How Not to Think About Evolution

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Evidence of evolution is all around us, but some still can't handle the truth. While outright rejection of the concept had been in decline in mainstream venues up till the mid-twentieth century, in recent years evolution skepticism and denialism have flourished among the U.S. electorate, legislators, and even teachers. For rising political figures on the Right who want to cater to their constituencies without burning all their bridges to modernity, "None of your business" has become an accepted position on the subject.[1]

The concept of evolution is thoroughly identified in the popular mind with the name of Charles Darwin (see, for example, the fish-with-legs bumper sticker with "Darwin" substituted for "Jesus"). Paradoxically, however, the main problem for rejectionists is not natural selection, the foundation of Darwin's theory. In the United States, few people, including die-hard creationists, take exception to the signature example of finches' beaks becoming remodeled over the course of many generations by differential survival of slight variants as conditions change. A 1992 article from *Creation*, a magazine published by Creation Ministries International, describes the finches of the Galapagos Islands with "a variety of bill shapes and sizes, all suited to their varying diets and lifestyles." It accepts Darwin's conjecture that they are all the offspring of an original pair of finches and that natural selection is responsible for the differences. Stating that "this is the explanation now held by most modern creationists," the author asserts that this concedes nothing to any presumed "amoeba-to-man transformation."[2]

The stumbling block for most contemporary evolution-skeptics is the notion of "macroevolution:" large-scale morphological changes—unicellular organisms into complex multicellular ones, fish-like forms into mammals, shrew-like forms into primates. For Darwin and his successors, adherents of the Modern Evolutionary Synthesis, macroevolution is just the result of incremental differences (the "microevolution" of the finch beak example) over time—what the philosopher Daniel Dennett has called "Darwin's dangerous idea."[3] It is the resistance to making this leap, not rejection of natural selection per se, which has prevented vast numbers of people from accepting evolution as the main process of diversification of life on Earth.

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It's not just benighted sectors of the populace, however, who question the connection between micro- and macroevolution. Significantly, some evolutionary biologists do as well. A century ago, the biologist V. L. Kellogg acknowledged that evolution is as central to biological science as gravitation is to physics, or affinity is to chemistry, but that "[d]oubts of Darwinism are not . . . doubts, of organic evolution."[4]

This viewpoint, though subterranean during much of the twentieth century, is now increasingly voiced, but still in hushed terms. With the recognition that the large-scale morphological diversification of body types of the "Cambrian explosion" of 500–600 million years ago occurred with little change in the set of "toolkit" genes that regulate development,[5] and the discovery that the products of these genes mediate developmental mechanisms of nongradual phenotypic change unforeseen by early evolutionists,[6] there are now credible alternatives to scenarios of adaptation by increments. But the standard model's defenders remain institutionally ensconced and have the advantage of paradigmatic inertia: nearly every evolutionary finding in the last one hundred years was interpreted, by default, in an adaptationist manner.[7]

The coincidence during the past century of the emergence of the Modern Synthesis and increasingly open public skepticism about macroevolution raises some uncomfortable questions. Is the rampant disbelief in one of the central facts of the natural world truly the fault of religion and superstition, as is generally claimed, or do bad scientific ideas also share in the blame? Few members of industrial societies, whatever religious beliefs they may hold, continue to think that the sun revolves around the earth or that thunderstorms are caused by angry spirits. The scientific explanations are obviously superior to the ancient and traditional ones. But while secular types have little option but to go with the dominant scientific narrative concerning the origin and variety of living beings, however unpersuasive, those with an alternative metaphysical framework at hand, such as religion, have resisted generic appeals to the authority of science as a justification for abandoning their received notions.

Adopting the gradualist Darwinian mind-set in fact requires discounting a great deal of commonplace evidence. Our experience of the living world is one of separate, identifiable forms, with nothing changing by small steps into anything strikingly different over human lifetimes or even historical periods. And while members of a given group of animals or plants can differ from one other in continuously varying features like height, weight, and the shapes of noses, flowers, and other organs, their body plans abound in discrete structures: fingers and toes, vertebrae and ribs, petals and leaves.

Darwin himself was cognizant of abrupt transitions in the tree of life, although his theorizing ultimately led him to discard such data and return instead to the Aristotelian *scala naturae*.[8] Though the first edition of *The Origin of Species* (1859) focuses on cycles of incremental refinement of form wrought by animal breeders, the author makes a passing reference to the rise of unprecedented novelties in both plants and animals,[9] and within the decade, in *Variation of Animals and Plants Under Domestication* (1868), wrote at greater length about "sudden variations or sports" in bird species, acknowledging that "[w]e are profoundly ignorant of the cause."[10]

Such observations were unavoidable for any conscientious naturalist. Jean-Baptiste Lamarck, no less committed to gradualism than Darwin, was nonetheless compelled to acknowledge that "often some organ disappears or changes abruptly, and these changes sometimes involve it in peculiar shapes not related with any other by recognizable steps."[11] And even earlier, Carl Linnaeus, the founder

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of modern taxonomy, had his own gradualist presuppositions shaken by a greenhouse discovery of an aberrant but fertile and true-breeding variant of a toadflax (*Linaria*) plant, which he likened to a cow giving birth to a calf with the head of a wolf,[12] and which led him to cross out the words "Natura non facit saltus" from his own copy of his *Philosophia botanica* (1751).[13]

Darwin's contemporary, Gregor Mendel, in creating the science of genetics (the second pillar of the Synthesis), employed qualitatively distinct variants of the pea plant (yellow vs. green, inflated vs. constricted pods, etc.) that were underlain by "factors" causally associated with these differences. The Synthesis itself, however, was forged in the early twentieth century by a move that simultaneously endorsed Darwinian gradualism and denied evolutionary relevance to "genes [actually alleles, i.e., gene variants] of large effect" like those studied by Mendel.[14] It is therefore helpful to appreciate what was originally so persuasive about incrementalist natural selection (or in the words of George Bernard Shaw, "Why Darwin converted the crowd"[15]), and why, as contrary evidence has mounted, it has hung on for so long. And most importantly, what are the alternatives?

The social milieu and intellectual culture of the nineteenth century were fertile grounds for the emergence of a theory like natural selection. Materialist science was on the rise in the 1840s and 1850s when Darwin and Alfred Russel Wallace were formulating their ideas. The earlier successes of Isaac Newton, Robert Hooke, Robert Boyle, Christiaan Huygens, and others in mechanics and optics, and of Antoine Lavoisier and Friedrich Wöhler in chemistry, had begun to demystify the notion that the natural world was capricious and unpredictable. And practical accomplishments of a burgeoning industrialism in engineering, clock making, and so forth, demonstrated the elaborate capabilities of complicated machines, raising the radical prospect that living things were just complex material objects. Although this did not negate the possibility that they had been designed by a supernatural creator (as the theologian William Paley famously pointed out[16]) or compel belief to the contrary (as noted by Immanuel Kant[17]), it was clear that for the new breed of scientists, including biologists, there was no turning back from materialism.

For nineteenth-century biologists interested in the fundamental properties of living systems, the problem was finding naturalistic mechanisms for the origination of complex forms, and then, once they existed, for their transformation. Of the four great physical theories developed during the eighteenth and nineteenth centuries, chemistry, thermodynamics, and electricity and magnetism deal with qualitative transformations of matter: metals and gases into salts; solids into fluids and back again; moving charges into magnets. This protean side of the natural world inspired the biological theories of a variety of scientists and philosophers concerned with the evolution and organization of living systems, including Lamarck, who thought of life in terms of "contained" and "subtle" fluids, Johann Wolfgang von Goethe, Étienne Geoffroy Saint-Hilaire, Lorenz Oken, and Richard Owen, "rational morphologists" who postulated "laws of form,"[18] and J. F. Blumenbach, C. F. Kielmeyer, and J. P. Müller, "teleomechanists" who, while adopting a naturalistic approach to anatomy and physiology, followed Kant's lead by adopting a teleological heuristic with respect to the ultimate organizing principles of living systems.[19]

The science of mechanics, as formulated by Galileo and Newton, was the oldest and most established of the four physical theories and the least concerned with qualitative change. This was the theoretical paradigm adopted by Darwin and Wallace. For Newton, matter was inert, altering its trajectory only when acted on by external forces. An even older, but equally familiar set of

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mechanical principles, formulated by Aristotle, applicable to moldable materials like clay, lacked even the (Galilean) inertia of constant motion. Things moved when pushed and then stayed put unless pushed again. Aristotelian and Newtonian mechanics ("classical" in two senses), successful as they were in their respective realms, were incapable of capturing the dynamic, self-organizing, and self-realizing qualities of living systems, or their capacity to undergo abrupt transformations in form and behavior, particularly during embryonic development.

None of the physical concepts known to nineteenth-century scientists was directly applicable to living systems, the compositional and organizational properties of which were mostly unknown. Thus the choice of a dynamical/internalist, or in Darwin's case a classical/externalist metaphor for evolutionary change, was mainly a matter of personal inclination, perhaps influenced by social experience. As I describe later, it took several twentieth-century revolutions in the physical sciences of condensed materials and dynamical systems (based on newly discerned connections between the earlier physical sciences), for a genuine theoretical understanding of the qualitative and transformative properties of chemical and biological systems to come into focus.

Several factors favored Darwin's more stolid theoretical stance: it made no unsupported hypothesis about how living beings arrived at the point of being subject to natural selection and it did not depend on knowledge of the sources of variation in organismal form and function. And significantly, it did not require an understanding of how living organisms were internally organized (something the rational morphologists and teleomechanists strived for, unsuccessfully). The variants selected in the Darwinian struggle for existence were so incremental as to permit agnosticism about the underlying structure of the perturbed forms.

The fact that a given object might have properties slightly different from those of other copies of the same thing, and that some of these small differences could be advantageous under particular circumstances, was the default industrial wisdom of an era in which so little was understood about the properties of materials. Indeed, for those eighteenth- and nineteenth-century entrepreneurs involved in manufacturing things reliably on a mass scale, and then improving them, systems governed by gradualist principles were the Holy Grail. Darwin's maternal grandfather, Josiah Wedgwood, the famous pottery manufacturer who has been referred to by a recent biographer as "the first tycoon,"[20] lamented in 1774:

> Moorstone & Spaith fusible [two components of his earthenware formulations] are the two articles I want, & several samples I have of the latter are so different in their properties that no dependence at all can be had upon them. They have plagued me sadly of late. At one time the body is white & fine as it should be, the next we make perhaps, having used a different lump of the Spaith, is of a Cinamon color. One time it is melted into Glass, another time as dry as a Tob[acco] Pipe.[21] . . . I cannot work miracles in modifying the properties of these subtle, & complicated (though native) materials. If I had more *time*, more *hands*, & more *heads* I could do something.[22]

Wedgwood eventually defeated the vicissitudes of his materials, coming up with Jasperware, his enormously successful company's iconic product. In the absence of systematic knowledge he was

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forced to follow a "Darwinian" scenario, testing approximately five thousand different formulations before arriving at the one that made his fortune.[23]

It makes sense, then, that an Englishman of Darwin's background and generation would have opted for an incrementalist theory of evolution based on the classical physical paradigms instead of one based on the speculative rationalism of the Continent which engendered thinkers like Goethe and Geoffroy Saint-Hilaire.[24] We now know a great deal about the actual chemistry of cellular life and the physics of embryonic development, however, and they have turned out to be nothing at all like classical physics. A cluster of cells (e.g., an early-stage embryo) can spontaneously separate into distinct layers by processes akin to phase separation of liquids. These clusters behave as "excitable media," in which the cells can coordinate their behaviors over broad domains by synchronization of internal biochemical oscillations. In other contexts these oscillations can generate segmented tissues (a prediction made by analogy to vibratory physical systems by the naturalist William Bateson at the end of the nineteenth century[25]). Positive and negative diffusible regulators of cell differentiation (itself a manifestation of the dynamics of multistable complex systems), can generate patterns as varied as ramified blood vessels, branching tubular glands, and jointed vertebrate limb skeletons.[26] One important characteristic of these physical-developmental mechanisms is their capacity to produce discontinuous patterns and forms, and, under slightly variant conditions, highly divergent morphological outcomes.

Considering that nineteenth-century physics is no longer the only materialist game in town, is there any justification in continuing to propound Darwinism (or paradigm-conserving extensions of it[27]), as the core of evolutionary theory? First we need to ask why Darwinism has become so heavily armed and fortified. A recent book, for example, had the temerity to review evidence in conflict with the strict correspondence of genotype and phenotype postulated by the Synthesis, and to examine the logical structure of claims that a given trait is an adaptation (as opposed to a "free-rider" of selection for a different trait).[28] It was met with a level of opprobrium reminiscent of the vitriol dripped by the late Ernst Mayr, the most famous enforcer of the Synthesis, for much of his one hundred years, upon the likes of William Bateson, D'Arcy W. Thompson, Richard Goldschmidt, and others who dared to suggest that the protean dynamics of developmental systems might play a role in evolution. (Of Bateson's late-nineteenth-century vibratory theory of tissue segmentation, Mayr asserted fifteen years before it was confirmed experimentally, "it simply retarded scientific progress."[29])

This defensiveness is actually compelled by the structure of Darwinism. Its claim to being *the* materialist theory of evolution is entirely based on one precise scenario for phenotypic (e.g., morphological) transformation. Small changes accumulated over many cycles of selection in response to changed external conditions can (by this hypothesis) generate any arbitrary structure. As Darwin famously wrote, "[i]f it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down."[30]

Though modern Darwinians (other than the most fundamentalist of them[31]) no longer defend this extreme version of the theory, Darwin's statement is logically entailed by the theory's central premise. While it can't be denied that unprecedented forms or "sports" may suddenly appear (see the aforementioned examples from the observations of Linnaeus and Darwin himself, and descriptions

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of other "hopeful monsters"[32]), these "saltations" are dismissed by Darwinians as having too poor a fit with the ecological niches of their originating populations to make a contribution to a new genotypic mean. What Darwinism requires, in other words, is a harsh, unforgiving world, in which any developmental misstep is met with likely extinction. This is the only basis on which it can be maintained that evolution is mainly driven by the rare, adaptively superior variant contributing disproportionately to a population's gene pool.

If, on the contrary, the hopeful monster had a reasonable chance of surviving and contributing offspring to the next generation, there would be no need to invoke gradualism as the exclusive or even primary mode of evolutionary change. The view that organisms are resourceful and inventive, creating their ways of life rather than passively succumbing to them, is known as "niche construction." As a component of evolutionary theory it can be traced back to Lamarck's conception of self-defined, striving organisms, and the zoologist and anarchist philosopher Petr Kropotkin's 1902 book *Mutual Aid*. Post-Synthesis, it was actively promoted by the evolutionary biologist Richard Lewontin, and has spawned a subfield in its own right.[33] It is clear that survival of animals and plants does not invariably depend on their good fit to the niche in which they originated. Countless reports of ecological and economic devastation wrought by invasive species should be enough to retire this supposition, as well as phenomena like "transgressive segregation," in which hybrid plants with extreme or novel properties set up shop in environmental settings more congenial to their biology.[34]

While genetic change can precipitate the origin of novel forms, so can environmental causes (the effect in both cases ultimately being due to properties of the developmental system, not the initiating factor). If the inducer is environmental, genetic change can follow to reinforce the production of any novel phenotype that is ecologically successful, for example by occupying a new niche[35] (see further on).

The occasional developmentally generated phenotypic jump or saltation does not disconfirm the Synthesis, nor does the possibility of active niche selection or construction. Put together, however, they are fatal to it. If the processes underlying animal and plant development are capable of generating wide ranges of discontinuous forms, and the variant organisms that result are often perfectly capable of making their way in the world, perhaps the main "danger" of Darwin's most famous idea now is to a persuasive, empirically based evolutionary theory.

What Darwin observed and theorized was, of course, not incorrect. But it was only the tip of the iceberg. The major organizational themes—"body plans"—of multicellular organisms emerged a half billion years ago, or more. In the succeeding period, successful forms acquired, generally by natural selection, reinforcing or consolidating genetic and biochemical circuitry that makes their developmental realization more reliable and true-to-type. The mid-twentieth-century evolutionary biologists I. I. Schmalhausen and C. H. Waddington (both of whose ideas ran somewhat obliquely to the mainstream of the Synthesis), respectively referred to the evolutionary reinforcement of the generation of an established phenotype as "stabilizing selection" (in contrast to Darwin's version, termed "directional selection"),[36] and the developmentally stable outcomes of this reinforcing process as "canalized."[37] While the origin of complex forms predated this canalization, the present-day developmental mechanisms that generate such forms can only be understood as hybrid physical-genetic processes that have changed their character over the course of evolution.

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So Darwin's experimental and observational material consisted of organismal types in the middle of a long evolutionary journey, with (compared with their likely ancient prototypes) minimal environment- or even mutation-dependent plasticity. With his penchant for uniformitarian explanations inherited from his geologist mentors, it is understandable why Darwin would have inferred that the resistance to saltational changes of Galapagos finches, and domesticated livestock and pigeons, was an eternal and essential characteristic of living beings.

What then, is to be gained from putting Darwinism to the side as a limiting case, an important historical advance in the scientific understanding of evolution, but one of only marginal power in explaining the origin of species and essentially none at all in accounting for higher taxa like kingdoms, phyla, and classes? First, accepting the reality of saltation would open the way to exploring the processes underlying the burst of morphological diversity in the early history of multicellular organisms, like the Avalon[38] and Cambrian explosions at the dawn of the animals, and the corresponding episodes at the origin of plants. Second, the related phenomenon of "punctuated equilibrium," the fits and starts of the fossil record associated with the origin of novel forms and their long periods of morphological stasis despite vast external changes[39] would no longer be a problem for the default evolutionary theory, continually inviting ad hoc justifications. Third, entertaining the notion that certain morphologies are inherent to living systems ("orthogenesis," a heresy to the Synthesis for its challenge to the doctrine that all forms arise by selection for adaptation) will facilitate the investigation of why organisms actually look the way they do: multilayered, hollow, elongated, segmented, branched, wrinkled, nodular, jointed, and so forth. While natural selection may refine these motifs, it does not produce them.

Finally, relegating Darwinism and the Synthesis to an appropriately limited role enables leaving behind a constricted, inert, classical materialism in favor of more applicable physical concepts of dynamical systems and excitable media, and to a truer notion of organisms as active subjects, not passive objects. For many scientists, and for the public, for a variety of partly contradictory reasons, there is the sense that the current model has reached its explanatory limits and something different is required. Sometimes incremental change just doesn't do it.

NOTES

1. Calefati, "Gov. Christie."
2. Wieland, "Darwin's Finches," 22.
3. Dennett, *Darwin's Dangerous Idea*.
4. Kellogg, *Darwinism Today*, 3.
5. Discussed in Conway Morris, "Darwin's Dilemma"; Rokas, Krüger, and Carroll, "Animal Evolution"; Newman, "Developmental-Genetic Toolkit."
6. Reviewed in Newman and Müller, "Epigenetic Mechanisms"; Forgacs and Newman, *Biological Physics*.
7. Gould and Lewontin, in "The Spandrels of San Marco," compare these narratives to Rudyard Kipling's *Just-So Stories*.
8. See Lovejoy, *Great Chain*, for the distinction between the discontinuous Platonic and continuous Aristotelian versions of the *scala*.

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9. Darwin, *Origin*, 29–30.

10. Darwin, *Variation*, 1: 213.

11. Lamarck, *Zoological Philosophy*, 69.

12. Quoted in Stubbe, *History*, 97.

13. Cited in Mayr, *Growth*, 256.

14. The arguments used by the Synthesis architect R. A. Fisher to reject the populational relevance of alleles of large effect are now recognized not to pertain to phenotypic novelties (see discussion in Clarke and Arthur, "What Constitutes"; Orr, "'Sizes'"). Indeed, such alleles are now known to make significant contributions to evolutionary change (see Bell, "Oligogenic").

15. Shaw, *Methuselah*, 35–37.

16. Paley, *Natural Theology.*

17. Kant, *Critique.*

18. Webster and Goodwin, *Form and Transformation*.

19. Lenoir, *Strategy.*

20. Dolan, *Wedgwood*.

21. Wedgwood, *Letters*, 75–76; letter of 21 July, 1774.

22. Wedgwood, *Letters*, 81; letter of August 30, 1774.

23. See the website of the Wedgwood Museum, Stoke-on-Trent, UK: http://www.wedgwoodmuseum.org.uk/learning/discovery_packs/2179/pack/2184/chapter/2344.

24. Depew and Weber, in *Darwinism*, present the Newtonian backdrop to Darwin's theory in an incisive fashion.

25. Discussed in Newman, "Bateson."

26. Examples of physical mechanisms underlying all the common morphological motifs of animal embryos can be found in Forgacs and Newman, *Biological Physics*.

27. Pigliucci, "Extended Evolutionary Synthesis."

28. Fodor and Piattelli-Palmarini, *Darwin*.

29. Mayr, *Growth*, 42.

30. Darwin, *Origin*, 158.

31. Gould, "Darwinian Fundamentalism."

32. This was a term introduced by the geneticist Richard Goldschmidt in *The Material Basis of Evolution*; see also, Chouard, "Revenge."

33. Odling-Smee, Laland, and Feldman, *Niche Construction*.

34. Rieseberg, Archer, and Wayne, "Transgressive Segregation."

35. West-Eberhard, *Developmental Plasticity*.

36. Schmalhausen, *Factors*.

37. Waddington, *Strategy*.

38. Shen et al., "Avalon."

39. Gould and Eldredge, "Punctuated Equilibria."

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