WHY DO PLATYPUSES FLUORESCE? OR WHY DARWIN DID NOT BELIEVE IN "EVOLUTION"

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Popular wisdom (seemingly well beyond question – hence this month's Sacred Bovine), says that Charles Darwin established and championed the scientific principle of evolution. But Darwin did not believe in *evolution*. Search the *Origin of Species* for the term. It's not there. Only a fleeting reference in the very final words. In closing, Darwin celebrates the grandeur that "endless forms most beautiful and most wonderful have been, and are being, *evolved*" (italics added). Why? What does this apparent omission mean?

Resolving this historical puzzle provides important clues to the meaning of evolution – both as a term and as a concept – and to our inherent cognitive dispositions. And that, in turn, may help us interpret a wonderful new discovery about platypuses. Our journey will lead us through a few of Darwin's books, other historically popular views of evolution, and some familiar misconceptions among biology students.

○ Evolution, or Descent with Modification?

Ironically, the term *evolution* was in use long before Darwin. The *Oxford English Dictionary* traces its use in biology to 1670. But at that time, it meant something very different than it does today. The word derives from the Latin *evolvere*: to unroll. Hence, evolution was seen as the natural maturation and emergence of features that were inherent in the object. That is, it referred to individual organismal development. More particularly, it described a preformationist view of development. That was what Charles Bonnet meant when he introduced the *theory of evolution* in 1762. Namely, the sequence of biological change was prescribed. Events followed an intended trajectory.

When naturalists began to appreciate how fossils revealed a history of life on Earth, the term expanded to include the changing sequence of species. The choice to use the same word reflected, in part, a belief that species-change, like organismal development, "unrolled" purposefully (Richards, 1992).

For decades, individual development and species history were regarded as manifesting the same basic principles of organic change – expressed by the same term, *evolution*. That is, change was viewed as *teleological* – having a guiding purpose or intent (Woodfield, 1976; Varella, 2018). That was certainly true in the work of Erasmus Darwin, Charles's grandfather, whose romanticized biological poems were an early influence on the young Charles (Richards, 1992).

But Charles eventually diverged from his grandfather's views, as we well know. For him, no cryptic force guided species "forward." Natural selection yielded change, yes, but in the context of the immediate environment. New structures did not arise spontaneously from need or desire, or even inherent progress, but resulted from the arbitrary opportunity of variants, followed by the limitations of historical context. Lineages exhibited continuity, yes, but not because they were "unrolling" in a purposeful way. That is, Darwin's concept – what *we* now call evolution – was wholly unlike what his contemporaries in 1859 understood by the term *evolution*.

Accordingly, in the first edition of the *Origin*, Darwin adopted other phrases, such as *descent with modification* (18 occurrences), *lines of descent* (11) or just *descent* (4 dozen more), *succession of forms* or *succession of organic beings* (25), *transmutation of species* (1), or, as in the title, *origin of species* (5). At the same time, he also shied away from the ambiguous term *development*. Darwin's unmistakable avoidance of the term *evolution* is a telltale indicator of how he wanted to distinguish his theory from prevailing concepts of organic change in his day. Namely, he dispensed with the normative aspect of "unrolling" in the then-popular conceptualizations. Species were not "supposed to" follow some idealized historical pathway. Darwin replaced it with a here-and-now causal mechanism, dependent on the vagaries of time and place. The concept of the succession of species was not really new. But conceiving natural history without inherent progression was a deep challenge to prevailing cultural perspectives. Freedom from purposeful guidance, not evolution itself, is ultimately what marked Darwin's thinking as revolutionary.

Darwin was certainly aware of the heritage of natural theology – the perspective that organic forms are designed and thus reflect the nature of their (divine) creator. Alternatively, we might call this view natural *teleology*. That is, the core assumption (ironically *not* its conclusion, I contend) was that Nature is necessarily ideal. It *presupposed* an intentional structure and only endeavored to decipher its character. Darwin's interpretation of the interplay of variation and selection neutralized the need to appeal to any "unrolling" plan. His insights helped expose the teleological assumption as an assumption only – with no exclusive explanatory role.

Darwin's immediate work *after* the *Origin* is telling. He did not delve immediately into his implicit promissory note that "light will be thrown on the origin of man and his history." Nor did he focus on taxonomic affinities, or biogeography, or embryology. Rather, he focused on what may have seemed like a conspicuously prosaic sequel: "the various contrivances by which orchids are fertilized" (Darwin, 1862; Ghiselin, 1969, pp. 134–137; Campbell, 1994; Beatty, 2006; Zimmerman, 2019). For many readers, the new work fit comfortably in the familiar tradition of the pastoral observation of nature, the bread and butter of natural teleology. That image may have reassured them, but it was misperceived. Through detailed analysis, Darwin showed in case after case how the assumption of

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intentional design left only unsolved puzzles. Why did so many dissimilar "contrivances" involve different floral parts to effect the very same function, cross-fertilization? By tracing instead the history of the orchid structures across related species, the cumulative effect of successive "chance" variations became evident. Darwin later acknowledged that he regarded the book as a "'flank movement' against the enemy": namely, to explain apparent design, but without intentional agency. To the attentive reader, the repeated irony of its many cases chipped away at the reigning teleology. Earlier, George Bentham had savagely criticized the *Origin* in a review. But he felt reassured by the *Orchids* book, which to him was no more than quaint natural history. He surely failed to appreciate the import of Darwin's potent insights about interpreting apparent "design" as necessarily purposeful.

Darwin's non-teleological, non-normative view was on display again in *The Descent of Man* in 1871 (by which time he had begun using the term *evolution*, now with its more modern meaning). There, he finally addressed the question of human origins. How might one tackle such a momentous topic? In his opening chapter, Darwin basically echoed the strategy of the *Orchids* book, but now for humans. He quickly dispensed with the preliminary topics of homologies (a modest four pages) and shared developmental patterns (three more). His primary focus was on *rudimentary organs* (14 pages; for a summary, see Table 1). These traits were puzzles to the theme that humans reflected purposeful design. Rather, they conspicuously bore witness to unpredictable and opportunistic history. Darwin concluded:

> Thus we can understand how it has come to pass that man and all other vertebrate animals have been constructed on the same general model, why they pass through the same early stages of development, and why they retain certain rudiments in common. Consequently, we ought frankly to admit their community of descent: to take any other view, is to admit that our own structure and that of all the animals around us, is a mere snare laid to entrap our judgment. (1871, p. 32)

Darwin's rhetoric was not merely to convey the succession of anatomical forms, but also to liberate human natural history from teleological intent and transcendental purpose.

○ Teleology, Then & Now

Darwin's approach transformed biology, of course. Cultural views, perhaps less so. During the 1800s, the populace at large developed an awareness of descent with modification, but often through sources other than Darwin (Lightman, 2010). As a result, filled with an aesthetic of organic "design," they generally understood species change as infused with purpose – the "unrolling" version of evolution, not the modern Darwinian one.

The 19th century witnessed significant changes in how the public understood science. Interest in new technology and remarkable new discoveries flourished. Readership expanded. Science had not yet become fully professionalized (with its formal communication networks), so scientific publications were available to anyone. New industrial-scale printing helped books and periodicals become cheap – no longer the exclusive privilege of elite salons (Secord, 2000). Unfortunately, such a market also opened the way to derivative and less well-informed works that nonetheless passed as scientific.

In this context, in 1844 (15 years before the *Origin*), Robert Chambers published his anonymous *Vestiges of the Natural History of Creation*. It offered a monumental historical epic, from the formation of galaxies to the development of society – an innovative narrative format that became a template for later scientific storytelling (used even today). *Vestiges* described the development of species – and, yes, the transformation from apes to humans – and the origin of the human mind through natural laws. Chambers described the trajectory as *progressive*, an alternative form of purpose that inspired many readers. "We see, from what remains have been found in the whole series, a clear progress throughout, from humble to superior types of being" (p. 124). *Vestiges* was a bit scandalous, perhaps, but it fueled a sense of wonder and seemed to explain humans' "natural" place in the cosmos, along with our future potential. It became, in historian James Secord's apt appraisal, a "Victorian sensation." It was read and discussed "in drawing rooms, libraries, churches, pubs, clubs, and railway carriages," becoming enormously influential (Secord, 2000, p. 522). Its cultural impact should not be underestimated. By 1890 it had been through 14 editions – and sold more copies than Darwin's *Origin* (p. 526). Evolution gained popularity, yes, but in a thoroughly teleological version.

Table 1. Rudimentary human organs mentioned by Darwin (1871, pp. 17–31; for a modern update, see Werth, 2014).

the panniculus carnosus (skin-twitching muscles)
a projecting point in the helix of the ear (a remnant of pointed ears)
the semi-lunar fold of the eye (vestige of the nictitating membrane)
sense of smell
scattered body hair
long eyebrow hairs (residue of the vibrissæ as sensory organs)
fetal facial hair
the posterior molars (or "wisdom teeth")
the appendix (that is, "the vermiform appendage of the cæcum")
the supra-condyloid foramen, a skeletal passage for nerves in the elbow
the tailbone, or coccyx
mammary glands and the vesicula prostratica (uterus) in men

Similar accounts of evolution were presented by self-styled philosopher Herbert Spencer. In 1852 (still prior to Darwin), he advocated the "development hypothesis" – namely, "the origination of species by the process of modification." "Throughout all organic nature there is at work a modifying influence," he claimed. It operated in individuals, too, for whom "the development of every faculty, bodily, moral, or intellectual, according to the use made of it – are all explicable on this same principle." He echoed those views more explicitly in his 1857 "Progress: Its Law and Cause." After Darwin published the ***Origin***, Spencer coined the ill-fated phrase "survival of the fittest." Yet, despite Spencer's nominal nod to natural selection, his views (like those of Chambers) were unmistakably imbued with a sense of progress as a motive force, which inherently guided human society as much as the organic realm – teleology in another guise:

> Slowly, but surely, evolution brings about an increasing amount of happiness. In all forms of organization there is a progressive adaptation, and a survival of the most adapted…. Thus the evils accompanying evolution are ever being self-eliminated. (Spencer, 1866, pp. 438–439)

Despite his themes – here, happiness and eliminating evil! – the public afforded Spencer ***scientific*** credibility. Spencer's many volumes on biology, psychology, sociology, and ethics – arguably all variants of the same ideological theme of progress – had sold over a million copies by 1900. Darwin's ***Origin***, by contrast, had sold just 56,000 (Lightman, 2010). Once again, the public seemed to embrace the purpose-laden version of evolution.

Historian Alvar Ellegård (1990) analyzed the response to Darwin in popular magazines from 1859 to 1872. Most authors endorsed evolution among nonhuman animals. But they were often skeptical of the extension of evolution to humans and of the role of natural selection, both cases where the normative dimension of "purpose" seemed central. Popular books by American John Fiske echoed Spencer, claiming that "the Darwinian theory shows us distinctly for the first time how the Creation and the perfecting of Man is the goal toward which Nature's work has all the while been tending." Evangelical Henry Drummond offered a Christianized version, devoid of natural selection, with a roguishly ironic title, ***The Ascent of Man***. Benjamin Kidd inserted a religious goal in his 1894 ***Social Evolution***, which was translated into 10 languages, including Chinese and Arabic. In only 15 months, it sold some 40,000–50,000 copies, placing it alongside the same period's best-selling novels (Lightman, 2010, quote on p. 13). In Germany, Ernst Haeckel helped popularize a view of Darwinism that, while underscoring the influence of the environment, was also inherently progressive. Evolution and interpretations of Darwin became immensely popular – but they were typically accommodated (however perversely) into value-laden teleological perspectives that implicitly justified human privilege. Thus, despite the avid readership of science in the 19th century, Darwin's view of evolution did not take hold in the public sphere.

Views today are not that different from those in Darwin's day. Hence, when students learn about descent with modification, they do not necessarily shed their view of adaptation or natural selection as purposive (Bishop & Anderson, 1990; Stover & Mabry, 2007; Bardapurkar, 2008; Gresch, 2020). No one should be surprised, perhaps, that (according to polls) roughly two-thirds of the Americans who do believe in evolution also believe that the process is guided or involves an intentional agent (Swift, 2017; Pew Research Center, 2019). Accordingly, we might perhaps add here a second Sacred Bovine: an unquestioned conviction that unrolling, guided "evolution" and chance-laden, context-driven Darwinian evolution are equally scientific, and that the choice between them is a matter of personal preference. That popular assumption is misguided, too.

But the problem is much deeper still. Teleology, or purpose, seems to be deeply embedded in our psychological architecture. It applies throughout biology, not just to evolution. Biology teachers may readily recognize how students attribute intentional purpose and agency to instructional DNA molecules, to enzymes, to hormones, to antibodies, to immune cells or brain cells, to self-balancing ecosystems, to self-regarding species, and more (Werth & Allchin, 2020). And so on, even beyond biology (Varella, 2018). We commonly acknowledge that dispositions to anthropomorphize and to interpret events and behavior in terms of purpose occur among children, yet these tendencies persist into adulthood alongside more mature perspectives (Guggenmos, 2012; Kelemen et al., 2013). Darwin's triumph, then, was not just elucidating a causal mechanism for evolution. It was exposing the teleology that permeates intuitive human thinking about natural history – and articulating its scientific alternative.

○ Evolution in Modern Biology Education

Many contemporary biology educators regard student assumptions about purpose and teleology as a major obstacle to understanding evolution and natural selection (e.g., Sinatra et al., 2008; Zeigler, 2008; Gregory, 2009; Allmon, 2011; González Galli & Meinardi, 2011; Kampourakis & Minelli, 2014; Barnes et al., 2017; and many others in earlier decades). According to the analysis of history above, however, the more important lesson may be about the role of purpose itself. Namely, how do we lead students into understanding not evolution itself, but the ***difference*** between ***unrolling*** "evolution" and Darwin's ***contextual and blindly unpredictable*** evolution? Imagine a gestalt switch in which the core emphasis shifts from teaching descent with modification or adaptation – which frames teleology as a subsidiary challenge – to teaching ***the very status of teleological perspectives*** in science.

To begin, we might honestly admit that teleological views seem to arise spontaneously with each new generation. Disparaging them seems both inappropriate and unproductive. As a cautionary tale, we may recall that Darwin's own early thinking was very much oriented to design and progress (Richards, 1992). His views shifted with more experience and learning. Hence, today, a ***primary*** educational goal for biology teachers may be to address how humans so readily interpret nature in teleological, or normative purpose-laden, terms. How are such dispositions exhibited? What are their implications? What are the alternatives? Why would science regard teleological views as inappropriate? Using constructivist approaches, teachers would help students recognize implicit teleological assumptions and engage in the problems they pose (Sinatra et al., 2008; González Galli et al., 2020; Gresch, 2020). Can we thereby address the psychological reasons why teleology seems so "sacred," and why the inescapable "what-ifs" of evolution sometimes feel emotionally threatening (Bland & Morrison, 2015)?

How might one approach this in the classroom? Darwin's own rhetorical strategy may offer clues. His review of human rudimentary organs was crafted to exhibit the outcome of historical contingency, in contrast to an unrolling plan. Most biology textbooks already include a section on vestigial structures as "evidence for evolution." Yet, as critiques on websites such as Creation.com or

AnswersinGenesis.org may illustrate, the meaning of vestigial organs for evolution requires first opening the very possibility of nonfunctional structures. We must first resolve the question of whether nature is purpose-laden. Thus, one may repurpose the standard textbook cases as (instead) "anomalies of organic 'design'" (perhaps a more accurate description of their explanatory role?). Ample cases exist (see, e.g., Morgan, 1990; Johnson et al., 2012; Werth, 2014; Senter et al., 2015; Allmon & Ross, 2018). So: teleology *foremost*, evolution *as secondary*?

Recall, too, Darwin's orchids. The primary aim there was not to describe natural selection or adaptation. Darwin implicitly assumed change. Rather, his "flank movement" (above) was to reveal contingency and the arbitrary nature of variation, contrasted to a model of idealized design or inevitable "unrolling" history. Such "evidence of contingent history" includes (a) "misfit" organisms (Bardell, 1997); (b) biogeographical puzzles (such as the similarities of the suite of Galápagos mockingbirds to the mainland species in a wholly different habitat); (c) variable structures fulfilling the same function in closely related organisms (Darwin's orchids; see also Bock, 2009, on paradaptations, with many examples); (d) evolutionary "reversals" (flightless birds, shell-less mollusks, air-breathing marine mammals, and so on; e.g., Johnson et al., 2012); and (e) other puzzles of comparative anatomy explained by meandering history (e.g., the panda's "thumb" or atavisms). That is, even structures that seem "designed" often have traces that bear witness to their haphazard history. Again, many of these examples are already familiar to biology teachers. But here the focus is not descent per se, but the difference between contingent, accident-driven history and purpose-driven history – or between evolution and "evolution." Ultimately, to foster a fuller understanding of natural history, our *primary* focus should be assumptions about teleology, purpose, or intentional agency.

Teleological perspectives have significance for culture, as well. Seeing nature as purposeful suggests that the world *should* be just as we find it. It thus supports the status quo as *intended*. In a sociopolitical context, it seems to *justify* the current distribution of power, profit, and privilege as an apparently inevitable outcome of "natural" processes (Butterfield, 1965). And that has overtones for addressing social injustice, for example. Teleology transforms nature into a normative model of "what was *meant to be*." But science can only describe. It cannot prescribe, either morally or ideologically. Attributing purpose to nature is a scientific misstep, a variant of the *naturalizing error* (Allchin & Werth, 2017, 2020; Werth & Allchin, 2020). So the difference between "evolution" (in the 19th-century sense) and evolution (as understood today) is not trivial. And that difference might motivate us to teach how teleology subverts good science.

The Moral of the Story?

And so, we arrive finally at the occasion for this essay – a concrete "test" for all these concepts. Not long ago, a few enterprising scientists discovered that platypuses *fluoresce*. They emit a fascinating blue-green color under ultraviolet light (Anich et al., 2020; Casella, 2020; Giaimo, 2020). An unexpected finding that delights us, surely. We may then wonder, "Why? What is the *purpose* of exhibiting such a distinctive color? How is it *adaptive* (useful) in some particular environmental conditions?" Speculation has already begun. A mating signal? Nocturnal camouflage? Something less obvious?

How might the historical sojourn above inform this case? *What if*, as the authors of the recent study suggest – echoing Darwin, perhaps – the platypus's startling trait has no ultimate "why" at all, besides history and happenstance (Gould & Lewontin, 1979)? Seeking its "purpose," not just its historical context, may very well betray the same teleological bias that permeated so many 19th-century and even current interpretations of evolution. Fluorescence is found in a wide diversity of organisms, from birds to corals, from pitcher plants to worms and squid. Yet in most cases, it fails to exhibit any clear adaptive significance (Marshall & Johnsen, 2017). The more significant and more fundamental question for students and teachers may thus be: Why do we *expect* to find a purpose? Would a lack of function in any way diminish the delight in learning about our cousin's colorful fluorescence? What would it mean to reconcile ourselves with a view of evolution that is not "unrolling," but – more as Darwin described – thoroughly contingent, where purpose is not sacred?

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