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# Homeostasis and Purposeful Evolution

by J. Scott Turner

Life is a thermodynamic phenomenon. It may exist in a physical world, but it is also marked by attributes not to be found in that world, such as intentionality, purposefulness, design, and intelligence. The Darwinian idea seeks to explain evolution while avoiding those essential attributes of life. On the grounds of simple logic alone, the Darwinian idea cannot provide an adequate theory for what it seeks to explain. The widely misunderstood and trivialized concept of homeostasis provides a basis for just such a coherent theory of evolution that accounts for life's essential purposefulness, intentionality, creativity, and the generation of evolutionary novelty.

## Introduction

The most significant shortcoming of modern Darwinism is its alienation from the very thing it seeks to explain. Darwin himself sought a natural law explanation for the origin (and relentless extinction) of life's "endless forms most beautiful," one which would be free from the vitalist muddy-headedness that then prevailed in natural philosophy. His thinking was deeply immersed in those beautiful forms, which he found in abundance among pigeons, barnacles, earthworms, and orchids. [1]

In the early twentieth century, the Darwinian idea transformed into a theory of gene selection. Darwin's "beautiful forms" were thereby reduced to vehicles for genes that conferred reproductive advantage, and which could carry out the business of transmitting "favored" genes across generations.[2] In that transformation, the fundamental attribute of adaptability was lost. In its stead, adaptation became the selection of favored "apt function" genes, which were identified as genes that were selected. This is an empty tautology that, in effect, nullifies the phenomenon of adaptation, and along with it, *life's* fundamental attribute.[3] In the hands of modern Darwinism, adaptation became an ouroboros, a snake eating its own tail, and in so doing stripped away any pretense that it could explain evolution as a phenomenon of *life*.

Adaptation is problematic for the Darwinian idea precisely because it is a frankly purposeful phenomenon. Darwin himself sought to escape the vitalist odor of purposefulness that swirled around natural philosophy at the time. Even so, he could not escape the essential purposefulness lurking at the heart of the phenomenon of adaptation. Darwin knew that somehow, adaptation had to be heritable. Without this, lineages would not evolve: species would simply spin the adaptive wheels starting anew with each generation. Darwin went so far as to propose his own theory of heritable adaptation, which he called *pangenesis*.[4] He did not succeed in his effort, in part because neither he nor anyone else understood heredity, save the Silesian monk Gregor Mendel, who labored in obscurity, and whose work would only be rediscovered at the turn of the twentieth century.

Between Darwinism's eclipse, and the rise of the Mendelian gene, a new form of the Darwinian idea emerged: Neo-Darwinism.[5] This was grounded in a solidly materialist philosophy, and recast Darwinian natural selection, not as the outcome of apt function, but as a sorting mechanism for genes. Thus, "favored" genes (those which are selected) could be passed from one generation to the next, while the transmission of "less-favored" genes was impeded.[6] The rise of Neo-Darwinism failed to shed the skin of the Darwinian ouroboros, but only bound it tighter. Adaptation, and the frank purposefulness that came with it, became cloaked behind circumlocutions and euphemisms like "apparent" purposefulness, "exaptation," neologisms like teleonomy, and cryptoplatonic ideas such as the adaptive state space.[7] I have described this elsewhere as a program of the "abolition of purpose."[8]

The denial of life's essential purposefulness might be crucial to the Darwinian idea, but it amounts to a denial of life's most distinctive attribute. This denial of life itself arguably makes modern evolutionary thought no longer a life science. To restore evolutionary thought to being a science of life again, what is needed is a credible theory of life's purposeful nature, which includes phenomena such as intentionality, creativity, and intelligence. In this article, I will lay claim to such a theory, which I have explored more fully elsewhere.[9]

## The Thermodynamics of Adaptation

A coherent theory of adaptation depends upon a coherent theory of life itself. This starts with that most fundamental science, thermodynamics. At root, life is a thermodynamic phenomenon. It is marked by a high degree of specified persistent orderliness: low entropy, to use the technical term. Low entropy is an unnatural physical state that inexorably degrades to high disorderliness, or high entropy. This is the Second Law of Thermodynamics.

Nevertheless, orderliness does exist in nature, and where it does, there is a thermodynamic explanation for it. Producing order from disorder takes work:

energy. Once an orderly state is created, it inevitably degrades to disorder. For an orderly state to persist, as it does in the living organism, work must be done continuously to produce order as fast as it degrades to disorder. If the work stops, as it does in death, the degradation to disorder prevails, and the corpus of the organism decays.

This thermodynamic aspect of life calls for a different metaphor for life and the organism. Where our language treats life and the organism as objects (as nouns), both are more appropriately treated as thermodynamic standing waves that persist through time (as verbs).[10] Just as Einstein famously asked us to imagine what it would be like to ride along next to a photon traveling at the speed of light, we can imagine life as an ongoing wave of low entropy that crackles persistently through time. We, and every living thing on the planet are riding the crest of that wave, drawing in energy and matter to do the work of staying at the low entropy crest as fast as we decay to entropy and disorder. As we gaze out upon a living landscape, we are seeing not only a collection of trees, leaves, birds, bacteria, fungi, worms, beetles, deer, and mice, we are seeing the complex crest of that standing wave, each ripple and eddy representing an organism, all shaped by the different forms of life drawing in streams of energy and matter, creating their transient orderliness, before that same matter and energy slides down the curl toward disorder.[11] The bucolic and unchanging scene you witness is actually a precarious balancing act of life in all its forms, riding the crest of the thermodynamic standing wave.

Adaptation may be defined as a suite of mechanisms that enable the standing wave to persist through time even as conditions change. Practically, this means channeling a flow of matter and free energy through the organism to sustainably generate its specific orderliness as rapidly as it spontaneously degrades to disorder. As an example, green plants use free energy in sunlight to mobilize disorderly carbon dioxide and water and form it into orderly sugar and oxygen. These are not only molecules but repositories for the captured energy from light: orderliness is stored energy. The plant then recombines the orderly glucose molecule with oxygen to power the order-producing work that sustains the plant, degrading the sugar and oxygen back to disorderly carbon dioxide and water in the process. Animals steal some of that stored energy to power their own forms of specified orderliness. Fungi and bacteria lurk to abscond with energy from all.

Should circumstances change—say temperature, or water availability, or a host of other factors—the mobilization of carbon dioxide, water, and energy must change *in order to* sustain the plant. Notice the deliberately purpose-laden language. Life is the *purposeful* persistence of a specified orderliness that otherwise naturally tends to disorder. Environments may either hasten the degradation to disorder, or slow it down. No matter what the circumstance, production of orderliness must match its degradation. Adaptation is therefore the *purposeful* persistence of a living thing in the face of environmental variations that may alter those flows of matter and energy. For example, the shape of a maple leaf may vary between different environments within a tree canopy, so that "sun" leaves are shaped differently from "shade" leaves.[12] Nevertheless, both sun leaves and shade leaves are unmistakably maple leaves that persist through time.

## Homeostasis

Modern Darwinism proposes that adaptation results from selection of apt function genes. If, for example, salt and water flux across a membrane are specified by a suite of genes, those that produce adaptive responses would be selected for. Organisms whose genes specify maladaptive flows would be selected against. Thus, apt function genes are defined by whether they are selected. Meanwhile selection favors apt function genes. This fundamental tautology is the bone that sits firmly lodged in the Darwinian craw.

To escape the tautology, somehow life has to *know* what is supposed to be. Adaptation cannot be explained without that self-knowledge, which modern Darwinism denies from the outset. Evolution cannot be convincingly explained without a coherent theory of adaptation. Darwinism lacks such a theory.

The missing philosophical nugget may be found in Aristotle's conception of the bioς, which is essentially an organism's internalized knowledge of what it *intends* to be.[13] The realized organism—the tangible organism we can see and hold—is the reflection of the organism's bioς. The organism itself may change form, but always in a way to sustain its bioς, which is unchanging. To follow from the example of sun leaves and shade leaves, each maple leaf has its own internalized bioς. Even as the tangible manifestation of the leaf's bioς varies with circumstance—sun leaves in sunny conditions, shade leaves within the canopy—its bioς always guides the leaf to being a maple leaf.

The bioς is an example of Aristotelian idealism, which modern science largely rejects.[14] It is also incompatible with evolutionism (which I will address below). However, the concept of the bioς survives to the present day in the form of a close cousin, homeostasis, which was originally expressed by the French physiologist and Darwin contemporary Claude Bernard.[15] The idea of homeostasis usually is introduced as a famous aphorism:

> The constancy of the internal environment is the condition for free and independent life.

Bernard's aphorism was later abbreviated by the American physiologist Walter B. Cannon as the more compact word "homeostasis."[16]

Bernard's aphorism is presently the only way he is usually introduced to us. This is unfortunate, because homeostasis (as Bernard himself conceived it) arguably is the most misunderstood and trivialized concept in modern biology.

The prevailing meaning of homeostasis presently is regulation of some property of the organism, such as its temperature, salt content, levels of nutrients, and so forth. This comes about because of some mechanism, usually involving physiological feedbacks of various kinds. If blood sugar rises, for example, this information feeds back through a complex chain of events onto the pancreas, which secretes insulin and brings blood sugar concentration back down. This is a distinct statement of cause and effect. Here, the effect is regulation of blood sugar concentration, while the cause is the feedback to the pancreas and insulin secretion. The cause is the mechanism, and the regulation is the effect. We may describe this as the cybernetic conception of homeostasis.

This misconstrues Bernard's own conception of homeostasis. While Bernard was a superb experimentalist, he nevertheless was a "small-v" vitalist.[17] That is to say that he regarded life as a unique phenomenon, distinct from all other phenomena in the universe. This demanded its own forms of explanation, of which homeostasis was key. What makes Bernard himself unique was grounding his explanations firmly on experimental demonstration. This distinguished him from his "large-V" vitalist predecessors and contemporaries, who had grounded their explanations in ineffable vital spirits or essences. Bernard regarded homeostasis as life's distinctive attribute, from which all the manifestations of life followed. The jarring conclusion of Bernard's thinking is thus the reverse of our modern conception of homeostasis: homeostasis is the cause, while the mechanism is the effect. To build on the example, steadiness of blood sugar is the cause, and all the complex feedback mechanisms stream from that, what we might call the vitalist conception of homeostasis. This reversal of cause and effect does not sit easily in the materialist and reductionist mindset that prevails in modern biology, even less so in the materialist and reductionist mindset of modern Darwinism. This is why the language of modern Darwinism is hedged about with neologisms, circumlocutions, and elaborate cryptoplatonism.

## The Adaptive Interface

The scientific question for the phenomenon of adaptation, and hence for the phenomenon of evolution, is how life's unique nature can be realized in a physical world that inexorably negates it (as through the Second Law of Thermodynamics).

One common means is through some form of encapsulation, which partitions environments into "internal" versus "external." The most basic form of encapsulation is the cell membrane, which divides an intracellular ("living") environment from an extracellular ("non-living") environment outside. The cell membrane is not simply a container for the life within, however. Rather, it is an *interface* which manages the flows of matter and energy between the internal and external environments, *so as to* sustain the complex living environment within, even as the external environment may change. The cell membrane is, in short, an *adaptive* interface between two environments, internal and external.

To be an *adaptive* interface, the cell membrane must also be a *cognitive* interface. It must be able to assess the state of the external environment, and to map that information onto the internal environment: to create some sort of cognitive representation of the external environment onto the cell interior. It must be an *intelligent* interface, mobilizing changes in, say, the cell's internal catalytic *milieu,* again *so as to* make adjustments that will sustain the life within. And all elements of the adaptive interface stream from the cell's own self-knowledge of what it *intends* to be.

## The Extended Organism

Adaptive interfaces are not limited to cell membranes. Rather, adaptive interfaces exist at multiple scales of organization. For example, coalitions of cells may organize into sheets called epithelia, which similarly partition environments. Epithelia relativize the meanings of "external" and "internal." For the cell, the internal environment is bounded by the cell membrane. The "internal" environment bounded by an epithelium, in contrast, may render the cell's "external" environment as an "internal" environment for the epithelium. It does not stop there. Just as epithelia are built upon coalitions of cells, and organs are built upon coalitions of epithelia, the organism itself is a coalition of adaptive interfaces of increasing complexity and scale. Tissues and organs may be formed from multiple epithelia, all folded within one another, with the outer boundary of the skin or integument seemingly being the ultimate coalition. Each level of complexity constitutes nested adaptive interfaces between organism and environment.

It goes farther still. The nesting of multiple levels of adaptive interfaces blurs the distinction one normally might draw between an internal "living" environment from an external allegedly "non-living" environment.[18] The blurring of living versus non-living arises from elementary principles of conservation of mass and energy. Adaptive interfaces work by managing flows of matter and energy across them. Thus, any such flows across the interface alter both the external environment as well as the internal. It follows that physiology—life, if you will—cannot be confined to an internal "living" environment that is distinct from an external "non-living" environment. Rather, physiology is necessarily *extended*: life on one side of an adaptive interface inevitably stamps a signature of life onto the environment on the other side of the interface. This includes homeostasis. If homeostasis is a fundamental property of the organism, *extended* homeostasis makes for an *extended* organism. The extended organism is, in essence, a conspiracy of environments to sustain a specified form of life.

The extended organism is most dramatically illustrated by the elaborate construction of social insect nests, which themselves act as adaptive interfaces between environments. In the mound-building termites of southern Africa, for example, the mound is an organ of physiology, a wind-powered lung for the underground colony.[19] It is constructed from mud. However, the colony's worker termites actively shape the mound, maintaining a functional network of tunnels inside the mound, as well as controlling the porosity of the mound surface. Thus, the mound does what any adaptive interface does: it partitions an internal environment (the nest) from an external environment, and imposes a regime of homeostasis within. In so doing, the mound maintains a low-flow environment within the nest that the termites want, and actively maintain. The mound is, in a radical sense, as much alive as the termites that build it. It is an extended organism, reflecting the extension of homeostasis from the worker termites to the constructed environment they inhabit.

## Adaptive Modification of Environments

The extended organism idea undercuts a fundamental assumption of the Darwinian idea: that "selection pressure" is imposed upon organisms by environments. In this view, organisms are either adapted or maladapted to environments. The closeness of fit (the aptitude) between organism and environment determines their fecundity, and hence their fitness. As outlined by several of the authors of articles in this feature, this explanation no longer carries much water. A viable alternative has yet to emerge, however.

The Extended Evolutionary Synthesis (also mentioned by the other authors of this feature) represents the most influential of the attempts to shore up the Darwinian idea. A significant part of the EES is niche construction theory (NCT) which comes closest to representing adaptation as a conspiracy of environments.[20] NCT, along with the related concept of Ecosystem Engineering, takes strong account of the fact that organisms modify the environments which they inhabit, and that they often do so in ways that are beneficial to them ("adaptive"). Again, social insect nests provide spectacular examples of this, but they are not the remarkable exception. Rather, adaptive modification of environments appears to be ubiquitous throughout the biosphere. Niche construction theory attempts to account for this.

While NCT frankly acknowledges living agency as an integral part of the evolutionary process, it nevertheless suffers from the same tautological reasoning that pervades modern Darwinian thought: it offers no independent means of identifying adaptive modifications of environments other than that the modifications are adaptive. Indeed, NCT began as a way to modify population genetics theory to explain selection of genes that specify environmental modifications that are favorable to survival of organisms.

The extended organism idea essentially represents an independently-derived physiological dimension of niche construction theory. Relying as it does on the fundamental concept of homeostasis, the extended organism concept introduces a particular view of agency that does not sit comfortably in niche construction theory, and by extension, the EES. The reason for this is clear: the extended organism idea casts adaptation as a frankly purposeful, frankly intelligent, and frankly intentional process. Niche construction theory, at least in its original form, sought to cast adaptation in the traditional (and tautological) Darwinian framework.

## Heritable Memory of Adaptation

Ernst Mayr has famously depicted evolution as shaped by the memory of past adaptation.[21] Adaptations that "worked" in past generations are "remembered" in future generations. While adaptation is a central phenomenon of organisms, how this shapes the evolution of a *lineage* of organisms turns critically on the nature of that memory. In modern Darwinism, the carrier of hereditary memory is the gene, particularly the memory encoded in self-replicating nucleotide sequences in nucleic acids ("genes"). It goes without saying that this adds no explanatory power, because genes that are "remembered" are construed as genes that "work," with no clear idea why they "work," other than that they are inherited. The poverty of this view has been exposed eloquently by other authors in this collection, so I will not elaborate farther.

Rather, I wish to ask a fundamental question about the nature of hereditary memory: is it object, or is it process? In the gene-centrist conception of evolution, the gene is an object memory, a memory token which specifies the processes that are encoded in it. Evolution proceeds on the basis of changes in the gene memory token (mutations), which are taken to be slow and gradual. This robs the organism of agency, since whatever the organism does is specified by its collection of memory tokens.[22]

However, what if hereditary memory was not object-memory, but what we might call process-memory? This vastly extends the scope of heritable memory, and hence the range of how adaptation may shape the evolution of lineages. The distinction is this: objects *exist*, while processes *persist*. Existence lacks a dimension of time: things either exist, or they do not. Genes, as they are conceived as repositories of memory, exist independently of time and generation, except as they mutate. In contrast, the dimension of time is the very essence of persistence. Processes may persist for a long time, or they may be of short duration.

When Mayr defines evolution as shaped by memory of past adaptation, he is invoking the standard conception of memory as backward-looking: a recollection of the past. There is also a forward-looking dimension to memory, however.[23] When a memory is formed, it biases the future. A gene that encodes a particular protein, for example, is a memory token that ensures a protein will be formed in the future that matches the protein it specifies in the present. If heritable memory is an object, its forward reach in time can be vast. If heritable memory is a process, its forward reach in time can range widely, from nanoseconds to millennia.

A confusion of object memory (the gene memory token) and process memory is at the heart of the Darwinian assertion that the gene is the sole object of natural selection. As Richard Dawkins and others have argued, the gene can be the only form of memory that can be transmitted across generations (that is, heritable), and hence is the only form of memory that can be selected. This is yet another expression of the tautology that runs through modern Darwinism, of course. It is also the basis of the radical distinction that is drawn between genotype (a collection of object memory tokens) and phenotype (the suite of processes that are specified by the genotype). If hereditary memory is process memory, however, the distinction of genotype from phenotype disappears: memory is as much process (phenotype) as are the comings and goings of proteins, material organizations, built structures, and so on that the memory shapes and specifies. In short, it's all process.

If everything, including memory, is process, the range of heritable memory expands. What now defines heritability of memory is persistence: if a memory persists beyond the lifetime of the individual organism, it arguably qualifies as a form of hereditary memory. The gene certainly qualifies, but as outlined by other authors in this collection, the gene is not simply a cipher to be decoded: it interacts in richly dynamic ways with the physiological *milieu* of the cell, and of the organism. Some of these include modifications that can be passed across generations, which fulfills Darwin's own quest for a means of heritable adaptation.

The extended organism idea further expands the range of heritable memory. Again, social insect colonies provide a stark example.[24] The construction of the mound by mound-building termites adaptively modifies environments at ecosystem-wide scales. These modifications persist well beyond the lifetimes of individual worker termites (a few weeks) and the colonies they comprise (10-20 years). These modifications constitute forms of heritable memory as much as genes do, however they are defined. Furthermore, termites are not the exception. The remarkable features of human culture, which includes language, oral traditions, cities, agriculture, literature, and religion, all constitute forms of heritable memory that have profoundly shaped the evolution of humans.[25] Culture is not limited to humans, of course: even slime molds have cultures of sorts.

## Cognition, Intentionality, Creativity, and Evolutionary Novelty

Adaptation may be defined as cognition coupled to homeostasis. To sustain the specified orderliness of the organism, an adaptive interface must assess the state of the environment on one side, and map this information onto the environment on the other, "living" side: a cognitive representation, in other words. Adaptation arises when that cognitive representation is compared to the living system's self-knowledge of what it intends to be (the bioς, as Aristotle called it), and mobilizes to bring the living system into conformity with its bioς.

The salient point here is that cognition in living systems is inevitably coupled to "engines" that do work. The work may be performed on the "living" environment contained within the adaptive interface. For example, a change of external environment may disrupt the flows of matter and energy that sustains the persistence of a cell. In response, the cell may alter its catalytic *milieu* to bring those flows of matter and energy back to what sustains the cell's persistence. Or the work may be performed on the "external" environment, at all levels of organization, up to the construction of adaptive interfaces *de novo,* as in the "dirt lungs" built by termite colonies. This form of "extended adaptation" negates the conventional view that adaptation is selection of codes (memory tokens, genes) determined by an imposed environment, as implied by modern Darwinism. Rather, adaptation is a dialogue, where organisms adapt to environments, and where organisms can adapt environments to themselves. In the jargon of modern Darwinism, life creates its own adaptive landscape (a Darwinian oxymoron). This means that fitness is not simply fecundity, it is a cognitive phenomenon governed by the living system's self-knowledge of what it intends to be.

What is that self-knowledge, and how does it come to be? Aristotle's bioς might be a handy shorthand for an organism's self-knowledge, but is it useful as a scientific tool? Claude Bernard apparently was able to make it so, but it should be remembered that Bernard's homeostasis was treated by him as a fundamental property of life. Fundamental properties are not amenable to dissection or reductionism. The fundamental is axiomatic, and the particulars all flow from that.

The main difficulty is that the Aristotelian bioς is incompatible with evolution, because the bioς is an unchangeable ideal of the organism's form and function. It is the goal toward which everything about the organism is directed. This presents a serious dilemma for a "scientific" evolutionism, as Darwinism has always claimed it to be, to wit: it is impossible to explain adaptation without some form of directedness toward the goal of realizing that self-knowledge, that is, teleology. Darwinism seeks to explain evolution without resort to teleology. Nobody has convincingly cracked that conundrum, in my opinion.

The extended organism idea offers a path forward, however, because it offers a framework for coupling homeostasis to adaptation and evolution.

In its simplest form, mapping of environmental state onto the cognitive representation is one-to-one, so that the cognitive representation simply tracks changes of the environment. If this then maps one-to-one onto a program for work, whether the work be external, or internal, this is cybernetics. There is no need for self-knowledge, nor any need for pursuit of a goal. It is the action of a machine, like a thermostat. Nor is there any possibility of evolution of such a system, save changes in the machinery itself. This boils down to the empty tautologies of gene-selectionism: Neo-Darwinism.

Adding self-knowledge (something akin to a bioς) to such a system offers a framework for exploring life's unique attributes.[26] For example, *intentionality* is a goal-directed modification of the environment. I *intend* to write these words, for example, even if I am not programmed to do so. I realize my intention by modifying my perceived environment (patterns on a computer screen) so that my environment is brought into conformity with my desired mental image of it. Similarly, *creativity* involves modifying the world to bring it into conformity with a mental representation that may arise *de novo,* decoupled to a degree from any sensory representation.

Intentionality and creativity are both aspects of a long-standing issue in evolutionism, to wit: the origin of novelty, of new ways of living, to coin a phrase. Darwin's invocation of life's "endless forms most beautiful" was his testimony to the extraordinary and ingenious novelty of evolving life. Neo-Darwinism can never keep up as long as it looks to new genes as the sole source of evolutionary novelty. The complex and dynamic nature of the translation of genome to function ameliorates the problem to a degree, although the extent of the amelioration is still uncertain. The same can be said for the Extended Evolutionary Synthesis.

There is another solution to the problem of evolutionary novelty, however, and the extended organism idea is at the center of it. Adaptive interfaces are continually negotiating the boundaries between life and environment, and in ways that serve adaptive ends. Because these negotiations are ongoing, they generate many and diverse ways of "solving" the problem of maladaptation, all the time driven by the essential striving of living systems to persist. This novelty can endure for the lifetime of an individual organism, tissue, or cell. It can also be embodied in the broad scope of hereditary memory, either in long-term modifications of the external environment, or through epigenetic modifications of DNA. In either event, it is the novelty that comes from the relentless negotiation of life and its environment that drives a lineage's evolution. Genes are no longer the privileged actor in evolution. Rather, they are dragged along in the wake of the ongoing negotiation of organism with environment.

## Against Darwinism

The core of the Darwinian idea—starting with Charles Darwin himself, continuing with the emergence of Neo-Darwinism and gene selectionism, onward to evolutionary ecology, and ongoing with the Extended Evolutionary Synthesis, has been the banishment of teleological thinking from evolutionism: the "abolition of purpose," as I described it at the beginning of this article.[27] This was a sensible strategy for Charles Darwin to pursue at the time, as he was reacting to the philosophical muddle that natural history then was. Through the twentieth century, new developments in the nature of heredity made the abolition of purpose not just sensible, but virtually compulsory.

That assumption has essentially run its course, however. This does not mean the approach has failed, or will not, at some point in the future, succeed. Science, after all, should never declare its mind made up. But as we have learned more and more about heritability, of the dynamic interaction of life with its environment and with its own legacy, of the nature of the organism, all at scales ranging from the molecular to the biospheric, it becomes ever more difficult to claim that evolution—indeed, life itself—can be explained without life's essential qualities of purposefulness, intentionality, creativity, intelligence, and design.

Arguably, the comprehensive and coherent study of life—including its evolution—will only come about through returning to the "small-v" vitalism that recognizes that life is a phenomenon that is unique among all other phenomena in the universe. The credible case can now be made that evolution is an intelligent, purposeful, and intentional process, which negates the fundamental premise of the Darwinian idea.

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