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Freedom and purpose in biology

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ABSTRACT

All seemingly teleological systems share a common hierarchical structure. They consist of a small entity moving or changing within a larger field that directs it from above (what I call "upper direction"). This is true for organisms seeking some external resource, for the organized behavior of cells and other parts in organismal development, and for lineages evolving by natural selection. In all cases, the lower-level entity is partly "free," tending to wander under the influence of purely local forces, and partly directed by a larger enveloping field. The persistent and plastic behavior that characterizes goal-directedness arises, I argue, at intermediate levels of freedom and upper direction, when the two are in a delicate balance. I tentatively extend the argument to human teleology (wants, purposes).

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1. Freedom

An American teenager graduates from high school in 1975 and sets out into the world. He finds a job on a steamer bound for Belgium, on arrival hitchhiking to Liege where he joins a farming commune. Tiring of this after a few weeks, he packs up one morning and takes a train to the south of France, where he connects with a group of amateur boat builders. Their goal is to sail the Mediterranean, but progress is slow, and after several months, the boat is still unfinished. Frustrated, he sells his belongings and flies back home. He rests for a week at his parent's house in New York, then takes off again, this time with the idea that he will walk across the country, from New York to Los Angeles, stopping at roadside diners and meeting "real" people. He makes it as far as his cousin's house in New Jersey, where he moves in and lives rent-free for the next three years. What is this young man up to? He might say that he is doing his own thing, being true to himself, trying to escape the suffocating constraints of middle-class expectations, of capitalism, of his parents. In the language I shall use here, he is trying to be free.

Let us not worry about whether this is the best way to understand freedom. The experience of that generation suggests that in some ways it is not, or at least, that it is only part of what freedom means. Still, it is one way to understand the word, one with a recent cultural history and one that is consistent with current folk understandings: freedom in the sense of the absence of organized external constraints. I shall come back to our peripatetic teenager.

The argument of this paper is that entities that are free, that move or change in the absence of large-scale or upper-level forces, tend to wander. They tend to vary. So robust is this expectation that when we do not see wandering and variation, when an entity's behavior is highly organized and directed, it strongly suggests the existence of upper-level directing forces. I argue that this partitioning of behavior into a free component and an upper directed component has consequences for our understanding of teleology, of goal-directedness and purpose in biology. Both components are essential to teleological behavior. Indeed, I shall argue that teleological behavior arises at a point in the middle, where freedom and direction by higher-level forces are in a delicate balance.

More generally, my mission here is to give a naturalistic account of teleology in biology, an account from the perspective of an engineer. I am addressing the question of how teleological systems are structured physically. How must systems be organized in order to seem to behave teleologically? I do not attempt anything like an analysis of concepts, or of how teleological terms are used. And

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therefore, the argument intersects most of the literature in this area only obliquely. In particular, the large modern-era literature on the naturalization of meaning and function—especially teleosemantics (MacDonald & Papineau, 2006) and treatments of functions as selected effects (Millikan, 1984; Neander, 1991; Wright, 1973)—is not directly relevant. Rather, the line of thought offered here grows out of the pioneering studies of the physical properties of hierarchically structured systems by Simon (1962), Campbell (1958), Wimsatt (1974, 1994), and Salthe (1985, 2009). My concern is not with what goal-directedness means but with how it works, extending the project begun in McShea (2012).

The title, freedom and purpose in biology, is somewhat immodest. I hope not overly so. What I offer is a way to think about causation that applies across a wide swath of biology. It is a perspective that unifies our understanding of how change works in evolution, in the development of organisms from embryo to adult, in the behavior of simple organisms, and even in the behavior of complex ones, including us. Further, it explains teleology, purposefulness. The Darwinian view is generally regarded as sufficient here. But it is not. Natural selection tells us about the process that gives rise to teleology. But it does not explain how it works. It does not point to any particular mechanism behind the mysterious moment-to-moment behavior, the seeking behavior, of seemingly purposeful entities. Selection also cannot explain the apparent goal-directedness of the Darwinian process itself, of selection itself. The viewpoint developed here does all this. The apparently purposeful movements of certain entities and the apparent purposefulness of adaptation emerge as special features of nested systems, as instances of a more general process.

Throughout, I often modify teleological terms with the word “seemingly” or sometimes “apparently.” This is not an eliminitivist move. The strange behaviors and capacities that we call teleological are real and have real causes. But almost no one today believes that the future causes the past, that literal “goals” which by definition lie in the future can have any causal influence on the present. This goes for human wanting, thinking, and behaving too. The so-called “goals” that guide our present thinking and behavior are hoped-for hypotheticals, existing in the present and presently intended to have a forward-causal connection to the future. We want and try to make things happen. But, as everyone knows, there is no backward-causal connection. There is nothing literally teleological about my getting in the car to drive to a picnic. The future picnic has exactly zero role in the process and indeed may not be there when I arrive. (If, say, I had the wrong day.) Indeed, maybe it is time to stop implying backward causation in our choice of words. My use of “seemingly” and “apparently” is a gesture in that direction.

2. Nestedness, freedom, and upper direction: three biological examples

I begin with three biological examples, one having to do with the movements of microorganisms, a second having to do with organismal development, and a third with evolution. In all of these systems there is an entity of some kind, one that can move freely on its own but that seems to behave teleologically when immersed within, nested within, a higher-level structure or field of some kind. The point is to illustrate by example what I mean by freedom and nestedness and also to introduce a new term, upper direction. (The next section offers a more formal discussion of upper direction.)

First, imagine a group of ten thousand bacteria, temporarily occupying the same cubic millimeter of water in a pond. I say temporarily because they are free to move and therefore unlikely to stay in that same cubic millimeter for long. Normally, in this species of bacterium, when an individual moves in open water its flagellum propels it in a series of what are called “straight runs,” interrupted occasionally by tumbles that randomly reorient it. It darts one way, tumbles, zooms off in another direction, tumbles, then zips ahead again, and so on, producing a kind of a random walk.

Interestingly, its behavior would change if it detected food, if it suddenly found itself inside, say, a gradient of increasing concentration of some food molecule, like the amino acid aspartate, leaching into the pond and diffusing from some distant source. When the bacterium detects an increase in aspartate concentration, a signal cascade within the organism kicks into action, triggering an increase in the length of the straight runs. It still tumbles, and still reorients randomly in each tumble, but the straight runs become longer, with the result that, on average, the bacterium tends to move up the food gradient, closer to the food source. That is what would happen in all of the bacteria in this example if they were embedded within a food gradient. They would all increase the lengths of their straight runs and move on average up the gradient. Notice what has happened here. With the introduction of a food gradient, the structure of the system becomes hierarchical. The bacterium becomes an entity nested within a higher-level structure, the food gradient, and the higher-level structure directs the bacterium toward the food source. We can say that the bacterium is now “upper directed.”

Let us return to the original setup. Suppose no food gradient or any other large-scale external factor affects the movement of the bacteria. And so they wander hither and thither. Straight run, followed by random tumble, followed by straight run, followed by random tumble, going nowhere in particular. In the language I am adopting here, the bacteria are free. They are free in the sense that they are governed entirely by the interaction between themselves and local forces, their movements determined by a combination of their own internal structure and the local external environment. More concretely, the movement of each bacterium during a tumble is determined by a combination of the mechanism governing its flagellar micro-movements and the currents, density, and viscosity of the water immediately around it. Its movement is independent of all of the other bacteria. And it is independent of large-scale influences. There are no factors acting over a large-area—no food gradients and no other large-scale fields, currents, or gradients.

In some cases, including this one, the interaction of an entity with local external forces is complex, so that the entity follows a random walk (technically, since the interaction is understood here to be deterministic, a pseudorandom walk). But freedom need not produce randomness. A bacterium with internal mechanisms programmed to make a 60° turn every centimeter, or to always swim in a direction opposite to the microcurrent in its immediate environment, is also free. Behavior is free whenever, and to the extent that, control is local.

Notice that the freedom of each bacterium makes for highly predictable behavior by the group. We do not know where any individual will go, but the group as a whole will certainly diffuse, expanding outward from the original cubic millimeter that contained them. Another way to say this is that the variance in their positions—whether measured along an east–west axis or a north–south axis or any other axis—will increase. Free movement among members of a group produces an increase in variance in the group as a whole. The group spreads out.

In sum, here is how I propose to describe the situation: in the absence of upper direction, in the absence large-scale external causes, each bacterium is free, and the result is that it wanders and the variance in position among all of the bacteria increases.

A second example. Consider the free movement of cells in a different context, the much larger eukaryotic cells in a