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EDITORIAL

Universal EvoDevo?

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As a philosophy of biology journal, *Biological Theory*'s contributors are concerned with, and its readers seek out, treatments of broad questions relating to the nature and identity of organisms, of mind, language, cognition, and behavior. The journal's editors are committed to the view that to fully understand any of these living properties it is important not only to know how it is organized and functions, but how it takes form in each generation and, most crucially, how it came into being in the first place. That is, evolutionary developmental biology—EvoDevo—is the foundation of our project.

The articles in this Thematic Issue on Astrobiology exemplify this orientation, addressing themes of biological origination and regeneration in the most vivid fashion by contemplating what life and mind would be like if they emerged elsewhere than on Earth. The articles deal with (among other things) the definition of life, the ethics of exploration and property beyond our planet, potential encounters with the extraterrestrial "other," and what would count as evidence of alien intelligence. One area that is only tangentially covered in these pages (in the article by Mariscal and Fleming (2017), this issue) are the conditions for the origination of multicellular organisms, and the predicted outcomes if these conditions pertained elsewhere.

To see what EvoDevo might bring to astrobiology it is useful to explore a conceptual world where it does not exist. A recent article in the *International Journal of Astrobiology*, "Darwin's Aliens" (Levin et al. 2017) (in which there is no mention of development) takes as its premise that "natural selection is the *only* explanation we have for the appearance of design without a designer" and that "[t]hings that appear purposeful, such as limbs, organs and cells, require the gradual selection of improvements" (p. 2; emphasis in original). The population biological analysis of Levin et al. suggests (much like the pre-Socratic philosopher Empedocles (c. 490–430 BC)) that each of the parts of complex organisms is "the vestige of a former individual." They further claim that the reason that hand cells and heart cells, for example, do not act as "cheaters" and try to independently send their genes into the next generation is that the "unicellular bottleneck" of the zygote stage ensures that their genes are the same as those of the sperm and the egg. In their view this inevitably makes each organism, whether on Earth or another planet, a "nested hierarchy" of agents with "aligned interests."

EvoDevo can take us a lot further than this. Notwithstanding the assertion by one of the field's founding thinkers, Stephen Jay Gould, that if the "tape of life" recording the last 600 million years evolution on Earth were replayed the kinds of organisms that appeared would be very different (Gould 1989), three decades on, the discipline is pointing to different conclusions. An important theme in EvoDevo is the cooperative self-organizational properties of interacting agents (Thorne et al. 2007). Since complexity is inherent to such systems, the imperative to evolutionarily suppress individual interests is not a precondition for morphological evolution. Moreover, there is an increased appreciation in the field of the extent to which some of the conserved "toolkit" genes of multicellular development mobilize physical forces to organize (in the case of animals) viscoelastic liquid-tissues (Forgacs and Newman 2005; Newman and Bhat 2009) and (in the case of plants) deformable solid-tissues (Hernández-Hernández et al. 2012; Romero-Arias et al. 2017) to generate characteristic morphological motifs: e.g., layers, segments, appendages,

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and cusps for animals; buds, branches, leaves, and flowers for plants.

A recent essay commemorating the work of D'Arcy Wentworth Thompson (one of the few scientists to keep the 19th-century "laws of form" perspective alive during the rise of the Darwinian Modern Synthesis), notes that multicellular systems have "intrinsic directives and constraints for the generation of individual shapes, helping to explain the 'profusion of forms, colours, and other modifications' observed in the living world" (Abzhanov 2017, p. 4284). The special issue of the journal *Development* (December 1, 2017) in which the essay appeared provides a variety of examples of how these ideas (aided by modern mathematical modeling and computer simulation) are finally entering the mainstream of developmental biology.

Recognizing the roles of nongenetic (i.e., physical) determinants in setting preferred directions for morphological change, and of specific genes (the "morphogenetic toolkit," e.g., classical cadherins, Wnt, and Notch in animals; extensins, PINs, and auxins in plants) in enabling those effects in multicellular biomaterials—dual accomplishments of EvoDevo—allows us to move past both the gradualist adaptationism of the Modern Synthesis and the heredity-agnostic physicalism of D'Arcy Thompson to address specific questions of the origin and nature of complex organisms in our world and, potentially, others. For example, are the morphogenetic properties of complex multicellular organisms truly tied to their having evolved via unicellular bottlenecks, or (as proposed by the "physico-genetic" model; Newman 2014) did sophisticated developmental pathways evolve independently of germ lines? If it is the latter (as some evidence suggests (Extavour 2008; Fields and Levin 2018)), what does the presence of certain morphogenetic toolkit genes in some clades, but not others (Newman 2012), tell us about the nature of phyla (Hejnol and Dunn 2016; Levin et al. 2016), or the driving forces of major evolutionary transitions (Newman 2016)?

The same materials will behave similarly anywhere the same physical laws pertain. Living matter would certainly not be precisely the same as on Earth on planets with different histories. (They are not even the same between animals and plants, which constitute a local model for multicellular astrobiology.) But the physics of condensed materials is, as far as we know, universal (Green and Batterman 2017). Analogously to the speculation by astrobiologists and their philosophical allies that there could be other chemical forms of storage of genetic information than DNA or RNA (Smith 2018, this issue), we could contemplate the evolution of extraterrestrial toolkit molecules that converted alien unicellulars into viscoelastic liquid- and deformable solid-tissues. Would those other worlds then be venues of familiar, or semi-familiar forms, behaviors, mentalities? Our enthusiasm about finding out will probably depend on how the news gets to us (Villeneuve 2016).

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