Gillett C (2003) The metaphysics of realization, multiple realizability, and the special sciences. J Philos 100:591–603

Grewal SIS, Elgin SCR (2007) Transcription and RNA interference in the formation of heterochromatin. Nature 447:399–406. doi:10.1038/nature05914

Griesemer JR (1996) Periodization and models in historical biology. In: Ghiselin MT, Pinna G (eds) New perspectives on the history of life. California Academy of Sciences, San Francisco, pp 19–30

Griffiths PE (1999) Squaring the circle: natural kinds with historical essences. In: Wilson RA (ed) Species: new interdisciplinary essays. MIT, Cambridge, pp 209–228

Hacking I (1991) A tradition of natural kinds. Philos Stud 61:109–126. doi:10.1007/BF00385836

Hamburger V, Hamilton HL (1951) A series of normal stages in the development of the chick embryo. J Morphol 88:49–92. doi:10.1002/jmor.1050880104

Harré R (1970) The principles of scientific thinking. Macmillan, London

Hempel CG (1952) Fundamentals of concept formation in empirical science. University of Chicago Press, Chicago

Hempel CG (1965 [1952]) Typological methods in the natural and social sciences. In: Aspects of scientific explanation and other essays in the philosophy of science. The Free Press, New York, pp 155–171

Hempel CG (1965 [1961]) Fundamentals of taxonomy. In: Aspects of scientific explanation and other essays in the philosophy of science. The Free Press, New York, pp 137–154

Hopwood N (2005) Visual standards and disciplinary change: normal plates, tables and stages in embryology. Hist Sci 43:239–303

Hopwood N (2007) A history of normal plates, tables and stages in vertebrate embryology. Int J Dev Biol 51:1–26. doi:10.1387/ijdb.062189nh

Hull DL (1965) The effects of essentialism on taxonomy: 2, 000 years of stasis. Br J Philos Sci 15/16:314–326 311–318

Hull DL (1978) A matter of individuality. Philos Sci 45:335–360. doi:10.1086/288811

Hüttemann A (2001) Idealizations in physics. In: Ferrari M, Stamatescu I-O (eds) Symbol and physical knowledge. Springer, Heidelberg, pp 177–192

Jenner RA (2006) Unburdening Evo-devo: ancestral attractions, model organisms, and basal baloney. Dev Genes Evol 216:385–394. doi:10.1007/s00427-006-0084-5

Jones MR (2005) Idealization and abstraction: a framework. In: Jones MR, Cartwright N (eds) Idealization XII: correcting the model. Idealization and abstraction in the sciences (Poznan studies in the philosophy of the sciences and the humanities, vol. 86). Rodopi, Amsterdam, New York, pp 173–217

Kauffman SA (1971) Articulation of parts explanations in biology and the rational search for them. In: Buck RC, Cohen RS (eds) PSA 1970. Reidel, Dordrecht, Holland, pp 257–272

LaPorte J (2004) Natural kinds and conceptual change. Cambridge University Press, New York

Lennox JG (2001) History and philosophy of science: the phylogenetic approach. Hist Cienc Saude Manguinhos VIII:655–669

Love AC (2003) Evolutionary morphology, innovation, and the synthesis of evolutionary and developmental biology. Biol Philos 18:309–345. doi:10.1023/A:1023940220348

Love AC (2006) Evolutionary morphology and Evo-devo: hierarchy and novelty. Theory Biosci 124:317–333. doi:10.1016/j.thbio.2005.11.006

Love AC (2007) Morphological and paleontological perspectives for a history of Evo-devo. In: Laubichler MD, Maienschein J (eds) From embryology to Evo-devo: a history of developmental evolution. MIT, Cambridge, MA, pp 267–307

Love AC Explaining evolutionary innovations and novelties: criteria of explanatory adequacy and epistemological prerequisites. Philos Sci (forthcoming)

Luisi P-L, Thomas RM (1990) The pictographic molecular paradigm: pictorial communication in the chemical and biological sciences. Naturewissenschaften 77:67–74. doi:10.1007/BF01131776

Mayr E (1959) Darwin and the evolutionary theory in biology. In: Meggers BJ (ed) Evolution and anthropology: a centennial appraisal. Theo Gaus' Sons, Inc, Brooklyn, NY, pp 1–10

Mayr E (1976 [1955]) Karl Jordan's contribution to current concepts in systematics and evolution. In: Evolution and the diversity of life. Harvard University Press, Cambridge, MA, pp 297–306

Mayr E (1980) Prologue: some thoughts on the history of the evolutionary synthesis. In: Mayr E, Provine WB (eds) The evolutionary synthesis: perspectives on the unification of biology. Harvard University Press, Cambridge, pp 1–48

Minelli A (2003) The development of animal form: ontogeny, morphology, and evolution. Cambridge University Press, Cambridge

Minelli A, Brena C, Deflorian G, Maruzzo D, Fusco G (2006) From embryo to adult-beyond the conventional periodization of arthropod development. Dev Gen Evol 216:373–383

Mitchell SD (2000) Dimensions of scientific law. Philos Sci 67:242–265. doi:10.1086/392774

Morrison M (2005) Approximating the real: the role of idealizations in physical theory. In: Jones MR, Cartwright N (eds) Idealization XII: correcting the model. Idealization and abstraction in the sciences (Poznan studies in the philosophy of the sciences and the humanities, vol. 86). Rodopi, Amsterdam, New York, pp 145–172

Nersessian NJ (2005) Abstraction via generic modeling in concept formation in science. In: Jones MR, Cartwright N (eds) Idealization XII: correcting the model. Idealization and abstraction in the sciences (Poznan studies in the philosophy of the sciences and the humanities, vol. 86). Rodopi, Amsterdam, pp 117–143

Nieuwkoop PD, Faber J (eds) (1956) Normal table of *Xenopus laevis* (Daudin): a systematical and chronological survey of the development from fertilized egg till the end of metamorphosis. North Holland, Amsterdam

Olson EC (1960) Morphology, paleontology, and evolution. In: Tax S (ed) Evolution after Darwin. Volume 1: the evolution of life, its origin, history and future. University of Chicago Press, Chicago, pp 523–545

Polly PD (2007) Limbs in mammalian evolution. In: Hall BK (ed) Fins into limbs: evolution, development, and transformation. University of Chicago Press, Chicago, pp 245–268

Psillos S (1999) Scientific realism: how science tracks truth. Routledge, London

Richardson MK, Minelli A, Coates MI (1999) Some problems with typological thinking in evolution and development. Evol Dev 1:5–7. doi:10.1046/j.1525-142x.1999.00112.x

Rieppel O (2006) 'Type' in morphology and phylogeny. J Morphol 267:528–535. doi:10.1002/jmor.10424

Rieppel O, Kearney M (2007) The poverty of taxonomic characters. Biol Philos 22:95–113. doi:10.1007/s10539-006-9024-z

Sarkar S (1998) Genetics and reductionism. Cambridge University Press, Cambridge

Schuster P (2005) "Less is more" and the art of modeling complex phenomena. Complexity 11:11–13. doi:10.1002/cplx.20107

Shubin NH, Alberch P (1986) A morphogenetic approach to the origin and basic organization of the tetrapod limb. In: Hecht MK, Wallace B, Prance GT (eds) Evolutionary biology. Plenum Press, New York, pp 319–387

Sober E (1980) Evolution, population thinking and essentialism. Philos Sci 47:350–383. doi:10.1086/288942

Sober E (2000) Philosophy of biology, 2nd edn. Westview Press, Boulder

Stadler BMR, Stadler PF, Wagner GP, Fontana W (2001) The topology of the possible: formal spaces underlying patterns of evolutionary change. J Theor Biol 213:241–274. doi:10.1006/jtbi.2001.2423

Stamos DN (2005) Pre-Darwinian taxonomy and essentialism—a reply to Mary Winsor. Biol Philos 20:79–96. doi:10.1007/s10539-005-0401-9

Steup M (2008) Epistemology. In: Zalta EN (ed) The Stanford encyclopedia of philosophy (Fall 2008 Edition). <http://plato.stanford.edu/archives/fall2008/entries/epistemology/>

van Fraassen B (1980) The scientific image. Oxford University Press, New York

van Fraassen B (2006) Weyl's paradox: the distance between structure and perspective. In: Berg-Hildebrand A, Suhm C (eds) Bas C. van Fraassen: the fortunes of empiricism. Ontos Verlag, Frankfurt, pp 13–34

van Inwagen P (2007) Metaphysics. In: Zalta EN (ed) The Stanford Encyclopedia of Philosophy (Fall 2007 Edition). <http://plato.stanford.edu/archives/fall2007/entries/metaphysics/>

Wagner GP, Laubichler MD (2001) Character identification: the role of the organism. In: Wagner GP (ed) The character concept in evolutionary biology. Academic Press, San Diego, pp 141–163

Walsh D (2006) Evolutionary essentialism. Br J Philos Sci 57:425–448. doi:10.1093/bjps/axl001

Waters CK (2000) Molecules made biological. Rev Int Philos 4:539–564

Weisberg M Three kinds of idealization. J Philos (forthcoming)

Wilson RA (1999) Realism, essence, and kind: resuscitating species essentialism? In: Wilson RA (ed) Species: new interdisciplinary essays. MIT, Cambridge, MA, pp 187–207

Wilson RA (2005) Genes and the agents of life: the individual in the fragile sciences (biology). Cambridge University Press, New York

Wimsatt WC (1974) Complexity and organization. In: Schaffner KF, Cohen RS (eds) PSA 1972. Reidel, Dordrecht, Holland, pp 67–86

Wimsatt WC (1980) Reductionistic research strategies and their biases in the units of selection controversy. In: Nickles T (ed) Scientific discovery: case studies. Reidel, Dordrecht, Holland, pp 213–259

Winsor MP (2003) Non-essentialist methods in pre-Darwinian taxonomy. Biol Philos 18:387–400. doi:10.1023/A:1024139523966

Winsor MP (2006) The creation of the essentialism story: an exercise in metahistory. Hist Philos Life Sci 28:149–174

Winther RG (2006) Parts and theories in compositional biology. Biol Philos 21:471–499. doi:10.1007/s10539-005-9002-x

Woodward J (2003) Making things happen: a theory of causal explanation. Oxford University Press, New York

Wray GA (1996) Parallel evolution of nonfeeding larvae in echinoids. Syst Biol 45:308–322. doi:10.2307/2413566