Revising scientific concepts with multiple meanings: beyond pluralism and eliminativism

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Abstract: In the recent debate about scientific concepts, pluralists claim that scientists can legitimately use concepts with multiple meanings, while eliminativists argue that scientists should abandon such concepts in favor of more precisely defined subconcepts. While pluralists and eliminativists already share key assumptions about conceptual development, their normative positions still appear to suggest that the process of revising concepts is a dichotomous choice between keeping the concept and abandoning it altogether. To move beyond pluralism and eliminativism, I discuss three options of revising concepts in light of new findings, and when scientists should choose each of them.

1. Introduction

The question of how scientists revise their concepts in response to new empirical findings is central to philosophical debates about conceptual change. Through detailed analyses of concepts such as “gene”, “force” or “acid”, we have learnt that many scientific concepts are polysemous—they develop multiple meanings when scientists apply them to related but different phenomena (Kitcher and Stanford 2000, Wilson 2006, Brigandt 2010). The recent debate contains two normative positions how scientists should revise polysemous concepts in light of new findings. Pluralists claim that scientists should keep the original term to facilitate communication across contexts in which scientists study the different kind of phenomena falling under the concept (Brigandt 2010, Novick and Doolittle 2021, Haueis 2021a). By contrast, eliminativists claim that scientists should revise their conceptual framework by abandoning the original term and replacing it with different subconcepts for each of the different phenomena (Machery 2009, Taylor and Vickers 2017).

In this paper, I argue that while pluralists and eliminativits already converge on key descriptive assumptions, their normative positions still suggest that revising polysemous concepts is a dichotomous choice between keeping the concept or abandoning it altogether. I argue that we can overcome this dichotomy once we recognize that there are different shades of being pluralist and eliminativist rather than just two opposing options available to scientists who revise polysemous concepts. I articulate three such options which incorporate elements of pluralism and eliminativism. The first option (conceptual housekeeping) incorporates pluralist elements by acknowledging that scientists often retain a concept despite multiple meanings, while also showing when scientists need to revise a concept to exclude certain phenomena from its extension. The second option (conceptual retirement) combines both pluralist and eliminativist elements: it specifies when scientists should stop using the concept in future research, while past research under the concept is still useful and has epistemically significant relations between phenomena the term refers to. The third option (concept abandonment) only applies when new findings suggest that there are no epistemically significant relations between the different phenomena to which the polysemous term refers.

The paper proceeds as follows. In section 2, I first show that pluralists and eliminativists converge on shared assumptions about polysemous concepts in science. I then argue that the debate still presents the process of revising such concepts as a dichotomous choice between keeping and abandoning a term with multiple meanings. In section 3, I present three different options of revising concepts and use the development of “cortical column” in neuroscience to illustrate the conditions under which scientists should choose each of them. Section 4 concludes.

2. Pluralism and eliminativism about scientific concepts with multiple meanings

2.1 Shared descriptive assumptions about conceptual development

Although their positions differ in detail, pluralists and eliminativists share three broad descriptive assumptions about how scientific concepts acquire multiple meanings in the first place. The first shared assumption is that many scientific concepts acquire multiple related meanings because they are used in a *context-specific* manner. Scientists will usually introduce a new concept by proposing how to use it in a particular investigative context (Taylor and Vickers 2017, 27; Wilson 2006, 516). According to Haueis (2021a), contexts are individuated by the particular phenomenon or feature that the novel term is supposed to characterize, the experimental or modeling technique that scientists apply to study the phenomenon, the length scale at which that phenomenon is studied, and the domain of objects to which the phenomenon belongs. For instance: biologists developed the classical gene concept to characterize inheritance patterns that they observed when applying cross-breeding techniques to *Drosophila* (Brigandt 2010). This use characterizes genetic differences at the scale of whole organisms.

One way in which polysemy arises is that after a concept has proven successful in the initial investigative context (e.g., by allowing explanations), researchers usually extend it to novel phenomena in adjacent contexts (Wilson 2017, 27–30; Brigandt 2010, 31).[1] For example, the molecular gene concept developed out of the classical gene concept once researchers applied this term to mechanisms within individual cells, using novel methods such as centrifugation and x-ray crystallography. The domain of these scale-dependent uses of "gene" differs because there are classical genes which are not molecular genes and vice versa

[1] In other cases, the concept complexifies in the original domain, splitting the original context into multiple ones (Machery 2009).

(Brigandt 2010, 29). Pluralists and eliminativists make similar points about various scientific concepts such as "acid" (Stanford and Kitcher 2000) "hardness" (Wilson 2006, Taylor and Vickers 2017) or "species" (Ereshefsky 1998, Novick and Doolittle 2021). Thus, both camps agree that concepts acquire multiple meanings because they have different contextual uses.

The second shared assumption is that the different meanings of a polysemous term are related because there are epistemically significant relations between the *phenomena* it refers to. Researchers do not extend their concepts to just any phenomenon, but to those which "are closely related to old phenomena, and yet subtly but significantly different" (Taylor and Vickers 2017, 27). These relations are epistemically significant if researchers can use them to generate knowledge about the behavior of the phenomena (Wilson 2006; Novick and Doolittle 2021; Haueis 2021a). For example: intergenerational patterns of inheritance and intracellular mechanism of protein synthesis are related because biologists discovered that the latter is a way to reproduce heritable traits in the offspring organism. Yet, both phenomena are also subtly but significantly different, since phenotypic differences are relations between organisms whereas protein synthesis products are molecular entities within an individual organism. Thus, the different meanings of the classical and molecular gene concept are related because the phenomena they refer to are related (Brigandt 2010). If scientists have reasons to believe that these relations are epistemically significant, there is a legitimate sense in which the different meanings of a term belong to the same concept (see section 3.3).

The third shared assumption is that besides the phenomena scientists study when using a concept, investigative contexts are determined by the *epistemic goals* or theoretical roles that concept is supposed to play (Brigandt 2010, Taylor and Vickers 2017, 29). Epistemic goals are the cognitive achievements the scientific community attempts to reach when using the concept in experimentation or modeling. For example: biologists use the classical gene concept the achieve the goal of predicting patterns of inheritance, and the molecular gene concept to explain how amino acids within the cell bring about their molecular products (Brigandt 2010, 26f.; 28f.). Pluralists invoke epistemic goals such as explanation of a phenomenon to account for the rationality of conceptual change in science (Brigandt 2010) or the flexibility of scientific language (Wilson 2006). Eliminativists see the plurality of epistemic goals associated with a term as a source of miscommunication (Taylor and Vickers 2017) or invoke goals such as formulating inductive generalizations to assess the utility of concepts with multiple meanings (Machery 2009). All these proposals presuppose that scientific concepts have epistemic goals, and that philosophers can use them to evaluate how scientists should revise them in light of new findings.

In sum, pluralists and eliminativists agree that scientific concepts acquire multiple meanings because researchers introduce them in a local investigative context and extend them to related but subtly different phenomena in pursuit of their epistemic goals. Yet, despite these descriptive agreements, both sides hold opposing views about how scientists should revise concepts with multiple meanings.

2.2 Revising concepts as choice between retaining and abandoning terms

Although pluralists and eliminativists converge on shared descriptive assumptions, they sometimes use these to provide opposing normative recommendations how scientists should revise polysemous concepts. First, consider Wilson (2006) and Taylor and Vickers (2017), who agree that terms like "hardness" in materials science have context-specific uses. Depending on the test and type of material, "hardness" can mean resistance to indentation, scratching or squeezing. Wilson (2006, 350) holds that "its associations with swift practicality guarantee that ["hardness"] will never vanish utterly from the colloquial vocabulary of anyone who works with material". By contrast, Taylor and Vickers (2017, 33) argue that "one just does not need the word 'hard' to communicate about materials – quite clearly, one can say everything one wants to say about materials using other terms". So, while pluralists like Wilson suggest that researchers should keep "hardness" because its context-specific uses have proven practically successful, eliminativists like Taylor and Vickers recommend to eliminate this term in favor of more precise terms.

Second, consider how epistemically significant relations between phenomena figure in pluralist and eliminativists arguments about revising concept in light of new empirical findings. Consider debates about keeping or eliminating general terms like "species" in biology or "concept" in psychology. Pluralists about "species", for instance, argue that we should keep the general term because there are "real connections" (Novick and Doolittle 2021, 75) that allow biologists to transfer knowledge and methods from the eucaryotic to the procaryotic domain and vice versa. Eliminating "species" and using different terms for each domain "runs the risk of underappreciating these connections" (ibid., 79). Here, the existence of relations between domains of phenomena is used to justify that keeping a concept with multiple meanings is beneficial.

With regard to other terms, however, eliminativists have resisted this conclusion. Machery (2009), for instance, argues that psychologists should eliminate "concept" from psychology in favor of "prototype", "exemplar" and "theory". Psychologists can still ask meaningful questions about the relations between all three kinds of storing knowledge (e.g., how they are coordinated) without using the term "concept" (Machery 2010, 338) thinks that. The danger of keeping the term is that scientists search for properties shared across all domain-specific applications "concept" (Machery 2009, 242), whereas the relations between prototypes, exemplars and theories may be local at best. So while pluralists hold that keeping a term allows scientists to pursue promising research projects which reveal significant relations between phenomena, eliminativists argue that scientists should abandon the term to avoid fruitless research into commonalities across domains where none exist.

Third, consider how Brigandt (2010) and Taylor and Vickers (2017) invoke epistemic goals to argue that researchers should keep or eliminate a polysemous concept. Consider again the molecular gene concept, which has several context-dependent uses which individuate genes differently on a molecular scale. Brigandt argues that: "the notion of a concept's epistemic goal points to some conceptual unity: underlying the various different uses of this term is a common motivation—to account for gene function" (ibid., 35). Biologists specify this *generic* epistemic goal in various ways when using "gene" in particular experiments. Biologists should thus keep the same term to facilitate communication across contexts, which helps them integrate explanatory practices (Neto 2020).

By contrast, eliminativists like Taylor and Vickers (2017, 28) worry that if scientists use a term to pursue many different epistemic goals, it will acquire many different meanings, thus increasing the risk of *miscommunication*. In the case of the molecular gene concept, biologists risk talking past each other if they pick out different molecular entities when using "gene" in different investigative contexts. On Taylor and Vickers' selective eliminativism, biologists should stop using “gene” in these contexts because the many different epistemic goals can lead to miscommunication. They would thus reject Brigandt’s appeal to generic epistemic goals because each contextual specification of this goal shifts the reference of the term, and thus is a potential source of confusion. It thus seems that when appealing to epistemic goals, pluralists argue that scientists should keep the same term to facilitate communication in pursuit of a shared epistemic goal, while eliminativists argue that scientists should abandon the concept to avoid miscommunication when pursuing different epistemic goals associated with it.

Let me stress that despite this apparent opposition of normative positions, some pluralists agree with eliminativists that not every new use of a concept is legitimate (Haueis 2021a) while some eliminativists concede that in some contexts, polysemy is unproblematic (Taylor and Vickers 2017). Yet it seems that framing the debate in terms of pluralism and eliminativism risks reiterating the dichotomy about retaining versus replacing concepts which some scholars aim to overcome. I thus think the debate can move forward once we recognize that scientists want to do all the things that pluralists and eliminativists recommend about revising polysemous concepts in light of new findings. Scientists want to use concepts to facilitate communication across related research, but also minimize miscommunication by sometimes rejecting new proposed uses of a concept. Researchers also want concepts which allow them to pursue promising new projects while avoiding degenerating research programs. I now present three ways in which scientists can revise concepts that incorporates both pluralist and eliminativist insights.

3. Three options for revising concepts with multiple meanings

3.1 Conceptual housekeeping

While scientists often fruitfully apply existing concepts to novel domains, they also sometimes explicitly reject a novel use as unjustified. In these situations, scientists engage in *conceptual housekeeping*, i.e. conscious and explicit efforts to regulate the use of a polysemous concept in light of new discoveries. This option of revising concepts acknowledges that scientists can legitimately retain a polysemous concept, but also specifies when they should reject particular uses of that concept.

There are two normative principles that govern conceptual housekeeping (Novick and Haueis forthcoming). First, the *principle of minimalism* holds that scientists should only actively regiment the use of a polysemous concept if problems arise. This principle reflects the fact that collectively, scientists are often reticent to regulate terminology even if such interventions could reduce polysemy and imprecision. Philosophers who discuss scientific concepts sometimes assume that simplicity and precision are the default and complexity requires special justification (Carnap 1950). Minimalism instead assumes that tolerance of conceptual complexity is the default, and active intervention requires special justification. This assumption is supported by the observation that the use of imprecise concepts is widespread in science (Neto 2020) and that polysemy per se does not pose communicative problems (Haueis 2021a). Scientists should only actively regiment polysemous concepts if problems arise and persist despite methodological improvements. Minimalism is good normative policy because some problems may be impermanent and resolvable by further research.

Second, the *principle of contextualism* holds that whether problem resolution requires narrowing or widening the extension of a concept depends on the epistemic goal scientists pursue within an investigative context. Epistemic goals pursued with a concept vary between contexts (section 2.1), but they also change over time within the same investigative context (Brigandt 2010, 30). Such diachronic changes are typically driven by new discoveries in the concept's domain of application. Contextualism reflects that relative to the epistemic goal pursued at t_1, researchers judge extending a concept to a novel case as justified, whereas relative to the epistemic goal pursued at t_2, researchers judge this extension as an unmotivated.

To see how minimalism and contextualism apply to conceptual housekeeping in practice, consider the concept "cortical column" in neuroscience. This concept refers to vertical structures in which neurons respond to the same sensory stimulus. "Cortical column" has multiple meanings because researchers have found such structures in various cortical areas at different spatial scales, and thus speak of "minicolumns", "columns" and "hypercolumns" (Haueis 2021b). In the 1970s, researchers proposed to extend "cortical column" to barrel-shaped structures in the mouse primary somatosensory cortex (Woosley and van der Loos 1970). A problem with this proposal is that barrels map *sensory topography*, i.e. they map the location of whisker hair on the mouse sensory surface onto the cortical surface. Hubel and Wiesel (1974) argued that columns are not constituted by sensory topography but map additional stimulus features, such as tactile modality or visual orientation. Despite this issue, Hubel and Wiesel (1974, 289) did not explicitly regiment terminology: "whether [whisker barrels] should be considered columns is a matter of taste and semantics". The principle of minimalism explains that this reticent attitude is rational because the issue of subsuming sensory topography under "cortical column" could be resolved by further research comparing different cortical structures.

The principle of contextualism explains why researchers like Mountcastle (1978) accepted extending "cortical column" to barrel structures. In the 1970s, neuroscientists used "cortical column" to pursue the goal of identifying a building block in the neocortex which has discrete anatomical boundaries and is present in all mammals (Haueis 2021b). The discovery of barrels supported these beliefs, because barrels are separated by cell-free regions and their presence in mice would extend the domain of "cortical column" from primates and felines to rodents. The goal of identifying a species-invariant, anatomically discrete building block thus justified extending "cortical column" to whisker barrels.

The issue of sensory topography, however, persisted despite improved methods to study cortical structures across species. These studies showed that cortical structures map sensory topography in an isomorphic fashion (so-called "cortical isomorphs"). This discovery suggests that the vertical structure of barrels is actually an artefact of the cylindrical shape of the body part being mapped (the mystacial vibrissa hair). Neuroscientists now saw an explicit need to regiment the application of "cortical column" to barrels (Horton and Adams 2005). They also lacked a positive justification to accept the wider extension because they longer used "cortical column" to identify a basic building block (see section 3.2 for details). In the absence of this epistemic goal, researchers vindicated Hubel and Wiesel's initial skepticism and excluded sensory topography as an acceptable instance of a functional columnar property (Horton and Adams 2005, 852).

Taken together, the principle of minimalism and the principle of contextualism explain why neuroscientists justifiably accepted extending "cortical column" to whisker barrels in the 1970s and rejected this wider extension as an unmotivated bend towards cortical isomorphs in the 2000s. Because this decision was driven by issues specific to the case of barrels, it left other uses such as "minicolumn" or "hypercolumn" unaffected. This shows that conceptual housekeeping only applies to specific uses of a concept when issues arise, and thus keeps with the pluralist insight that scientists often retain a concept with multiple meanings.

3.2 Conceptual retirement

While conceptual housekeeping is appropriate to deal with particular problematic use of a polysemous concept, sometimes new discoveries can affect most if not all of its meanings at once. Under such conditions, researchers may question the adequacy of the entire polysemous concept for ongoing research, even if they acknowledge its historical importance. Haueis (2021b) proposes the phrase *conceptual retirement* to capture when researchers should stop using a polysemous concept to describe novel discoveries, while still using past research using the concept as guide and cautionary tale. This option of revising concepts incorporates the pluralists insight that researchers should retain useful findings from past systems of practice even if the terminology is outdated (see Chang 2012 on "phlogiston"). Conceptual retirement combines this with the eliminativist view that researchers should sometimes stop using a term to avoid fruitless research projects (Machery 2009, 242).

According to Haueis (2021b, 10) scientists should retire a concept "if it fails to contribute to the central epistemic goal for which it was created, while still being useful to subsidiary guiding roles that are independent of that central goal". Let's call this the *principle of goal failure*. It reflects the fact that while scientists use many concepts to achieve multiple different goals, they deem some of these goals more important or more centrally connected to a particular concept (Brigandt 2010, 23). While these authors present no principled criterion of how to identify an epistemic goal as central, I think we can extract a heuristic from Haueis (2021b). An epistemic goal counts as central when both proponents and critics agree that researchers should achieve that goal when using the concept. This heuristic distinguishes cases of goal failure from cases in which different researchers simply disagree on which epistemic goals one should pursue when using the concept in an investigative context. Retiring a concept that *permanently* fails its central goal is good normative policy because unlike in conceptual housekeeping, there is little reason to believe that the issues of using the concept can be resolved by further inquiry.

The case of "cortical column" presents a case where neuroscientists should retire a concept. First, both proponents and critics of the concept agree that it should help researchers to identify a basic building block in the neocortex (Mountcastle 1978, Horton and Adams 2005). But beginning in the 1980s, researchers discovered issues across multiple uses of "cortical column" which speak against the view that it identifies a functional module with discrete anatomical boundaries across species. Vertical rows of cells ("minicolumns") are present everywhere in the cortex but there are no discernable boundaries between them, as they are heavily horizontally interconnected. Larger circuits ("cortical column") sometimes show uniform functional responses to sensory stimuli, but neuroscientists also discovered functional heterogeneity within primary sensory areas and widespread noncolumnar organization in the rest of the neocortex. In some areas columnar functional responses are ordered in a regular fashion ("hypercolumn"), while in others sequence regularity ranges from perfect to chaotic. These discoveries suggest that 'cortical column' fails to identify a basic building block, but rather refers to different *kinds* of scale-dependent columnar structures (Haueis 2021b). According to the principle of goal failure, researchers should thus stop using "cortical column" when describing functional cortical architecture. The continued use of the column concept would mislead researchers to look for relevant similarities where only differences between different domains can be found (Horton and Adams 2005, 837).[2]

While recommending bigger revisions than conceptual housekeeping, conceptual retirement is still less radical than a wholesale elimination of the term. Researchers can still use a retired concept to pursue goals that are independent of its central epistemic goal. In the case of "cortical column" such goals are calibrating new instruments, studying cortical

[2] Some researchers may want to continue the pursuit of that central epistemic goal. If so, they should search for a replacement concept which avoids the limits of the retired concept.

development or studying cylindrical units in simulations of neural activity (Haueis 2021b, 11). Neither of these uses require that “cortical column” refers to a basic building block. Conceptual retirement also still allows researchers to acknowledge that relations between phenomena discovered in past research are epistemically significant. For example: neuroscientists acknowledge that relations between sensory topography, periodic connections and receptive field characteristics discovered in column research are important to understand functional brain organization. Yet they may justifiably believe that continued use of “cortical column” would hinder a better understanding of these relations rather than fostering it.

3.3. Concept abandonment

Since the first two options already include norms for avoiding miscommunication and fruitless research project, researchers only need to choose the option of *concept abandonment* when conceptual housekeeping and retirement are no longer sufficient. Based on the shared assumptions about conceptual development, I propose that researchers should abandon a polysemous concept if there are no epistemically significant relations between the phenomena which are grouped under the polysemous concept. This proposal reflects that to achieve their epistemic goals, scientists often exploit the relations between phenomena that a polysemous concept refers to (Haueis 2021a, 29f.). If there are no such relations or if they cannot be used in an epistemically fruitful manner, then scientists have no reason to group these phenomena under the same general term.

I suggest that the *defeater principle* specifies when scientists should abandon a polysemous term. This principle is based on the defeater strategy for rejecting characterizations of phenomena (Colaço 2018). Characterizations of phenomena are typically supported by inferences from experiments producing a particular type of data to features occurring in the description of the phenomenon. The defeater strategy holds that researchers should reject a phenomenon characterization if each of the inferential relations between data and features mentioned in the characterization has been defeated. One way to do find such “undercutting defeaters” (ibid., 8) is to show that the relation is due to a confound and disappears once the confound is eliminated. The defeater principle extends this strategy to inferential relations between uses of a polysemous concept which refer to (features) of a different phenomenon. If the relation between data and features occurring in different phenomena has been defeated, then researchers have no reason to group them under the same concept.

The defeater principle presupposes that researchers already operate with characterizations of distinct phenomena, which themselves are construed as stable and regularly co-occurring features (cf. Colaço 2018, 7). Yet, it still helps us to see what kind of evidence researchers need to undercut the relation between two phenomena. Consider again the relation between sensory topography and vertical columnar organization. The case of barrels shows that the relation between sensory topography and vertical structure is contingent on the body structure being mapped, and thus does not generalize across all sensory domains in which researchers found columnar responses to sensory stimuli. To abandon “cortical column” altogether, researchers would require similar defeating evidence for *all* the relations between phenomena described by “minicolumn”, “hypercolumn” and “cortical column”.

The defeater principle is both more stringent and parsimonious than current versions of eliminativism. It is more stringent because researchers would actually need to eliminate all inferential relations between uses of a polysemous concept, rather than just point to risks of miscommunication or fruitless research projects. It is thus possible that the proposed elimination of particular terms such as “concept” (Machery 2009) or “species” (Ereshefsky 1998) do not satisfy the defeater principle, and thus rather represent cases of conceptual housekeeping or retirement. In any case, the benefit of the defeater principle is that it parsimoniously justifies concept abandonment without additional assumptions about the need for conceptual precision (Taylor and Vickers 2017), natural kinds (Machery 2009) or the unity of categories (Ereshefsky 1998). It should thus also be more acceptable to pluralists who reject one or several of these assumptions (Neto 2020, Novick and Doolittle 2021, Haueis 2021a).

4. Conclusion

I have argued for three options of revising polysemous scientific concepts, which continues efforts to overcome a stark contrast between pluralism and eliminativism. Conceptual housekeeping starts from the pluralist intuition that polysemous pose no issue or even facilitate communication, while respecting the eliminativist demand that sometimes, scientists should actively reject particular uses of a term to avoid confusion. Conceptual retirement goes a step further by acknowledging that sometimes, scientists should stop using a polysemous concept to describe novel findings. Yet it is less radical than wholesale elimination because scientists can use the term to pursue subsidiary research goals and acknowledge that past research using the concept revealed epistemically significant relations between phenomena. Finally, concept abandonment applies the defeater strategy to inferential relations between uses of a polysemous concept to reformulate a demanding version of eliminativism that is also acceptable to pluralists. These options provide philosophers of science with a more fine-grained taxonomy of revising polysemous concepts with multiple meanings than what the contrast between pluralism and eliminativism sometimes suggests.

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