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Beyond blindness: On the role of organism and environment in trial generation

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ABSTRACT

In this paper we aim to amend the traditional analogy at the heart of evolutionary epistemologies. We shall first argue, contrary to what has been frequently done, that both hypothesis generation and the processes of generation of genetic and phenotypic change are often directed as well as environmentally conditioned. Secondly, we shall argue that environmental influence does not affect trial generation directly but that environmental information is processed by the epistemic agent and by the biological organism respectively. Thirdly, we suggest conceiving hypothesis generation as a process of manipulative abduction and the generation of biological variation as a process mediated by phenotypic plasticity. Finally, we argue that manipulative abduction and environmentally-induced biological variation modulated by plasticity are analogous because they both involve a conjectural response to environmental cues. Our analysis thus vindicates a revised version of evolutionary epistemology ascribing a fundamental role to both organism and environment in trial generation. This perspective, in our opinion, offers support to the thesis, inspired by the theory of embodied cognition, that hypothesis generation is sometimes explained by an appeal to phenotypic plasticity.

1. Introduction

Many philosophers and scientists have suggested, since Darwin's times, that the process of scientific discovery — or, more generally, the growth of knowledge — may be usefully conceived as analogous to the process of biological evolution by natural selection (see, for instance, James, 1979; Popper, 1972; Campbell, 1974; Stein & Lipton, 1989; Simonton, 2004): both involve *blind trials* — corresponding to, respectively, the hypotheses and the biological variants generated — and subsequent sorting (e.g., selection) of the trials with respect to certain ecological constraints. Despite being the core thesis of traditional evolutionary epistemologies (Bradie, 1986), the analogy has also been frequently criticised (Skagestad, 1979; Bunge, 1983; Ruse, 1986; Thagard, 1993; Dasgupta, 2004). The critics basically consider it flawed: in the first place, biological variation is blind, whereas hypothesis generation is guided; secondly, the former is independent of the environment, whereas the latter is not. Kronfeldner (2010, 2011) has probably offered the most exhaustive and systematic account of the vast and multidisciplinary literature on the topic, concluding that the main problem of the analogy is that it is ultimately uninformative. We shall use Kronfeldner's analysis as our benchmark. Many critics have argued that there is a crucial difference between biological variation and hypothesis generation that fatally undermines the explanatory power and the heuristic value of the analogy. Kronfeldner's analysis clearly identifies this crucial difference. Kronfeldner clarifies that while biological variation, according to the standard neo-Darwinian interpretation, is "blind" in the sense that it is undirected (e.g., mutations does not occur *because of* their adaptive value) and causally decoupled from selection, hypothesis generation, albeit "blind" in the sense that it is not clairvoyant, is always directed towards a goal that somehow guides the trial. Once this profound difference is acknowledged, Kronfeldner argues, the resemblance between scientific discovery and biological evolution appears superficial and trivial.

Kronfeldner is certainly right in arguing that, according to an orthodox neo-Darwinian conception, the generation of biological variation is due to causal processes that are decoupled from selection, whereas in scientific discovery hypothesis generation and

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selection are at least partially coupled. She indeed bases her entire analysis on the assumption that "… there is a broad consensus that undirectedness holds for biological evolution." (Kronfeldner, 2010, p. 196). This consensus is based on the Modern Synthesis interpretation of the available evidence, particularly concerning mutagenesis (Futuyma, 2005, p. 178; Lenski & Mittler, 1993; Luria & Delbrück, 1943; Merlin, 2010). The major limit of the consensus view is – as Kronfeldner (2010, note 4) foresees – that its theoretical support has been progressively eroded. Two strands of research are particularly relevant in order to account for this process of erosion. Firstly, molecular research on mutagenesis has demonstrated the inducing role of the environment and its frequently adaptive nature (Koonin & Wolf, 2009; Razeto Barry & Vecchi, 2016; Rosenberg, 2001). This means that mutation frequently produces directed changes. Secondly, a more general point concerning all biological variation - rather than merely one type of genomic change - should be highlighted: the environment is capable of generating variation through the process of environmental induction (West-Eberhard, 2003; Gilbert & Epel, 2009; Badyaev & Oh, 2008). Significantly, biological (i.e., genetic or phenotypic) variation might be considered partially directed in case it is positively influenced by the environment (i.e., if it is fitness-enhancing).[1] The environment is thus a source of potentially adaptive variation (as it allows organisms to produce phenotypes with higher fitness) and not merely a filter that selects existing variants.[2] As Kronfeldner (2010, p. 196) acknowledges, an environmentally induced process generating adaptive variation can be seen as intrinsically coupled with selection, and henceforth as directed. Thus, research on mutagenesis and environmental induction point in the same direction: biological variation is, firstly, not necessarily blind and, secondly, it is frequently not independent from the environment. As a consequence, the evolutionary analogy is defensible. The problem of its original formulation was to stress the blind and decoupled nature of both hypothesis generation and biological variation, while the case is precisely the opposite: both hypothesis generation and the processes of generation of biological variation are often coupled with sorting processes, generating directed trials.

However, in this article we are not interested in defending the traditional analogy. Rather, what we aim to achieve is a reformulation of the analogy itself. Evolutionary epistemologists like Popper or Campbell generically identified scientific discovery with a hypothetic-deductive dynamic (e.g., conjectures and refutation, trial and error etc.). They also relied on a rather simplistic interpretation of the theory of natural selection (as testified by Popper's numerous misunderstandings on this topic; Vecchi & Baravalle, 2015). Contemporary defenders of the analogy are far more precise (see, for instance, Simonton, 2004), but their claims are arguably not empirically supported (Kronfeldner, 2011, p. 65–71). In this article we endorse the view that the *abductive model* of scientific discovery (Magnani, 2001, 2009) is a fair representation, at a suitable level of abstraction, of the processes of scientific discovery. The fundamental reason supporting our stance is that the abductive model concomitantly confers a role to environment and epistemic subject alike in hypothesis generation: the subject enjoys a certain degree of "freedom" in generating her trials while at the same time being guided by environmental information. We believe that analogous considerations can be applied to the generation of biological variation. In fact, when the environment induces genomic or phenotypic changes, the process is typically mediated by phenotypic plasticity. Environmental information is not passively "inflicted" on the organism but "modulated" (an expression inspired by Lewontin, 1982, p. 161) by it. Therefore, our general thesis is that both the environment through induction and the organism through the appropriate modulation of environmental information play a fundamental role in the processes of hypotheses generation and generation of biological variation alike.

After having presented the general framework of the article, let us proceed to introduce its argumentative structure. In Section 2, we shall briefly show in what sense the biological consensus taken for granted by Kronfeldner to the amount that biological variation is undirected is obsolete. In Section 3, we shall defend abduction and, more specifically, *manipulative abduction* as a suitable model for scientific discovery. In particular, we shall stress the conjectural character of hypothesis generation and the central role played by the environment in both the generation and the evaluation of the trials, as well as the compatibility of this model with more traditional accounts of scientific discovery, like the hypothetico-deductive model. In Section 4, we shall show that, even though, *prima facie*, environmental induction is not analogous to manipulative abduction – since the latter implies an active role of the subject in hypothesis generation while apparently, in the former, the organism simply undergoes external influences –, it is frequently accompanied by *plastic responses*, which actively modulate environmental cues. In the conclusion, we shall assess the explanatory power and the heuristic value of the analogy.

2. Biological variation is often directed

Kronfeldner has offered a rich analysis of the claim that biological variation is an undirected process. This account has many virtues. However, Kronfeldner merely takes for granted that biological evolution is based on undirected variation (Kronfeldner, 2010, p. 205). The aim of this section is to amend this particular limitation of her analysis.

One of the peculiarities of the debate concerning the nature of variation within evolutionary epistemology is that it has been assumed that in order to demonstrate the undirectedness of all processes of generation of biological variation it was sufficient to show that one particular process (i.e., mutation) produced undirected changes. But generalising from one particular process to the whole spectrum of processes of generation of biological variation is clearly illegitimate. Nonetheless, in this section we shall challenge this biased perspective directly and focus on the evidence in favour of the directed nature of mutagenesis. Our aim is to uncover the lack of theoretical support for the general thesis that biological variation is undirected.

Let us first explain Kronfeldner's conception of undirectednes, which links the concepts of adaptiveness and coupling:

> A new variant occurs undirected, if it occurs randomly with respect to its adaptivity. (…) In formal terms, as philosopher Sober (1992, p. 39) puts it: "Let u be the probability of mutating from A to a and v be the probability of mutating from a to A. Mutation is directed if (i) u > v and (ii) u > v because

[1] The question of transgenerational inheritance is not crucial for our argument. Nonetheless, empirical evidence suggests that environmentally influenced variation may be inherited, to some extent, both genetically (cf. Koonin & Wolf, 2009; Koonin, 2012) and epigenetically (cf. Jablonka & Lamb, 2010; Rankin, 2015). Indeed, many biologists and philosophers (cf., for instance, Pigliucci & Müller, 2010; Laland et al.2015) argue that such alternative inheritance mechanisms should be integrated within an extended Darwinian framework.

[2] Darwin (1888, p. 159) admitted that he should have given more weight to direct environmental influence in his theory. However, as he himself acknowledged (Hoffmeyer, 2008, p. 197; Kirschner & Gerhart, 2010, p. 256–7; Andrade, 2011, p. 295), environmental induction would render natural selection less important. In fact, as West-Eberhard has noted: "[phenotypic evolution] could be clearly 'Non-Darwinian' if it did not involve differential survival or reproductive success associated with different phenotypes, but dependent entirely upon differential environmental induction" (West-Eberhard, 2007, p. 450).