# Teleology’s Long Shadow

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**Abstract** We describe the ubiquity of teleological language and thinking throughout biology, as a context for understanding how students think about evolution, as well. Examples can be found in molecular biology, physiology, ecology, and taxonomy, at least. Recent research documents a deep human psychological tendency to attribute purpose or intent (and thus normative meaning) to natural phenomena. We present a possible evolutionary explanation. Still, these cognitive habits help foster scientific errors of projecting human norms onto natural phenomena (what we have elsewhere termed the naturalizing error). Subsequent appeals to “nature” are used (inappropriately) to justify cultural ideologies.. Accordingly, we advocate explicit learning about teleological dispositions and their cultural consequences as an essential countermeasure.

**Keywords** teleology ▪ appeal to nature ▪ naturalizing error ▪ information metaphor ▪ balance of nature ▪ intentional agency

## A Historical Inspiration

Alexander Humboldt was the premier naturalist of the early 19th century. His 7-volume *Personal Narrative of Travels to the Equinoctial Regions of America* was a bestseller that inspired Darwin’s later account of his own voyage on the *Beagle*. A polymath, Humboldt explored plant geography, meteorology, terrestrial magnetism, volcanic geology, and the role of precious metals as money standards. He collected and drew specimens, collaborated with Goethe, and opened a free school for miners. Along with these notable achievements, Humboldt also sharply criticized Carl Linnaeus’s taxonomic scheme. He rejected its implicit assumption of a divine, hierarchical order, one that was “meant to be.” (That prevalent view of design in nature was soon articulated in the publication of the Bridgewater Treatises.) Having witnessed, too, how humans damaged nature, Humboldt doubted that they could be beneficiaries of a world created just for them (Wulf 2015, Wulf and Melcher 2019). In short, the renowned Humboldt took strong exception to the popular view that nature embodied an intentional value, or purpose.

The problem that provoked Humboldt nearly two centuries ago still haunts us today. Teleology—defined here as a perspective that imparts intent and goal-oriented agency (or normative purpose) to actions in the world around us—is widespread. Humans seem to readily attribute meaning and intentional value to what they merely observe.[1] Here, we echo Humboldt's cautionary comments and survey how traces of teleological thinking may be found throughout biology (first section below). That is, the problem extends well beyond just how students interpret evolution, we claim. Psychological research has documented that teleology is deeply rooted in human cognition, perhaps as a heuristic strategy, or bias, shaped by evolution itself (second section below). This broader context should ideally inform how science educators address the problem.

More importantly, normative teleological perspectives have profound cultural consequences, as Humboldt noted in the case of human attitudes toward exploiting nature or the environment (third section below). Assumptions about a purpose-laden nature frequently guide ideological views. Indeed, advocates often appeal to nature (or human nature) as ultimate justification for their view. But regarding nature as a valued or inevitable benchmark reflects a teleological outlook: namely (again, under our definition), that nature exhibits a self-justifying or intended outcome. However, nature just "is." Alone, it does not provide any ethical warrant, or "ought": the familiar naturalistic fallacy. Descriptive and normative modes of reasoning, while distinct, can easily (albeit inappropriately) be conflated. Worse, scientists may project their own cultural norms onto nature—another, yet different problem that we call the *naturalizing error* (discussed more fully below). Their supposedly "objective" portrayals may exhibit a personal or social bias. Appeals to nature in such cases, buoyed by an invisible teleology, may carry forward scientific errors, which ironically seem grounded in empirical evidence. Students need to be aware of how teleological perspectives, especially in concert with biased science, can shape cultural discourse, often adversely.

## The Ubiquity of Teleology

Historically, biology educators have been chiefly concerned with the role of teleology in evolution education (for example, Bartov 1978, 1982 as an early benchmark and, more recently, Galli & Meinardi 2011; Werth 2012, 2014; and others in this volume). Concerns highlight (at least) misleading images of progress, of inevitability, of directed (Lamarckian) variation, of "intelligent" design (as if mediated by a Creator), of functional optimality, and of privileged taxa or lineages. That is, there is inadequate appreciation of historical contingency (or "chance" or "accident"), natural selection as stepwise and local, changing environments, evolutionary "reversals," vestigial structures, pleiotropy, genetic drift, evolutionary branching, and the role of teleonomic explanations. All are indeed important. However, our focus here is much broader. We show how teleological thinking — or at least teleological language and metaphors —

[1] We acknowledge that teleology may be defined in many ways (see informed overviews by Reiss, 2009; Varella, 2018; and Woodfield, 1976). Many (perhaps most) discussions in biology to date have focused on causality (harkening back to Aristotle's final causes). However, in the misconceptions that we observe among students (and that concern us here), the chief problem is the normative dimension of purpose. In our view, the intuitive beliefs that are typically labeled teleological are answers to "why?" questions that seek normative meaning and justification, not simply a descriptive causal explanation (see analysis by Woodfield, 1976, esp. pp. 205-207, 211-215; also Yudkowsky 2008). For example, normativity seems to characterize the purpose/function distinction (and perhaps the teleological/ teleonomic distinction). We regard normativity as intimately linked to the roles of intention and motivated agency (and thus to diffuse anthropomorphic tendencies) in popular (student) conceptions (Varella 2018). Thus, while there may ultimately be a narrow set of legitimate uses of teleology in biology (using other definitions or conceptions of teleology), we do not consider these highly stipulative cases to reflect those encountered in educational settings and that foster the kinds of misunderstandings about *normative* justification that we address here.

permeate student thinking other areas of biology, as well.

Consider, first, Humboldt's case of taxonomy. Linnaeus, of course, imposed a welcome order on what was earlier a vast and unwieldy catalog of living creatures. But while his "method provided desperately needed standards… its criteria for classification were somewhat arbitrary" (Helferich 2004). Linnaeus judged organisms largely by appearance, failing to recognize that external similarity is often a poor guide to structural or developmental relatedness. He also believed in the immutable fixity of species as expressions of an eternal plan of creation. For example, mammals were named mammals in part to profile mammary glands as essential by design, including related "natural" maternal responsibilities (Schiebinger 1993). With the advent of Darwinian evolution, our view of the diversity of life shifted substantially. We now think phylogenetically, in terms of homology and derived features. We think in terms of common ancestors and branching, not of hierarchical levels of similarity. And yet the underlying philosophy of organization that Humboldt so vigorously critiqued remains largely intact. Seven levels stretch from kingdom to species, each registering a presumptive degree of similarity. Today's Linnaean taxonomic system is a vestige, in a sense, of 18th-century teleology.

Another powerful teleological concept in biology has been the "balance of nature." Professional ecologists today have certainly rejected the notion. But historically, many biologists embraced it (Egerton 1973; Kricher 2009). For example, Rachel Carson used it effectively as a central and persuasive theme in *Silent Spring* (Allchin 2014). Students nowadays espouse notions of balance, once considered good biology (for a summary of research, see Allchin 2014). Namely, populations supposedly self-regulate their size so as not to exhaust food resources. (Even the concept of carrying capacity implies that one can imagine a population in a stable—or "sustainable"— equilibrium.) "Balance of nature" is also taken to mean that species coordinate interactions, contributing to a harmonious coexistence. For instance, predators "need" to keep prey populations in check (often, for their mutual benefit). Accordingly, a reduction of the wolf population in Yellowstone was described by a journalist in 2009 as leading not just to more elk, but to an "overabundance" of elk. Likewise, fungi and reducers are "needed" to recycle nutrients in an ecosystem. Also, stability is the norm. So one does not expect untoward disturbance (floods, hurricanes, volcanoes)—or else things quickly return to their "normal" ("balanced") state. In almost all cases, "balance" is a normative concept of how nature *should* be (Zimmerman & Cuddington 2007): nature is balanced (teleologically) because it is *supposed to be* balanced. Hence, one might hear that forest fires are "needed" to rejuvenate communities or to pave the way for ecological succession. Such appeals to the balance of nature, while scientifically discredited, still permeate the rhetoric of environmentalism, where it appears under the guise of scientific respectability. While ecologists formally eschew the concept of balance of nature, it remains a widely adopted preconception and a feature of language that seems not to disappear entirely.

Students also exhibit a similar normative misconception that the body should exhibit an inherent "balance" or intended "normal" state, and that this is governed by immanent "wants" or "needs," quite apart from any meaningful understanding of homeostatic mechanisms. Namely, the body achieves stability because, ultimately, it is *supposed to be* stable. For example, a hit 1960s love song celebrated the presumed standard body temperature (in °F): "Hey, 98.6, it's good to have you back again." Deviation seems *wrong* (in a normative sense) and *thus* leads to restoration of a "normal" or essentialist state. Someone who is ill will "get well soon," regardless of and independent of any immunological system. Thus, for centuries, scientists misled themselves into viewing fevers as "unnatural" and symptomatic of pathology. The unstated assumption of an "ideal" steady state as a "natural" norm eclipsed the concept of a dynamic equilibrium, where the body might instead have an adaptive response (to reset temperature, making an unwecome envrionment for pathogens).

Likewise, medicine was long prejudiced by a presumed universal "normal" condition as a prescriptive norm. Medical ethicists have now recognized "normality" as a value judgment, not any objective state (see, for example, Boorse 1977; Caplan 1989; Englehardt 1974; Sacks 1985). So, too, for genetic development. Even among scientists, rare developmental conditions were long considered pathological "monsters" or "errors," not instantiations of expected variation (for fuller discussion, see Allchin 2017, pp. 125-131). Genetic conditions such as muscular dystrophy, cystic fibrosis, sickle cell anemia, phenylketonuria, Down's syndrome, and so forth, are still typically characterized as "diseases." Yet that label presumes a narrow sense of what "should" develop: another normative expression of intentional purpose.[2] Physiology and development, like ecosystems, are commonly interpreted as meant to purposefully stay in "balance."

Consider, next, teleology at the level of molecules: most prominently, in how biologists conceptualize and talk about DNA, especially to non-biologists (see Heine 2017; Moss 2003). That is, the standard characterizations of genetics lend a sense of intentional agency and even intelligent purpose to genes and the cell processes they indirectly help precipitate. Namely, DNA/genes provide *information*. Ostensibly, that indicates a cognizant, "informed" agent. DNA, one hears, provides the "blueprints" or "instructions" for life, implying an architect or designer who drafted the plans. Indeed, DNA has its own "language." The language is of base pairs, typically designated with 4 letters (A, T, C, G): the image conveyed is thus of *abstract symbols*, not of *physical three-dimensional shapes* that constrain molecular interactions. Intention continues. The "message" of the DNA is "read" by an enzyme which "transcribes" the information, generating a "messenger" molecule, RNA. The reality of large macromolecules tumbling randomly through cellular protoplasm and occasionally encountering a complementary shape does not readily spring to mind. The "information" may then be "edited," as though by a purposeful editor, and "carried," as though by a purposeful courier, to the ribosome, which again "reads" the "message" and "translates," as though by a purposeful cryptologist, its genetic "code." The role of entropy and energy release as ineliminable causal factors are rarely mentioned. The whole causal cascade seems to depend on autonomous linguistic agents deliberately communicating to one another, not on thermodynamics.

Collectively, the terms we use to describe DNA are potent. They contribute to its image as a purposeful "master molecule." Its agency extends (through a planner's mindful "blueprints," recall) to the development of a whole organism from just one cell. Genes seem to have extraordinary power. That might include one allele exerting "dominance" over another (a view that elicits many further misconceptions about evolution and population genetics; see Allchin 2005). At the extremes, we encounter talk of "selfish" genes and genocentric evolution. An organism is supposedly no more than a genome's way of making another genome. No one should wonder why students (and the broader culture) develop a misleading view of genetic determinism (Heine, 2017): it is embodied in the very language that biologists use, imparting agency, purpose, and, indeed, intent to a set of molecules whose shapes incidentally have

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[2] Elsewhere, we have discussed how treating evolutionary adaptations as a "normal" benchmark or intended outcome (a normative "purpose" achieved through natural selection) reflects what we call *crpytoteleology* (Allchin & Werth, forthcoming). This echoes folkbiological approaches to species essentialism: a belief that an organism's essence will reassert itself after a distorting influence (Griffiths, 2002, pp. 78-80).

particular causal relevance.

For biologists, of course, the notion of information may be formally "just" a metaphor. But in their analysis of the *Metaphors We Live By*, philosophers George Lakoff and Mark Johnson (1980) remind us that analogies and contingent associations carry with them substantive and constitutive meaning. It may well be impossible to communicate without metaphors, but this does not discount their import. In this case, the DNA-as-information metaphor embodies considerable teleology. When instructors educate beginning biology students with such loaded language—even if unwittingly and with the best of intentions—they promote a view of individual molecules either acting with deliberate agency or by their fulfillment of a plan inscribed in them by some other agent.

The teleological view of genetics helps further foster a teleological view of species essentialism: that each species' distinctive traits are universal, determined by its own unique "purpose" (on the iconic case of tiger stripes and leopard spots, see Allchin 2019). Folkbiological essentialist conceptions of species exhibit idealism and include a distinctive normative dimension (Gelman & Rhodes 2012; Griffith 2002). Like "just-so stories," these essentialist conceptions describe a species that (in the holder's mind) is "self-justified" and inevitable. But nowadays, identity is frequently traced to genes (for a fuller discussion, see Allchin 2017, pp. 141-144; Heine 2017). Thus, altering a species' genetic make-up is viewed as tampering with its "natural" essence. Insert a few genes (or just one) in a crop plant and it suddenly becomes seen as a monstrous "Frankenfood." Genetically modified organisms (GMOs) are thus widely condemned as "wrong" simply because they are "modified." They are perceived as compromised or "unnatural," violating an implicit norm of essentialist purpose (for fuller discussion, see Allchin 2017, pp. 192-197). By contrast, when similar genetic changes occur in humans, where they are labeled gene *therapy*, they are widely endorsed as a benefit. The term "therapy" is not suggestive of any essential change. It seems more like a welcome transplant via molecular surgery. The teleological views of species identity and genetics are closely allied.

The information metaphor is also found in physiology. Hormones are typically described as "messengers," likening them to a telegram or courier that "delivers information" to a "receptor" cell surface protein that "interprets" it. It is not the hormone itself, nor its physical shape, that seems causally important, but again the abstract "information" it somehow contains or encodes. In addition, hormones are typically depicted as traveling from their source directly "to" (teleologically) their "target" cells. No bloodstream "pinball," with repeated mismatches as the hormones collide randomly with cell surfaces until a matching receptor protein is encountered —quite the contrary to a sense of messages "delivered" straight to where they "ought to go"

In a similar way, neurons and nerves are described as carrying information, too. The inevitable image is one of telephone wires or fiber optic cables running through the body. But such information-rich human communication channels are misleading models for the binary action of neurons: they either send an impulse (when causally triggered) or they remain in a ready state. The impulse itself has no further "information." True, the impulses may vary in frequency, and nerve pathways may converge or diverge at synapses with significant effect. However, the basic "message," if there is one, is hardly more than a percussive beat. The "pain signal" from a finger, or the "blue signal" from a retina, or the "stretch signal" from a carotid artery, are all fundamentally the same: a burst of neurotransmitters into the synaptic cleft as the result of an all-or-none action potential down the cell's axon. The thing that differentiates them is which pathway has been stimulated—like when manor house servants hear an indefinite bell ring and, to discern which room has requested service, have to consult the lingering motion of one particular bell among many bells on the cellar wall. The "meaning" of the nerve impulse is determined solely by the map of the network, not by the nature of the impulse. Neurons are not, any more than hormones, teleological agents.


Figure 1. Servant bells displayed at "Downton Abbey: The Exhibition" (photo by Alex Welsh, courtesy of the New York Times).

Information and cognition is also implied in the concept of immune "memory." Thus, one might hear that an antibody "recognizes" an earlier pathogen type, like someone recalling the face of a former intruder. But there is no conscious "recognition," only a rapid positive feedback cycle triggered by the renewed presence of an antigen. Immune cells are also said to "recognize" self from non-self. They "communicate" with one another through a secure "double-handshake"—in the mode of a conscious acknowledgment upon greeting another cell that can provide the secret counter-password.

Other examples abound. Here, we briefly mention just a few more—a mixture of student misconceptions and unguarded classroom talk. For example, ions "need to" cross membranes to flow down concentration gradients. Ligands "need to" bind with their target receptors. Plants grow roots *towards* water (not just in all directions until they encounter moisture). Plants also somehow sense heat or wind and close their stomata "so that" they prevent water stress before its onset. Plants "need" pollinators, "so as a result" they produce nectar and develop brightly colored flowers to attract them (not the other way around). Seeds "need" dispersal, so plants develop fruits to attract them, which change color to signal when they are ripe. Viruses regulate their virulence, "in order to" not kill the host they depend on. Animals "need to" defend against pathogens, so there will always be an appropriate antibody ready and waiting. Sweat glands respond independently and secrete sweat "in order to" cool off, not as part of a complex thermoregulatory system involving the hypothalamus, remote sensory cells and hormones. Intentional agency and purpose seems to be everywhere in living systems.

We hope that these many examples help illustrate the ubiquity of teleological imagery, conceptualizations and language throughout biology, not just in evolution. Ultimately, through teleological framing, cells, molecules, organs, species, populations and organisms all become active, purposive agents. They each seem to largely guide their own fate, while contributing ("adaptively," of course?) to the overall survival and well-being of the organism and the shared ecosystem. We hope that our survey may indicate the scope and depth of the teleology problem for educators.

Of course, in none of these cases does teleology compromise credible scientific research. Biologists learn, through their professional acclimatization, to regard such conceptualizations and language as mere conveniences, or shorthand (Dawkins 2004). The teleological framing is an expedient convention, generally used to help avoid more convoluted phraseology. The challenge for educators, then, lies not merely in instructing (nor possibly misleading) future scientists, but in helping non-biologists achieve a similar level of sophistication and simply recognize these tropes as tropes. In our view, students should thus learn explicitly and reflexively about human cognitive dispositions: how, and perhaps why, we tend to think teleologically, and thus why such teleological frameworks permeate much of biological thought.

Consider J.B.S. Haldane's famous response when asked what a lifetime spent studying nature can teach us about a Creator: "An inordinate fondness for beetles" (Hutchinson 1959). Even if delivered tongue-in-cheek, Haldane's quip has resonant staying power because it appeals to our teleological intuitions. It fits our conscious or subconscious expectation that the world unfolds as part of some prescribed plan or purpose. It is difficult for us to imagine that complex natural phenomena (such as nearly half a million described species of beetles) arise spontaneously, without conscious planning on the part of some deliberative agency. We presume that even life itself must have some goal, even if it is merely to reproduce. Yet flames, like beetles, also reproduce. Fire rapidly spreads and conquers just by growing, and with no underlying motive or intent. We can appreciate that fire might arise from wholly material, unplanned causes such as a lightning strike or a piece of burning lava tossed into dry grass by a volcanic ejection. Why do we presume that beetles, or life itself, spreads in any way differently than fire does? Why do we ask "*Why* are there so many beetles?" when we don't similarly ask "*Why* does fire spread so effectively?" Of course, one can easily find people who would in fact argue that hurricanes, earthquakes, and other non-living natural phenomena are just as much the purposeful, teleological handiwork of a deliberate creator as Earth's multitudes of beetles. Such views, coupled with the many cases throughout biology, from DNA and hormones to ecosystems and body temperature, underlie our orientation to teleology as fundamentally about normative purpose, rather than causality.

## An Evolutionary Interpretation of Teleology Itself

Spend any time with young children and you will experience a master class in how humans concoct stories that help us make sense of the world. As we construct causal narratives, we almost invariably adopt a default "intentional stance" (Dennett 1995). We presume that everything operates intentionally, according to a mindful design. Children speak of rocks being flat so birds can land on them, or soil being soft so worms can dig in it. Children are, as Deborah Kelemen (1999, 2003, 2004) describes them, "intuitive theists." This disposition does not necessarily wane with age (Guggenmos 2012; Kelemen & Rosset 2009). It is also found among diverse cultures (Mills & Frowley 2012; Rottman et al. 2016). As Richard Dawkins observed (1995), we have "purpose on the brain." Ernst Mayr (1988) similarly suggested that people generally prefer vitalistic explanations to mechanistic ones. We easily impute intentions even to meteorological or celestial events, to geological features, and to cars, computers, copiers, phones, malfunctioning appliances, and other forms of mechanical technology. The behavior may be so common that we seldom notice it until someone calls attention to it. Studies show that even when we consciously try to break the teleological paradigm, we inadvertently revert to it under conditions of mental stress (Kelemen & Rosset 2009). As educators, we need to consider whether teleological schema, the "function compunction," may be hardwired in our brains.

Many authors have suggested that the ubiquitous teleological thinking may have evolved because, ironically, it has adaptive value (Atran 1998; Kelemen 2004; Kelemen & Rosset 2009; González Galli & Meinardi 2010). There is no accepted evolutionary account, but one may entertain plausible scenarios.[3] One possibility highlights how humans evolved in a social context. Such an environment puts a premium on social cognition and negotiating one's way through various social dynamics. For example, mirror neurons seem to provide us access to how other people feel and to imagining what they are thinking (or plotting): a valuable *social* tool, particularly for developing empathy in such a highly social species. Accordingly, it would be advantageous as a default working hypothesis, or heuristic, to attribute agency to any observed behavior and to decipher, "Who did this? What was their motive?" That might easily be applied, indiscriminately, to interpreting causes more generally: "What unknown agent do I need to monitor?" The whole world may be treated as an extended social environment. Haselton and Buss (2000) and Tooby and Cosmides (2008) further suggest that when interpreting possibly threatening behavior, the cost of a false-negative is higher than the cost of a false-positive. Hence, one might expect a bias towards over-attribution of agency, intent or purpose. Might teleological tendencies have resulted merely from a selective advantage of "hedging one's bets"?

Or, in a quite different scenario, as purposive agents ourselves, we may simply generalize from our own deliberative action when interpreting other observed causes (Epley, Waytz & Cacioppo 2007). That is, we may project intentional agency upon all forms of movement or change. Only with time do we learn that a physical world exists apart from a living one, and that sometimes it behaves capriciously, with no motive or purpose.

Of course, educators need to be cautious. Our speculation may itself reflect teleological "bias": are we fabricating yet another "just so" story without the rigorous evidence to confirm it? Our intent, here (again), is not to provide a definitive scientific explanation of the origins of teleological thinking, but to open consideration of plausible evolutionary interpretations (which might shed light on how to deal with their far-reaching ubiquity).

Regardless, it can be helpful to situate human teleological tendencies in the evolutionary context of ancestors and related organisms (primates, and mammals, more generally). We certainly observe elements of forward-looking (intentional?) thinking in other animals. For example, chimpanzees, bonobos and orangutans (at least) are able to think ahead, plan, and select tools for later use (Mulcahy & Call 2006; Ruiz and Santos 2013). Primates are also good at social cognition and planning strategic political behavior (de Waal 1982, 1989; Small 1995). Experimental evidence strongly indicates that even rats grasp underlying cause-and-effect relationships and plan accordingly (Blaisdell et al. 2006). Mice, too, demonstrate empathy of others' pain (Langford et al. 2006). Emery and Clayton (2009) survey the ability to interpret goals and/or beliefs in twenty non-human species. Are these the biological roots of human teleological thinking? We need to continue to be attentive to research that might inform our

[3] Based on a wide review of teleological and other anthropomorphic biases, Varella (2018, pp.5-6) regards teleological/anthropomorphic reasoning to combine three separate cognitive processes, each with its own behavioral context and evolutionary origin: a function/design stance; a goal-oriented interpretive bias; and an attribution-of-intent disposition. Such lively theorizing warrants further investigation.

evolutionary understanding of what seems to be a strong cognitive disposition.

Regardless, the teleological way of thinking is firmly entrenched, even among well educated scientists. When subjected to cognitive overload in test conditions, even veteran physical scientists resort to teleological explanations (Kelemen, Rottman & Seston 2013). We cannot eliminate or entirely suppress the teleology. But we may learn to regulate its effects—a prospective goal for education. This involves awareness and strategies for noticing teleology in action (again, even beyond the realm of evolutionary concepts) and for keeping its misleading effects in check, not just trying to avoid it or imagining its shadow will disappear with the "light" of appropriate evolution education.

## Teleology's Dark Shadow

Does any of this truly matter? As we noted above, teleological thinking among students fosters many misconceptions about evolution, of concern to science educators. However, our chief concerns are not about the familiar evolutionary misconceptions, nor about the philosophical subtleties of interpretations of causality or the status of intentionality in homeorhetic systems. Rather, we focus more deeply on how teleology tends to blur the distinction between normative and descriptive reasoning about nature. Namely, teleological claims go beyond mere causal *explanation* to become a form of normative *justification*. They posit purposes as reasons for particular organic structures or processes: not how they formed, but why they should exist at all. Namely, in teleological frameworks, they were *intentional* products. The appeal to purpose fundamentally answers a metaphysical "why" question rather than—as is often assumed in discussion of teleology—a causal "how" question. One is implicitly arguing that the way nature *is*, is because that is the way it was *meant to be*. What appears to be a neutral description of nature—even an apparently scientific one—may be perfused with normativity (see also Goodfield 1976).

Teleological views thus seem to form the psychological basis for one of the classical logical fallacies: the appeal to nature (also sometimes called the naturalistic fallacy). Namely, an appeal to nature seems attractive (or legitimate) because of a primary belief that nature embodies purpose, and also that one can enlist a plain description of nature as a model, to justify similar actions or behavior. In teleological perspectives, the natural world is an implicit ideal, or norm. It is, after all, presumably the ultimate expression of an intentional or purposeful (perhaps "intelligent") agency, or of a more diffuse inherent tendency that ensures "progress" and "good" outcomes. Through teleology, nature becomes normative. But this normative ascription is unwarranted. Alas, the teleological interpretations throughout biology, imbuing nature with purpose, indirectly support this common fallacy. Ironically, science apparently lends credibility to what is widely regarded as an *unjustified* form of justification, or argumentation.

Such appeals to nature can be potent. The conclusions seem based on what is "natural," inherent, or inevitable. There is thus no recourse. Natural purpose seems both inescapable and irrefutable. Thus, even if one can imagine things differently, or argue that they "ought" to be different, one seems bound to the inevitable. Teleological-based claims can thus function as a powerful method of persuasion. Socially, they are a sort of rhetorical weapon. Nature, with its aura of intended outcomes, acts like a trump card to eclipse alternative arguments.

This style of persuasion becomes acutely problematic in a general cultural context, where ideological arguments invoke the "facts" of nature: for example, in common appeals to "human nature." While normative arguments may well be informed by science, there is a risk that science may be misportrayed, or that the science itself may be cryptically biased. For example, for many years forest and wilderness management policy was dictated by a “scientific” image of the balance of nature, which cast forest fires as a disruptive interference. However, that scientific reasoning was misguided by teleology, as was the subsequent appeal to nature. Likewise, for years doctors regarded as pathological any individual who did not fit the (then) “normal” heterosexual model, and thus recommended coercive conversion therapy. Consider, too, how much environmental policy is guided by the aim to protect endangered species, applying the Linnaean taxonomic category of species as the relevant unit. Humboldt’s critique helps us recognize the teleology in that assumption. Environmental ethicists now wonder if preservation of wilderness and whole habitats is a more appropriate strategy. Teleological reasoning fostering faulty science, at least, can be culturally problematic.

Consider, for example, the shaky science that was presented to justify the “Paleo Diet.” Here, teleology took center stage. The plausible premise was that we should eat what we were “intended” to eat. Namely, our diet should reflect our adaptive history: our enzymatic capabilities and immune sensitivities. However, there were several further assumptions: that our digestive enzymes evolved primarily during the Paleolithic Era; that the human diet at that time consisted of primarily meat and vegetables (absent agricultural grains and domesticated dairy products); and, finally, that not much has changed since then (with too little time for further natural selection). Science seemed to conveniently justify what many took to be a healthy and desirable diet anyway. Alas, all the key assumptions proved unfounded (Zuk 2013). The justification for the Paleo Diet was no more than wishful thinking with a flawed scientific gloss. What is important here, however, is the original impetus to secure the science. In this case, the scientific reasoning was strongly shaped by the desired conclusions. The promoters of the Paleo Diet tried to inscribe their ideals and tastes into “objective” nature (which would then, teleologically, carry substantive persuasive weight). The science exhibited a fundamental error: converting their personal values into supposed “facts” of nature — what we have called the *naturalizing error* (Allchin & Werth, 2017). Cultural ideology masqueraded as science through faulty rationalization. But here the masking effort would have been pointless without a teleological view of nature and the implied virtue of following nature as it was “intended.”

The naturalizing error, with its roots in a teleological image of nature, can have profound political overtones, as well (see Allchin 2008; 2017, pp. 117-152; Allchin & Werth 2017; forthcoming). For example, gender roles in society seem to depend in large part on a strict (and unproblematic) biological dichotomy of the sexes: hence, male and female. For many people, discrete sexes is a “safe” scientific fact. Yet biological research has profiled the complexity of sex, its sometimes hybrid nature, its fluidity in tropical reef fish (for example), and the complex dynamics of mating and outcrossing (in one species of ant, using more than two sexes) (see Allchin 2013, pp. 117-124). We can see that cultural ideology has contributed to naturalizing gender through science as an expression of “essential” sex differences. But if we disallow nature as an implicit (teleological) model, cultural rationales about gender falter. Similar efforts have sought to naturalize the nuclear family through faulty reasoning about adaptive economic history (Smith, 1993) or through natural history museum exhibits (Haraway 1989, pp. 26-58). Cultural debates about monogamy as a norm have detoured to discussion of pair-bonding in birds, while controversies about sexual orientation repeatedly drift to genes for “natural” arguments. Indeed, the whole field of evolutionary psychology is rife with flawed efforts to biologize and thereby legitimize a large handful of behaviors, from rape, infidelity and territorial aggression to cooperation and pacifism. Bad biology can still be persuasive in some contexts.

Ample historical, sociological and cognitive evidence now indicates that scientists can project their ideological views onto nature. They can yield gendered, racist, classist, and other prejudicial "scientific" claims (for example, Gould 1981; Haraway 1989; Schiebinger 1993; Young 1975). With teleological perspectives, one can easily interpret these cultural biases as "natural" and purposeful. Worse, these biased accounts may be used inappropriately to justify social policy. For example, the author of the Google Memo appealed to certain "facts" about gender to justify inequities for women in the tech industry. His facts were cherry-picked and misleading but more importantly, here, his style of argument sought authority in nature and its apparently manifest purpose (Fuentes 2017; Sadedin 2017). In a similar way, advocates appeal to nature in arguing alternative positions about sexual orientation. On one side, the possibility of a "gay gene" is seen as proof that sexual orientation is "natural." On the other, it is an "unnatural" violation (mutation) of a species' "natural" reproductive function. Both sides appeal to nature, reflecting an implicit belief that nature exhibits a purpose that can resolve the cultural issue.

Even so seasoned and august a biologist as E.O. Wilson has succumbed to (or astutely tried to exploit?) the naturalizing error (Allchin 2018). Wilson has posited that humans have an emotional affinity for life—what he calls biophilia—which he strategically promotes to justify conservation of biodiversity and wilderness. Again, we see an appeal to nature to justify an ideological stance, as though nature expressed a purpose we should emulate or follow. Wilson has thus claimed that biophilia is "innate" and "part of human nature": a "biological imperative." It is a "psychological phenomena that rose from deep human history" and thus is "resident in the genes themselves." The implication is that we must heed our destiny. However, no solid evidence for this disposition exists. It is, as Wilson briefly admits at one point, no more than speculation. Biophilia is another example of hopeful teleology at work culturally through flawed science.

Teleological explanations foster a "laissez faire" attitude toward the natural world. The world was made this way—all is as it should be—and there is no use trying to change the natural scheme, especially with the frequent addendum (that Humboldt criticized among his contemporaries): that this scheme was purposely made for the sake of humans. Nature, as currently found, is presumably intended, as well as inevitable — and not to be tampered with or changed. That might constitute an argument for preserving wilderness. It might equally, ironically, exonerate those who have damaged the environment.

The teleological view of the world equally affects political perspectives in culture. That is, the status quo becomes inherently privileged. It is assumed that the current state of affairs is a product of "natural" purpose or intent. The order is *ordained*. It is not from "accidental" forces. Nor from a random convergence of events. Nor from a series of successive contingencies. Hence, it is all too easy to imagine that social injustice or disparities in society were intended or reflect some ideal, rather than arising from arbitrary luck or the exercise of unequal power. Teleology is a nefarious handmaiden to justifying the existing social order and its power structure. (No wonder, then, that the privileged elite more readily endorse the teleological notion of genetic determinism; Heine 2014, pp. 46, 256; Lewontin, Kamin & Rose 1984). Understanding the origin and cognitive status of teleological thinking patterns (in biology or elsewhere) has potentially significant political overtones.

These are, then, the dark shadows cast by teleological thinking: misleading arguments and bogus justification not only within science but for ideology and social policy, all with the presumed imprimatur of "solid" (unequivocal and unquestioned) science. The teleological notions of Linnaean hierarchy, of genetic determinism, of a balance in nature, of species essentialism, of immunological defense, and of "normal" health all have indirect, but concrete social consequences. The appeal to nature, the naturalistic fallacy and the naturalizing error all emerge from teleological perspectives. And they all erode the important distinction between descriptive and normative reasoning (Allchin & Werth, forthcoming). However, educators may strive to expose these powerful and pervasive errors and sketch remedies or alternatives.

## Educational Implications

It seems difficult to overstate the entrenchment of the inherent human disposition to explain natural phenomena in terms of intent and goal-oriented agency (or purpose). It is found in "naive" children, in adults from many cultures, as well as in some commonplace scholarly explanations. Teleological preconceptions have long been recognized in evolutionary biology, but we have shown here that teleology's tendrils extend through all of biology, from ecology and taxonomy to physiology and molecular biology, and thence into general culture. Teleology is here to stay. Rather than try to eliminate it outright, we need to accommodate it and consider "workaround strategies" to regulate its adverse effects (Varella 2018, pp. 14-16).

What can be done? First, awareness is key. Educators must be aware of their own tendencies, openly acknowledge them, and patiently explain alternatives. When a student uses a teleological expression, the instructor should pause class, identify it and explain the cognitive disposition, invite collective reflection on its normativity, and articulate how scientists use a non-teleological alternative. Students tend to approach biology with a normative orientation. They are chiefly interested in "why" (not "how") questions. We need to help students recognize this intuitive bias and to appreciate alternative, purely descriptive explanatory frames that do not appeal to mind-like intent or conscious ideals. This may include describing the limits of science, which can elucidate how structures concretely *function* and how they originated, but not reveal some transcendental *purpose* or *intention* of what they "should" be (Goodfield 1976). We consider it crucial to couple teleological and non-teleological perspectives together, contrasting descriptive and normative views, as a bridge to noticing and regulating teleology's influence.

Second, while teleology is not limited to evolution, evolutionary examples can be very helpful. Structures that seem to contradict an assumption of intentional purpose are occasions to bring the teleological assumption into relief. Cases of non-optimality, such as pleiotropic structures, design "compromises," apparent structural or genetic limits of functional parts, and so on, are potential "discrepant events" or anomalies that (when mindfully managed by a teacher) activate curiosity and fuel explicit reassessment. Again, the contrast between normative teleological assumptions and the descriptive alternatives should be underscored.

Similarly, one can introduce possibly puzzling examples that highlight the role of evolutionary history, *rather than* functional "design." The aim is to illustrate the role of historical contingency, or "chance accident," inconsistent with a normative or intentional agent. For example, textbooks already typically present vestigial structures and atavisms as evidence of evolution, but their meaning for teleology may deserve further discussion (Johnson et al. 2012; Warren & Ross 2018; Werth 2014). Evolutionary "reversals"—flightless birds, whales (with air-breathing blowholes), shell-less mollusks (octopii, squid, cuttlefish), blind cave fish with eyes, and others—help illustrate wandering ancestry in contrast to a premeditated and uniform design-laden direction. Comparative biology is helpful in revealing how structures might have ended up quite differently, even through modest developmental changes (for case examples, see Allchin 2019; Werth 2012). Indeed, one can use any structure that bears witness to historical change, even if it is fully functional and may seem "designed." Beginners may turn to Neil Shubin's *Your Inner Fish* (2009), for numerous examples of how structures and genes have persisted and changed (see also HHMI Interactive 2015; Rosenfeld 2014). This was certainly Darwin's aim in the first chapter of *The Descent of Man* (another valuable source of examples). Ironically, historical continuity (of structure) is as important as historical change (of function or context), here. Biological cases will later become exemplars in cultural contexts: for interpreting historical contingency or an unjustified appeal to "natural" ideals.

As always, active learning and engaging students in their own conceptual development is optimal. Teachers should offer guided inquiries to help students recognize and contend with their own preconceptions (see Werth 2009, 2012). Following Shermer's (2006) view, we need not wholly deny that evolution generates "design" and an impression of purpose. But we do need to show that ordered organization can emerge non-teleologically in a stepwise, "bottom-up" process rather than through "top-down" foresight or intention agency (Dagg 2011; Dennett, 1995; Dunkelberg, 2003). Through exploring some of the cases mentioned above, students can decipher process and appreciate how evolution works continuously in-the-current-context, without reference to some transcendental ideal. Again, the aim is to couple the impression of teleological (and normative) purpose with a non-teleological, non-normative understanding.

Still more is needed, however. We have argued that teleology's pernicious effects extend beyond science and shape key sociocultural perspectives. Normative appeals to nature, apparently based objectively on scientific descriptions, are common. Reasoning to justify personal choices or public policy decisions frequently rely on views of "human nature" or to how nature was "meant to be." One encounters efforts to enlist biological science to resolve such cultural issues as sexual orientation, gender roles, inherent behavior based on skin color or geographical ethnicity, genetic destiny, norms of health, determinations of when life begins and ends, and more. As we have shown, such science is frequently biased, or even corrupted, by teleological perspectives. As much as educators may prudently wish to avoid "hot-button" political or cultural issues, they also have a responsibility to defend good science. They should be teaching about the naturalizing error. That is, biology educators should show how nature can sometimes be misrepresented—and science misappropriated—in rhetorical appeals to nature. For a sampling of cases, from the naming of mammals and human tool use, to developmental "monsters," evolutionary psychology and genetic determinism, see Allchin (2017, pp. 117-152) and Allchin and Werth (2017), as well as the sources cited above discussing the Paleo diet, gender roles and the male/female dichotomy, biophilia, monogamy, and sexual orientation. Examples may be introduced, their assumptions described fully, and then discussed, with an emphasis on how (like "just-so" stories in evolution) *descriptive* teleological accounts of nature seem to be readily but illegitimately transformed into *normative* justifications of how things "are meant to be" (and sometimes, vice versa)  In our view, identifying bad science and the adverse cultural consequences of appeals to bad science are as important as any discussion of pseudoscience or science denial. Learning about the naturalizing error should impress students with the concrete relevance and value of their science class.

Our species demonstrates remarkable ability in imagining and planning for the future. We can apply these skills in helping to solve Humboldt's dilemma. As educators we can look ahead—*purposefully*—creating lessons to help students learn about the common, dark, and very long shadow of teleology.

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