Commentary on **David L. Hull, Rodney E. Langman & Sigrid S. Glenn (2001). A general account of selection: Biology, immunology, and behavior. BBS 24(3):511–573.**

Abstract of the original article: Authors frequently refer to gene-based selection in biological evolution, the reaction of the immune system to antigens and operant learning as exemplifying selection processes in the same sense of this term. However, as obvious as this claim may seem on the surface, setting out an account of "selection" that is general enough to incorporate all three of these processes without becoming so general as to be vacuous is far from easy. In this target article, we set out such a general account of selection to see how well it accommodates these very different sorts of selection. The three fundamental elements of this account are replication, variation and environmental interaction. For selection to occur, these three processes must be related in a very specific way. In particular, replication must alternate with environmental interaction so that any changes that occur in replication are passed on differentially because of environmental interaction.

One of the main differences among the three sorts of selection that we investigate concerns the role of organisms. In traditional biological evolution, organisms play a central role with respect to environmental interaction. Although environmental interaction can occur at other levels of the organizational hierarchy, organisms are the primary focus of environmental interaction. In the functioning of the immune system, organisms function as containers. The interactions that result in selection of antibodies during a lifetime are between entities (antibodies and antigens) contained within the organism. Resulting changes in the immune system of one organism are not passed on to later organisms. Nor are changes in operant behavior resulting from behavioral selection passed on to later organisms. But operant behavior is not contained in the organism because most of the interactions that lead to differential replication include parts of the world outside the organism. Changes in the organism's nervous system are the effects of those interactions. The role of genes also varies in these three systems. Biological evolution is gene-based (i.e., genes are the primary replicators). Genes play very different roles in operant behavior and the immune system. However, in all three systems, iteration is central. All three selection processes are also incredibly wasteful and inefficient. They can generate complexity and novelty primarily because they are so wasteful and inefficient.

GAS doesn't "turn the engine" when states are sequential or context-dependent

Liane Gabora

Department of Psychology, 3210 Tolman Hall, University of California, Berkeley, CA, 94720–1650 and Center Leo Apostel for Interdisciplinary Studies (CLEA), Free University of Brussels, Belgium.
http://www.vub.ac.be/CLEA/liane/ liane@berkeley.edu

Abstract: Selection theory requires multiple, simultaneously-actualized states. In cognition, each thought changes the "selection pressure" against which the next is evaluated; they are not simultaneously selected amongst. Cognitive change occurs not through selection among discrete "neural configurations," but through interaction between conceptual web and context. This introduces a non-Kolmogorovian probability distribution, hence a classical formalism (e.g., selection theory) cannot be used.

Hull et. al. (2001) wait until the last sentence of their response to commentators to invite us to refer to their General Account of Selection as GAS. I will do so, although – insightful and provocative though it is – I am not completely convinced it is the highest octane stuff around.

One problem with their attempt to unite biology, immunology, and behavior under the same umbrella is, as many commentators pointed out, the failure to identify what constitutes a "replicator" in operant learning. Since this is something I have addressed in detail elsewhere (Gabora, 2004), here I address the problem of the conditions under which selection theory is applicable. Pepper & Knudsen (2001) point out that the mathematical formulation of selection theory requires that at any given iteration there be "multiple concurrent replicators that differ in their replication rate" (p. 550). Okasha (2001) makes the same point (p. 549):

> The authors note a significant disanalogy between operant learning and standard examples of Darwinian selection. In the latter, the variants on which selection operates are present at the same time, while in the former the variants form a temporal sequence, each one existing for a moment, before being replaced by another. The authors do not think this disqualifies operant learning from qualifying as a Darwinian process, but I am less sure.

Okasha then reasons that in attempting to apply selection theory to such a temporal sequence, whether or not something gets selected depends arbitrarily on how you break up the sequence. Hull et al. respond that things are not so tidy in biology either, and ask (p. 566) "what might 'the same time' mean in the case of organic evolution?"

There is a fairly straightforward answer to this question, which is intimately tied to their concept of iteration. In biology, there exist multiple entities at any one time and, although the selective pressure undergone by them will never be *identical*, they all at least constitute part of the *same iteration.* So by "same time" we mean there are multiple entities undergoing the selective pressure of a given iteration. However, this is not the situation where a sequence of thoughts is concerned. Because each instant of thought contributes to the context in which the next is evaluated, never do two thoughts or cognitive states undergo the same "selective pressure"; they are not being "selected amongst." Pepper & Knudsen (2001) suggest that, despite their reservations, the enterprise can be salvaged as follows (p. 551):

> If replicators consist of specific neural configurations that produce tendencies or proclivities for certain behaviors, it is not hard to imagine a population of such replicators that compete for the opportunity to be expressed as behaviors (interactors) and to be therefore strengthened or weakened according to their relative "success" (e.g., in eliciting positive affect). It is also not hard to envision that stronger neural configurations would be more likely to persist and to spawn variants.

However, the distributed, overlapping, contextually-elicited nature of memories and concepts prohibits there being multiple, distinct neural configurations from among which to choose. The conceptual network is a weblike structure; on what basis can one say it divides itself up into different "neural configurations" and selects one? This would require enough space to store, prefabricated in advance, every thought or idea one could possibly have! Surely instead the mind exists in a state of *potentiality,* and the situation or circumstance provides the *context* that actualizes a particular thought or cognitive state. Why is this a crucial issue as far as GAS is concerned? Because if there are multiple preexisting, fully actualized states from which some are selected, then this is a deterministic process that can be described by a classical probability theory such as selection theory. However, it has been proved that in situations where a state of potentiality can only be resolved through interaction with a context, the change of state is nondeterministic, and this introduces a non-Kolmogorovian probability

https://doi.org/10.1017/S0140525X04280207 Published online by Cambridge University Press

model on the state space; a classical probability model cannot be used (Accardi & Fedullo 1982; Aerts 1986; Aerts & Aerts, 1997 Piron 1976; Pitowski 1989; Randall & Foulis 1976).

Because it is not the different possible pre-specified neural configurations that are being selected amongst, but the different possible *contexts* that the entire conceptual network could encounter, each of which would give rise to a different interaction dynamics, to describe the relevant change of state requires a nonclassical probability model (Aerts & Gabora 2005a; 2005b; Gabora & Aerts 2002; in press). Selection theory, a classical formalism, is inappropriate for the description of cognitive change, and because operant behavior rests on cognitive processes, it is not able to provide a complete description of that either. But this need not dash all hopes of a unifying theory of evolution. There is no a priori reason such a theory has to be Darwinian or even involve selection except as a special case. In one such approach, evolution is viewed as the context-driven actualization of potential or CAP (Gabora & Aerts 2005a; 2005b). Different forms of evolution vary with respect to the degree of indeterminism due to context, the degree of context independence, and the degree to which context-driven change is retained in future lineage(s). The approach gives us a glimpse of what a theory of change that applies across the social, psychological, biological, and physical sciences might look like (though only time will tell if CAP gets us further down the road than GAS). It should be noted that physicists use the word "evolution" without implying that any sort of selection is involved. As I see it, it is only because Darwinian evolution received so much attention as such an *unusual* form of evolution that it eventually cornered the word "evolution."

Although this commentary is critical of the section on operant behavior, it is probably this section that generated the most fruitful discussion, and that will have the greatest impact on future "lineages of thought." One doen't go too far out on a limb proposing that selection is important in biology. Given Hull's previous writings, it is a bit surprising that there is no section on culture. It might have been more interesting for the *BBS* readership to have a section on culture instead of one on immunology. But this is all after the fact, and I applaud Hull et al. for bringing these important issues onto the table. GAS may not replicate, but it provides fuel for thought.

ACKNOWLEDGMENTS

I thank Diederik Aerts and Samir Okasha for comments and discussion of this commentary, and acknowledge the support of Grant FWOAL230 of the Flemish Fund for Scientific Research.

Authors' Response[1]

Multiply concurrent replication

David L. Hull[a] and Sigrid S. Glenn[b]

[a]*Department of Philosophy, Northwestern University, IL 60208;* [b]*Department of Behavior Analysis, University of North Texas, Denton, TX 76203.*
d-hull@northwestern.edu **glenn@scs.unt.edu**

Abstract: If selection is interpreted as involving repeated cycles of replication, variation, and environmental interaction so structured that environmental interaction causes replication to be differential, then selection in gene-based biological evolution and the reaction of the immune system to antigens are relatively unproblematic examples of selection processes. Operant learning and cultural evolution pose more serious problems. In this response we deal with operant learning as a selection process.

As the title of our target article (Hull et al. 2001) indicates, we tried to set out a General Account of Selection (GAS) for three sorts of phenomena: gene-based selection in biological evolution, the reaction of the immune system to antigens, and operant learning. **Gabora** is more interested in a fourth sort of phenomenon: social learning. Most of her paper concerns thoughts, cognitive states, memories, concepts, culture, and the like. In this response we do not discuss social learning as a selection process because we did not treat it in our original BBS target article. However, as Gabora notes, one of us has in the past discussed sociocultural evolution as a selection process (Hull 1988) and another has used GAS to explore the role of operant learning in the emergence of cultural interactors (Glenn 2003). Quite obviously we would like to see GAS extended to selection in sociocultural evolution, but unfortunately any attempt to deal with selection in sociocultural evolution in this response would require too much space and depart too radically from our target article. Instead, we will deal with Gabora's objections to our treating operant learning as a selection process.

As we mentioned in our target article, theories of operant learning come in a variety of forms. We chose to investigate what we thought was one of the best versions of this theory. We did not claim that operant learning involves nothing but selection, only that selection processes play a role in learning, an important role. Nor are we claiming that all behavioral phenomena involve operant learning. The issue is not how adequate or comprehensive operant theory is but whether it incorporates a selection process. B. F. Skinner, the father of operant learning, thought so, but he might well have been mistaken.

The most fundamental and pervasive problem with respect to our general account of selection stems from the fact that it is an instance of conceptual analysis. Some of the earlier commentaries on our target article wanted our analysis to be more stringent; others wanted it to be less so. Unfortunately, no cut-and-dried methods exist for making such choices. One begins with what one hopes are the most clear-cut cases and proceeds from there. For a long time, gene-based biological evolution was the main example of a selection process and it was treated as such. Any departures from selection in gene-based biological evolution counted against any additional examples. Too often, however, peculiarities of this paradigm example were treated as if they were essential. Our increased knowledge of the immune system has helped to rectify that bias. The reaction of the immune system to antigens is as good an example of selection as is traditional gene-based selection in biology. We now have two paradigm examples of selection.

Gabora's main objection to operant learning as a selection process is that it does not include anything that might be treated as a replicator; and even if it did, it does not allow for multiple concurrent replicators that differ in their replication rates. In this response, we deal with four questions: (a) Does selection require replicators? (b) If so, can replicators be discerned in operant learning? (c) Can these replicators be construed as multiply concurrent? and, finally, (d) Must they be?

In our target article, we characterized selection as consisting of "repeated cycles of replication, variation, and environmental interaction so structured that environmental interaction causes replication to be differential" (p. 513; italics deleted). We then discussed each of these entities

https://doi.org/10.1017/S0140525X04280207 Published online by Cambridge University Press