Living Books About Life

Cognition and Decision
in Non-Human Biological Organisms

Edited by Steven Shaviro

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Introduction

What is the relationship between life and thought? Are all living organisms capable of thinking? Or is thought restricted to animals with nervous systems and brains? Or is it restricted only to human beings, or to us and a few of the other 'higher' animals? In any case, what is the relation between thought (which takes place, we like to say, in the mind) and the actual physical processes that take place in the brains of animals and human beings when they are thinking? For that matter, what does it mean to say that thinking, like other forms of organic activity, is subject to, and determined by, physical laws? Is it meaningful to ascribe 'free will' to human beings and other organisms? Or are thought processes strictly deterministic, so that 'free will' is just an illusion?

These are all speculative, metaphysical questions, which philosophers have been actively discussing for at least several thousand years. They cannot be answered by science alone. But at the very least, biological research of the past several decades has given us vastly more information about cognition and thought, in

human beings and in other organisms, than we ever possessed before. In what follows, I would like to look briefly at some of this research, and ponder its implications.

Bjorn Brembs points to research by himself and by others (including his collective work with Maye*et al.*) that suggests the 'common ability of most if not all brains... to choose among different behavioural options even in the absence of differences in the environment and perform genuinely novel acts.' That is to say, even fruit files and other invertebrates with tiny brains possess a sort of 'free will.' It is easy to see how such a capacity for decision might have evolved. For animals, complete predictability of behavior is not viable. Any organism that reacted to outside stimuli in a completely predictable manner would quickly be wiped out by predators who were able to anticipate its responses. Therefore, Brembs argues, 'predictability can never be an evolutionarily stable strategy. Instead, animals need to balance the effectiveness and efficiency of their behaviours with just enough variability to spare them from being predictable... Competitive success and evolutionary fitness of all ambulatory organisms depend critically on intact behavioural variability as an adaptive function. Behavioural variability is an adaptive trait and not "noise".' All this suggests that motile animals, at the very least, have evolved mechanisms to generate behavioraly variability-- action that is not pre-determined, and hence not predictable. Moreover, organisms are able to control the extent of this variability. In many circumstances, routine, habit, and 'instinct' are the best strategies; but 'faced with novel situations, humans and most animals spontaneously increase their behavioural variability.' Such 'self-generated actions' seem to take place in all

sorts of animal organisms, and not just among vertebrates.

Gabor Balazsi and his colleagues go further than Brembs, when they suggest that 'decision making' takes place not only in the nervous systems and brains of animals, but more widely: on a cellular or sub-cellular level, in viruses, bacteria, and unicellular microbes, as well as in the individual cells of multicellular organisms. These lower-level biological units make 'decisions,' in the sense that -- like Brembs' fruit flies -- they select among behavioral alternatives spontaneously and gratuitously. That is to say, they make choices that are not motivated either by heredity or by environment, since they occur 'without an associated genetic or environmental difference.' Such non-predetermined behavior works to 'generate nongenetic cellular diversity,' which is necessary for 'survival in a fluctuating, frequently stressful environment.' Even the way that embryos develop into full-fledged organisms is not entirely programmed in advance; a lot depends upon spontaneous 'decisions' made by the cells themselves, in the course of their process of differentiation.

Balazsi's research suggests that cognition and decision are not just properties of animal nervous systems; they seem to be intrinsic to all forms of life, and to all cells (and even to viruses, bits of active organic matter that are not themselves biological cells). This is borne out by studies such as Ben Jacob *et al.*'s work on bacterial cognition, and Trewavas' and others' work on plant cognition. Ben Jacob *et al.* suggest that bacterial self-organization (both on the intra-cellular level, and on the level of coordination among masses of bacteria that form colonies) requires a sophisticated sort of

information processing. Bacteria gather information from the environment, process this information, share this information, and make decisions on the basis of it. These processes are not instinctual or automatic; they imply that the gathered information becomes meaningful to the bacteria in some way. That is to say, even bacteria display 'meaning-based natural intelligence'; such intelligence is likely to be 'a fundamental requirement of life.'

Anthony Trewavas' work on plant intelligence, together with Baldwin *et al.*'s recent research on volatile signaling in trees, demonstrates that plants, just like bacteria, and no less than animals, engage in the processing of information about the environment, and decide upon responses to the data that they gather and interpret. Evidently thinking behavior is not necessarily dependent upon the existence of brains and neurons and nervous systems, which only animals possess. Other types of cells, and even literally brainless forms of life, are capable of the basic operations of thought: sensation, interpretation, cognition, generating meaning, and making decisions. (It may well be that neurons, and the larger structures like brains that are constructed out of them, can think more powerfully, efficiently, and concentratedly than other types of cells but it seems clear that thinking evolved first, and the cell types specially devoted to thinking only evolved later).

Slime molds are among the most fascinating organisms in existence, because of the way that they bridge the gap between unicellular and multicellular forms of organization. The 'cellular' slime molds begin life as unicellular organisms; but in order to reproduce they agglomerate into large masses, which in turn grow

‘fruiting bodies’ that emit spores. The ‘true’ slime molds don't even have a unicellular stage: they are large masses of protoplasm with numerous nuclei, but no cell divisions at all. Both groups of slime molds display astonishing mental abilities. Nakagaki *et al.*, and other researchers as well, have shown that slime molds can ‘solve’ mazes, and optimize network patterns, by working out the most efficient pathways between multiple food sources.

Even more astonishingly, Latty and Beekman have shown that slime molds make ‘economic’ decisions when offered imperfect alternatives among their food sources, much as human beings do (according to the recent discipline of ‘behavioral economics’). That is to say, slime molds, like human shoppers in our consumer society, do not make ‘economically rational choices,’ but do in fact use quick and dirty ‘comparative valuation rules’ in order to determine what to do. There is a difference, however. Behavioral economics considers each shopper as an entirely separate individual, uninfluenced by others; collective behavior is understood as the simple summation of individual decisions. Much the same approach is used to understand self-organization in ant colonies and insect swarms; a set of simple decisions on the individual level adds up to emergent behavior on the collective level. But slime molds don't fit into this pattern, because they are not exactly composed of separate individuals. Even though ‘the behaviour of the [slime mold as a] collective is a result of the behaviour of its underlying parts,’ these parts do not exist separately and on their own. As the researchers put it, ‘owing to the slimy nature of acellular slime moulds, it was not possible to test [rationality] in individuals,’ but only in populations. The key point here is that, due to the ‘slimy nature’ of

this organism, it cannot quite be defined either as a single individual, or as a conglomeration of separate individuals -- it is something oddly in-between.

It is also noteworthy that Latty and Beekman discovered that, ‘even within a treatment group, slime moulds varied in their choices. This is particularly surprising as we controlled for weight, nutritional state and genetic differences.’ In other words, even the slime molds' compliance with comparative valuation rules is not absolute. It is a statistical result, rather than something observed in every instance. This again suggests that there is a margin, or remainder, of indeterminacy that allows for unconstrained, spontaneous decision. The authors suggest that ‘some of the variability we observed arises from slight differences in the experiments' initial conditions... These small differences in initial condition, combined with feedback via biomass recruitment mechanisms, could ultimately result in the observed variability.’ However, as sensitivity to initial conditions approaches a point of indiscernibility, we get ever closer to Brembs' claim that ‘determinism versus indeterminism is a false dichotomy'; Brembs himself bases this claim in part on observing situations of extreme sensitivity to initial conditions.

In this way, we are led back from the consideration of cognition in brainless organisms (bacteria, slime molds, and plants) to the idea that such organisms are able to make spontaneous (unforced, or ‘free’) decisions. When an organism cognizes and interprets the information it receives from its environment, and subsequently acts in response, this means precisely that the organism's action is not determined by the external, environmental situation to which it is responding. Rather, there is a

certain degree of spontaneity and creativity in its response. As the philosopher Alfred North Whitehead wrote long ago, every living organism 'originates novelty to match the novelty of the environment' (121).

How all this might be possible is worked out by Brembs, again, in his discussion of 'the importance of being active.' Organisms do not just collect and respond to information that streams into them from their surroundings. Rather than just responding with behavioral output to the sensory input that they receive, insects and other organisms also work in the reverse way, according to an 'output-input' model. They engage in a 'process of generating activity and evaluating its consequences,' by comparing the outcome of the activity with what can only be called their prior expectations. This suggests that both cognition based on acquired data, and spontaneous decision and action, presuppose other sorts of mental stances -- what we would describe, in human terms, as feelings, expectations, attitudes, and moods. I would argue, philosophically, that this has to do with the affective basis of all cognition and all decision. Understanding and willing are cognitive activities, but they have their necessary basis on some pre-cognitive level of affect or feeling. And this is true of bacteria, slime molds, and insects, just as it is true of human beings. As the recent research of Bateson *et al*. suggests, the bees in a colony can exhibit a mood like depression, or what the authors call 'pessimistic cognitive biases.' Neither cognition nor decision could exist in the absence of such 'biases,' whose basis is pre-cognitive and emotional. And this would seem to be the case for all forms of life, not solely for human beings and other 'higher' animals.

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Attributions

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