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## Do Species *Want* to Evolve?

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**Abstract:** Darwinism, in all its various forms, seeks to explain evolution without the intervention of intelligence, purposefulness or intentionality: in short, via the abolition of purpose. Yet life is arguably a profoundly purposeful phenomenon, most evident in the phenomenon of adaptation. Modern Darwinism fails because it has no coherent theory of adaptation, and hence no coherent theory of life. Without this, it cannot claim to be a coherent theory of evolution. Here, I argue that a coherent theory of evolution will arrive when the inherent purposefulness of life can be reincorporated into our evolutionary thinking. Life's fundamental property of homeostasis, coupled with the expanding conception of hereditary memory emerging from epigenetics and niche construction theory, can credibly restore purpose to our thinking about evolution. The evolution of lineages will no longer then be under the control of natural selection, but rather imbued with striving and intentionality: with "wanting" to evolve.

### Keywords:

Darwinism;  
teleonomy;  
purposefulness;  
homeostasis;  
cognition;  
evolution;  
hereditary memory;  
niche construction theory

## Introduction

Natural history prior to Darwin was frankly teleological, finding its most cogent expression in the famous argument from design, exemplified by William Paley's doctrines of natural theology.<sup>1</sup> One could not reflect upon nature's marve-

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<sup>1</sup> See William PALEY, *Natural Theology; Or, Evidences of the Existence and Attributes of the Deity*, John Morgan, Philadelphia 1802; Jonathan R. TOPHAM, "Biology in the Service of Natural Theology: Paley, Darwin, and *Bridgewater Treatises*", in: Denis R. ALEXANDER and Ronald L. NUMBERS (eds.), *Biology and Ideology From Descartes to Dawkins*, University of Chicago Press, Chicago 2010,



lous contrivances, so the argument went, without being led to reflections on the nature of the contriver. In turn, such reflections led inevitably, again according to the argument, to affirmation of the Platonic God.

For Charles Darwin, and later Alfred Russell Wallace, species were the most marvelous of nature's contrivances, so it was natural for them to ask the basic question: how did species come to be? The Linnaean species concept that then prevailed was little help. Rather, Linnaeus had sought to bring order to the taxonomic chaos that then prevailed: for example, there was no standard scheme for naming species, which were typically named with long Latin descriptions. Linnaeus pursued his task by asking nature to speak for itself. But Linnaeus was not an evolutionist, and the question Linnaeus wanted to ask was what the organization of living nature had to say about the mind of the Creator.<sup>2</sup> Linnaeus' concept of the species was thus frankly teleological and Platonic: species were a striving of living nature toward abstract and disembodied ideas. If species could be defined logically by their physical characteristics, such as the number of stamens in the flower, this reflected something about the logical mind of the Creator.

Platonic idealism, no matter what its context, is inconsistent with the very idea of evolution: ideals are eternal, and therefore so should species be. By the early 19<sup>th</sup> century, this had become an unsustainable stance. The growing evidence of the fossil record was making it progressively clear that species were not eternal. They changed over time, and originated and became extinct at certain times. At the same time, a growing mountain of evidence was pointing to the Earth's long history and the transience of species, both working over time scales that were inconceivably vast. For Darwin, evolution was a real phenomenon that demanded explanation, which idealist conceptions of species like Linnaeus's could not provide.

When Darwin was a young man, evolution was "in the air", and was firmly implanted in his mind by his grandfather, Erasmus, who had been an early advocate of the newly emerging "transmutationism".<sup>3</sup> Natural history was revealing a re-

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pp. 88–113.

<sup>2</sup> See ERNST MAYR, *The Growth of Biological Thought: Diversity, Evolution, and Inheritance*, The Belknap Press of Harvard University Press, Cambridge — London 1982.

<sup>3</sup> See DESMOND KING-HELE (ed.), *Charles Darwin's The Life of Erasmus Darwin*, Cambridge University Press, New York 2003; ERASMUS DARWIN, *The Loves of the Plants*, J. Johnson, London 1806;

markable diversity of living forms that, if anything, signaled that living nature was continually pulling away from ideal forms, not striving toward them. Thus, by Darwin's time, the Platonic foundations of natural history had been thoroughly eroded. The challenge taken up by both Darwin and Wallace was to build a new foundation, which both Darwin and Wallace sought to construct by casting the origin of species as a process of natural law, akin to how Newton's law of universal gravitation explained the motions of the planets.

Darwin and Wallace both found their analogue to Newton's universal law of gravitation in Thomas Malthus' emerging macroeconomic theories.<sup>4</sup> Populations were governed by mathematical laws of increase, limited by complementary laws of resource limitations. An inevitable "struggle for existence" would ensue, in which some variants would be more fecund than others. Darwin's and Wallace's conception of natural selection followed inevitably from this Malthusian logic. The proliferation of species, and of Darwin's "endless forms most beautiful", would spin naturally from the clockwork mechanism of natural selection. No conception of teleology, of purposeful striving, was necessary, as it had been for Linnaeus. Indeed, purposefulness was contradictory to the Darwinian conception for how new species came to be.

Since its inception, the Darwinian idea has undergone several radical reinterpretations. By the end of the 19<sup>th</sup> century, for example, Darwinism was in "eclipse", battered by new theories of inheritance and embryonic development.<sup>5</sup> In the 1920s, it was revived by the genetic theory of natural selection, which reconceptualized it as the sorting of gene variants rather than success in the struggle for existence.<sup>6</sup> In more recent years, the so-called Extended Evolutionary Synthesis has sought to unite divergent strains of evolutionary thought under a common umbrella of Darwinian natural selection.<sup>7</sup>

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ERASMUS DARWIN, *Zoonomia; Or, The Laws of Organic Life. In Three Parts*, Thomas & Andrews, Boston 1809.

<sup>4</sup> See FRANCIS DARWIN (ed.), *Charles Darwin: His Life Told in an Autobiographical Chapter and in a Selected Series of His Published Letters*, D. Appleton and Company, New York 1893.

<sup>5</sup> See PETER J. BOWLER, *The Eclipse of Darwinism: Anti-Darwinian Evolution Theories in the Decades around 1900*, Johns Hopkins University Press, Baltimore — London 1983.

<sup>6</sup> See RONALD A. FISHER (ed.), *The Genetical Theory of Natural Selection: A Complete Variorum Edition*, Oxford University Press, Oxford — New York 1999.

There has been a common theme through all the reinterpretations of the Darwinian idea, which I call the abolition of purpose.<sup>8</sup> I argue here and elsewhere that this has been Darwinism's fatal mistake.<sup>9</sup> Arguably, living things are distinguished from the non-living world by their purposeful striving toward aptness of form and function. The premise of the Darwinian idea dismisses life's fundamental distinctiveness from the non-living world as illusory. The question must be asked, whether any coherent theory of evolution can emerge that fences off life's purposeful nature, as the Darwinian idea has consistently sought to do.

My argument here is that it cannot. The challenge for evolutionism, I assert, is to build a scientifically credible theory of purpose into our thinking about evolution. What is to follow will be an argument for how this could be done. It is, admittedly, an idiosyncratic one, developed over several years and outlined in three books.<sup>10</sup>

## The Problematic Nature of Adaptation

Life's purposeful nature finds its expression in the phenomenon of adaptation: that is to say, adjustment to an environment. Adaptation translates literally as a tendency to aptitude, the ability to adjust form and function to prevailing circumstance. Living things actively do this, so that they may persist through time. The non-living world, in contrast, simply degrades into chaos and entropy.

By the 19<sup>th</sup> century, natural historians had built up an impressive catalogue of "adaptation stories" all deeply rooted in what we may call the two purposeful philosophies of nature: Platonism and Aristotelianism.<sup>11</sup> The Linnaean concept of species was arguably the culmination of the Platonic natural history tradition (al-

<sup>7</sup> See Massimo PIGLIUCCI, "Do We Need an Extended Evolutionary Synthesis?", *Evolution* 2007, Vol. 61, No. 12, pp. 2743–2749.

<sup>8</sup> See BOWLER, *The Eclipse of Darwinism...*; PIGLIUCCI, "Do We Need...", pp. 2743–2749; William B. PROVINE, "The R. A. Fisher — Sewall Wright Controversy" in: Sahotra SARKAR (ed.), *Boston Studies in the Philosophy of Science*, Vol. 142, Kluwer Academic Publishers, Boston 1992, pp. 201–229.

<sup>9</sup> See J. SCOTT TURNER, *Purpose and Desire: What Makes Something "Alive" and Why Modern Darwinism Has Failed to Explain It*, HarperOne, San Francisco 2017.

<sup>10</sup> See TURNER, *Purpose and Desire...*; J. SCOTT TURNER, *The Extended Organism: The Physiology of Animal-Built Structures*, Harvard University Press, Cambridge 2000; J. SCOTT TURNER, *The Tinkerer's Accomplice: How Design Emerges from Life Itself*, Harvard University Press, Cambridge — London 2007.

though Platonism has lately been enjoying a renaissance in the form of Intelligent Design Theory). By the 19<sup>th</sup> century, the Platonic idea had proven inadequate to the species problem, as both Darwin and Wallace appreciated.

If not Platonism, what of Aristotelianism, the other purposeful philosophy? Aristotle had his own theory of adaptation, centered on his concept of the βίος. This was an ideal form and function toward which an organism would continually strive. Each kind of organism was distinguished by a unique βίος; a starfish βίος, a horse βίος, a mosquito βίος, etc. The Aristotelian βίος was therefore every bit as teleological as Plato's ideals, but with an important difference. While Plato's ideals were otherworldly and abstract, Aristotle lodged the βίος within the organism itself. This offered a purposeful perspective on adaptation that Platonic idealism could not provide.

The organism itself was not the βίος, but was the embodied expression of it. A pigeon βίος would direct the *construction* of a pigeon, but the pigeon was not itself the βίος. How the βίος was expressed — that is to say, what form the organism took — depended upon the environment. If the environment was cold, for example, the *expression* of the βίος would change, reshaping the organism in whatever way was needed to ensure that the βίος would persist: thicker plumage, larger body size, etc. This was Aristotelian adaptation.

Like Plato's ideal forms, the Aristotelian βίος is antithetical to the evolutionary idea. Embedded within its unique explanation for adaptation, however, is a bridge to a coherent theory of evolution. Darwin's own conception of fitness — success in the “struggle for existence” — boils down essentially to subtle variations that equipped certain individuals to compete for scarce resources: to aptitude in form and function, essentially. The question for Darwin was the source of that aptitude: adaptation, in a word.

Darwin himself had compiled innumerable “adaptation stories” which equipped him to test his ideas against the natural world he knew so well.<sup>12</sup> He

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<sup>11</sup> See Anselm H. AMADIO and Lorenzo MINIO-PALUELLO, “Aristotle and Aristotelianism”, *Encyclopædia Britannica* 1994, Vol. 14, pp. 55–71; FRANCISCO J. AYALA, “Teleological Explanation in Evolutionary Biology”, *Philosophy of Science* 1970, Vol. 37, No. 1, pp. 1–15.

<sup>12</sup> See CHARLES DARWIN, *The Variation of Animals and Plants Under Domestication*, John Murray, London 1868; CHARLES DARWIN, *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, P.F. Collier & Son, New York 1909.

concluded, for example, that for new species to arise from the struggle for existence, adaptation had somehow to be heritable. His solution to this problem conceived of two forms of heritability. “Hard” inheritance would determine the organism’s basic form and function: pigeons would always produce pigeon offspring, for example, rather than crow offspring. “Soft” inheritance would transmit adaptation in one generation to the next. Darwin’s model of soft inheritance was his theory of pangenesis.<sup>13</sup> Adaptive change during an organism’s lifetime would be embodied in particles of soft inheritance which Darwin called gemmules. Adaptation in a tissue, such as darker plumage developed in cold conditions, would produce specific “dark plumage gemmules” that could be conveyed to the gametes and hence to its offspring. In this way, adaptation in individuals could accumulate into adaptation in lineages of organisms: evolution.

Darwin’s pangenesis idea failed to find support among his scientific contemporaries, who were increasingly focused on “hard inheritance” — what came to be the Mendelian gene, and ultimately the conception of the gene as nucleotide sequence code in DNA. The failure of pangenesis contributed substantially to Darwinism’s early-20<sup>th</sup> century eclipse.<sup>14</sup> The genetical theory of natural selection<sup>15</sup> breathed new life into the Darwinian idea, but the lifeline was bought at a price. The genetical theory was a theory of hard inheritance only, and this left no room for soft inheritance, and hence no room for life’s essential quality of adaptation.

Much of the subsequent history of Darwinism has been a struggle to reconcile the obvious fact of adaptation with a theory of inheritance that denies a place for it. The struggle has led Darwinism into some obvious philosophical traps, such as the tautological explanation of adaptation as the natural selection of “apt function” genes. The struggle has also led Darwinism into deeper and more abstract metaphors for adaptation. These include such concepts as Sewall Wright’s adaptive landscapes, adaptive state spaces, the Hutchinsonian niche, *ad hoc* punctuated equilibrium, and, most recently, niche construction theory (NCT). These metaphors have proven to be extraordinarily rich, and have powered Darwinism

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<sup>13</sup> See DARWIN, **The Variation of Animals...**; William F. McCOMAS, “Darwin’s Invention: Inheritance & the «Mad Dream» of Pangenesis”, *The American Biology Teacher* 2012, Vol. 74, No. 2, pp. 86–91, <https://doi.org/10.1525/abt.2012.74.2.5>.

<sup>14</sup> See BOWLER, **The Eclipse of Darwinism...**

<sup>15</sup> See FISHER (ed.), **The Genetical Theory of Natural Selection...**

into what was arguably its intellectual golden age, stretching approximately from the 1950s to the 1990s. At the heart of these brilliant explorations, however, remained the abolition of purpose, with an ironic result: purpose could not so much be abolished as cloaked behind various forms of cryptoplatonism. The niche concept, for example, is as Platonic a concept as the Linnaean species: it is an abstract metaphor for a species' ideal "place in nature". The Hutchinsonian concept of the niche is descended from this Platonic idea, from which ecologists have spun ethereal (Platonic?) ideas such as hyperdimensional adaptive spaces. More recently, the Extended Evolutionary Synthesis (EES) has sought to incorporate unrelated trains of evolutionary thought — genetics, developmental biology (evo-devo), and ecology (evo-eco-devo) — into a hoped-for comprehensive Darwinian framework for evolution. The EES remains wedded to the broader program of the abolition of purpose, however: where adaptation is not ignored completely, it barely warrants mention. Evolutionism, it seems, continues to choke on the adaptation nut. Is there a different way to break down the adaptation problem? <sup>16</sup>

## Object-Thinking and Process-Thinking in Evolutionism

Modern Darwinism is a theory of objects. The organism is a thing, an object specified by other things, namely material object-genes. Natural selection is a sorting mechanism for organism-objects, from which descend other organism-objects, again specified by gene-objects that are passed from generation to generation. The organism-object evolves through conformity to a niche-object, which comes about through the object-sorting mechanism of natural selection. Species are objective categories of discrete kinds of organism-objects. Such object-thinking can produce a simulacrum of life, but no actual life need ever be involved for it to work. <sup>17</sup>

Actual life is distinguished by adaptation, however, which is not a phenomenon of objects, but of process. The two cannot be separated entirely, of course. Life lives in a physical world, and any life process will inevitably be an expression of flows of matter and energy, constrained by laws of thermodynamics and conservation of mass. A process is not wholly material, however. Processes introduce

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<sup>16</sup> See TURNER, **Purpose and Desire...**

<sup>17</sup> See JESSICA RISKIN, **The Restless Clock: A History of the Centuries-Long Argument Over What Makes Living Things Tick**, The University of Chicago Press, Chicago — London 2016.

a dimension of time, for example, that does not apply to material objects, which merely exist, independently of time. When it comes to evolution, this poses a fundamental conundrum of cause-and-effect. The default position of modern Darwinism is that processes are determined by the object-genes that specify them. Adaptation, the process, is therefore regarded as an epiphenomenon of object-thinking. But what if the tables were reversed: if the *object* gene were the epiphenomenon of the *process* of adaptation? As recently as two decades ago, such a proposition would have been unthinkable. As we come to understand more about the relationship between DNA nucleotide code and the form and function of the organism it is looking ever more likely that the process of adaptation actually can specify the object-gene.<sup>18</sup>

This mutuality of cause and effect — the gene is the cause of the process which in turn is the cause of the gene — shifts our thinking toward adaptation and its heritability as dynamic, and purposeful, processes. Where Aristotle's βίος was incompatible with evolution, we may now revisit Aristotle's idea in a new scientific light. The rehabilitation of the βίος began in the late 18<sup>th</sup> century, in a new form of vitalist philosophy, so-called "process vitalism", which departed radically from earlier forms of so-called "metaphysical vitalism", derived from Hippocratic theories of medicine, which construed life as a balance of ineffable vital essences. By the late 18<sup>th</sup> century, the Hippocratic model of life was becoming unsustainable. Vital essences and vital forces proliferated willy-nilly as the complexity of the organism came better to be appreciated. Process vitalism emerged from reaction to this profligate tendency. In process vitalism, life is no longer defined by its vital essences, but by uniquely vital *processes*. To illustrate, the French physician Theophile de Bordeu argued that the living organism was the expression of an ongoing process of negotiation and mutual accommodation among the "many little lives" comprising the organism.<sup>19</sup> Remarkably, Bordeu's "many little lives" con-

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<sup>18</sup> See Stephen B. BAYLIN and Kornel E. SCHNABEL, "The Epigenomic Era Opens", *Nature* 2007, Vol. 448, No. 7153, pp. 548–549; Gary FELSENFELD, "A Brief History of Epigenetics", *Cold Spring Harbor Perspectives in Biology* 2014, Vol. 6, No. 1, article number: a018200, <https://doi.org/10.1101/cshperspect.a018200>; Eva JABLONKA and Marion J. LAMB, "Epigenetic Inheritance in Evolution", *Journal of Evolutionary Biology* 1998, Vol. 11, No. 2, pp. 159–183.

<sup>19</sup> See Charles T. WOLFE, "From Substantialist to Functional Vitalism and Beyond: Animas, Organisms and Attitudes", *Eidos* 2011, Vol. 14, pp. 212–235; Charles T. WOLFE and Motoichi TERADA, "The Animal Economy as Object and Program in Montpellier Vitalism", *Science in Context* 2008, Vol. 21, No. 4, pp. 537–579; J. SCOTT TURNER, "Homeostasis, Complexity and the Problem of Biological Design", *Emer-*



cept led him to an early conception of the honeybee swarm as a *superorganism*. The many little lives of individual bees cooperated to form an entity — the swarm — that had many of the attributes of the organisms that made up the swarm: coherency, coordination, integrity. For their parts, organisms themselves were the manifestation of this ongoing process of negotiation and mutual accommodation among the “many little lives” of the organs, and later the cells, of the body.<sup>20</sup>

By the mid-19<sup>th</sup> century, Bordeu’s process vitalism had matured into Claude Bernard’s conception of homeostasis, stated in his famous aphorism: “the steadiness of the internal environment is the condition for a free and independent life”.<sup>21</sup> From this aphorism, Bernard founded the modern school of experimental physiology. Parsing Bernard’s aphorism carefully reveals an interesting philosophical twist. Note that it is the “steadiness of the internal environment” — what came later to be named homeostasis — that is the predicate for the “free and independent life” of the body. For all that Bernard is rightly celebrated for grounding medicine on a firm foundation of chemistry and experiment, the fact remains that Bernard’s homeostasis is a firmly grounded *vitalist* philosophy: the living organism is a unique phenomenon. Homeostasis is thus a cousin to the Aristotelian βίος, recast into the materialist language of experimental physiology. Bernard’s process vitalism also reveals an interesting twist of cause and effect: in his conception, homeostasis is *the* fundamental property of life, from which stream the mechanisms to implement it. It is not physical and chemical processes that *determine* homeostasis, as we tend to think today: it is the other way round.<sup>22</sup>

## The Adaptive Boundary

Adaptation is a process that operates through what we may call adaptive boundaries. The cell membrane is the most obvious example of an adaptive

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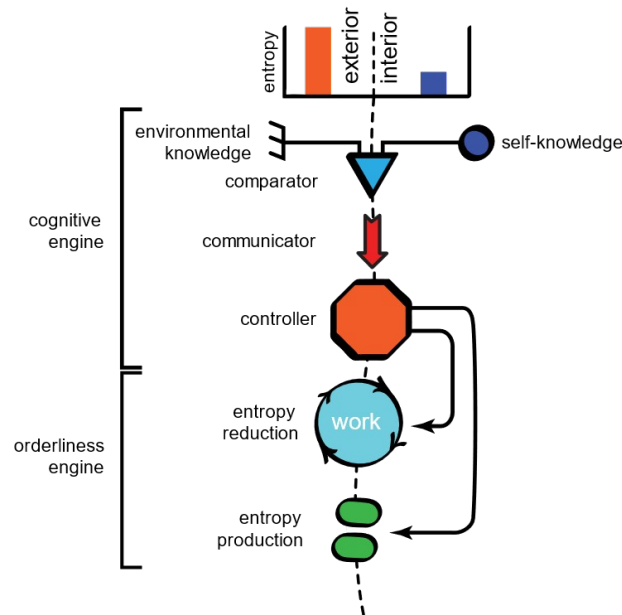
*gence, Complexity and Organization* 2008, Vol. 10, No. 2, <https://tiny.pl/wg4cr> [14.09.2022].

<sup>20</sup> See J. Scott TURNER, “Many Little Lives”, *Inference: International Review of Science* 2018, Vol. 4, No. 1, <https://www.doi.org/10.37282/991819.18.16>.

<sup>21</sup> Claude BERNARD, *An Introduction to the Study of Experimental Medicine*, trans. Henry Copley Greene, *Classics of Medicine Library*, Henry Schumann Inc., 1927; Charles G. GROSS, “Claude Bernard and the Constancy of the Internal Environment”, *The Neuroscientist* 2008, Vol. 4, No. 5, pp. 380–385.

<sup>22</sup> See TURNER, *Purpose and Desire...*; TURNER, *The Extended Organism...*; TURNER, *The Tinkerer’s Accomplice...*

boundary. The membrane partitions space into internal and external environments: respectively, within the cell membrane, and the *milieu* in which the cell lives. The adaptive boundary manages the flows of matter and energy between the environments on both its sides (Figure 1).



**Figure 1.** Schematic of the elements of the adaptive boundary. The boundary (dashed line) does work to sustain specified low entropy in its interior. To do so, work must be done through an “orderliness engine”. The work of the orderliness engine is governed by a “cognitive engine”, which compares a sense of the external environment against “self knowledge”. Homeostasis is realizing the system’s self-knowledge.

The adaptive boundary is explicitly goal-directed: it is to do the work necessary to sustain a specified orderliness within the boundary. The adaptive boundary is an engine of homeostasis, in other words. To do so, the adaptive boundary must also be a *cognitive* interface. The cell membrane contains embedded devices which sense the environment and use that information to control the flows of matter and energy across it. At the same time, there must be some form of self-knowledge: the cell must somehow “know” what its internal state should be, and know how to organize the work necessary for it to persist, no matter what the external circumstances might be. Adaptation is therefore properly seen as a form of homeostasis, with the persistence of the peculiar orderliness of the interior being

its βίος. This transforms our conception of homeostasis: rather than being a doctrine of constancy, as it is usually portrayed today, homeostasis is fundamentally a doctrine of adaptability and therefore change.<sup>23</sup> It is through adaptation that the βίος may be reconciled with evolution.

## Adaptive Boundaries Are *extenso*

Adaptive boundaries exist in many forms. The organism itself is an assembly of numerous adaptive boundaries nested within one another: cells organized into the sheet-like epithelia that line our intestines and lungs, epithelial tissue organized into organs and organ systems, culminating in the ultimate adaptive boundary that is the organism. Keeping with Bordeu's conception of the "many little lives", homeostasis at the *organismal* level is the outcome of the ongoing cooperation and mutual accommodation of the innumerable adaptive boundaries nesting within the organism. The organism is a conspiracy of homeostasis.

Adaptive boundaries can also extend beyond the conventionally defined organism. All organisms, ourselves included, construct adaptive boundaries in which to live. The nests of social insects, beaver ponds, houses, and communities are other examples of so-called extended organisms.<sup>24</sup> There is nothing mystical in the extended organism idea: it is derived from elementary principles of thermodynamics, conservation of mass, and cybernetics. The conspiracy of homeostasis within the organism now becomes an adaptive conspiracy of organism and environment. Combined with homeostasis as a goal-state it produces a parallel with the Aristotelian conception of the organism as the embodiment of a βίος, but now recast in the modern language of physiology and homeostasis.

The extended organism idea is, at its root, a theory of adaptation in living organisms. It does not by itself explain evolution, which requires a theory of adaptation in *lineages* of organisms: what Darwin intended his pangenesis idea to account for. We return, then, to the fundamental conundrum: modern Darwinism can never provide a coherent theory for evolution, because it is committed to the object-gene as the sole object of heredity. A coherent theory of evolution, meanwhile, requires a coherent theory of adaptation, which is explicitly purposeful.

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<sup>23</sup> See TURNER, **The Tinkerer's Accomplice...**

<sup>24</sup> See TURNER, **The Extended Organism...**

This puts the phenomenon of adaptation into fundamental conflict with the Darwinian ambition of the abolition of purpose.

## Teleonomy, Memory, and Novelty

Modern Darwinism has sought an escape from this philosophical trap through a kind of *faux* teleology called teleonomy. Proposed in 1958 by Colin Pittendrigh,<sup>25</sup> teleonomy is defined as the “apparent purposefulness and goal directedness of structures and functions of living organisms brought about by natural processes like natural selection”. Teleonomy purports to connect adaptation, a phenomenon of organisms, to evolution, which is a phenomenon of lineages of organisms,<sup>26</sup> and thereby bring coherency to a gene-centered (that is to say, an object-centered) conception of evolution. In other words, adaptation in one generation of a lineage reflects a memory of adaptation in past generations. In the gene-selectionist form of Darwinism, hereditary memory is carried solely on the object-gene, essentially nucleotide sequence code. Natural selection sorts codes which are carried across generations from codes that are not. Codes for apt function in the struggle for existence are therefore selected, whereas codes for inapt function are not. Any notion of purposefulness is therefore illusory: it is “apparent purposefulness”, in the language of the definition. No other conclusion is possible if evolution is a phenomenon of objects.

The logic of teleonomy does not support such an easy dismissal of purposefulness, however. We may generalize evolution as adaptation informed by memory. Memory of adaptation in previous generations informs adaptation in future generations. This can encompass Darwinian natural selection and gene selection, certainly. Yet our conception of hereditary memory has been broadening considerably in recent years,<sup>27</sup> with profound consequences for how we think about evolu-

<sup>25</sup> See Colin S. PITTENDRIGH, “Adaptation, Natural Selection and Behavior”, in: Anne ROE and George Gaylord SIMPSON (eds.), **Behavior and Evolution**, Yale University Press, New Haven 1958, pp. 390–416.

<sup>26</sup> See PITTENDRIGH, “Adaptation, Natural Selection...”, pp. 390–416; Ernst MAYR, “Weismann and Evolution”, *Journal of the History of Biology* 1985, Vol. 18, No. 3, pp. 295–329, <https://doi.org/10.1007/BF00138928>; August WEISMANN, **The Germ Plasm: A Theory of Heredity**, trans. W. Newton Parker and Harriett Rönfeldt, *The Contemporary Science Series*, Walter Scott Limited, London 1893.

<sup>27</sup> See JABLONKA and LAMB, „Epigenetic Inheritance...”, pp. 159–183; Laurent LOISON, “Epigenetic Inheritance and Evolution: Historian’s Perspective”, *Philosophical Transactions of the Royal Society*

tion. Instead of residing solely in the replicable object-gene, which *specifies* form and function, the path connecting DNA sequence code to form and function now weaves through a complicated *milieu* of context, syntax and interpretation. Hereditary memory can therefore no longer be construed as object-memory, but only as *process-memory*, which exists in an interactive and dynamic relationship with adaptation. Process memory is now defined by persistence, not existence, as is the criterion for the object-gene. To use the language of the extended organism, adaptation and hereditary memory are drawn into a conspiracy of process. Adaptation can now shape hereditary memory, an idea that would be unthinkable if genes were the sole repository of hereditary memory. The broader scope of hereditary memory now opens the door to alternative evolutionary schema: ones in which overt purposefulness is logically possible.<sup>28</sup>

## Adaptation and Process Memory in Termite Colonies

The termite colonies (*Macrotermes* spp.) I study are a useful illustration of these concepts.<sup>29</sup> The *Macrotermes* colony is organized around the cultivation of a specialized fungus symbiont (*Termitomyces* spp.) that composts woody material,

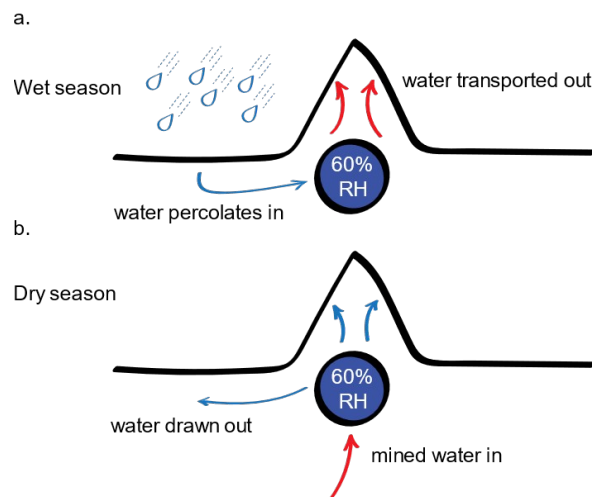
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*B: Biological Sciences* 2021, Vol. 376, No. 1826, article number: 20200120, <https://doi.org/10.1098/rstb.2020.0120>; Peter WARD, **Lamarck's Revenge: How Epigenetics Is Revolutionizing Our Understanding of Evolution's Past and Present**, Bloomsbury Publishing, New York — London — Oxford — New Delhi — Sydney 2018.

<sup>28</sup> See JABLONKA and LAMB, „Epigenetic Inheritance...”, pp. 159–183; WARD, **Lamarck's Revenge...**; Eva JABLONKA and Marion J. LAMB, **Evolution in Four Dimensions: Genetic, Epigenetic, Behavioral and Symbolic Variation in the History of Life**, *Life And Mind: Philosophical Issues in Biology And Philosophy Series*, The MIT Press, Cambridge 2005; Rémy MARCHAL, Alexandra CHICHEPORTICHE, Bernard DUTRILLAUX, and Jacqueline BERNARDINO-SGHERRI, “DNA Methylation in Mouse Gametogenesis”, *Cytogenetic and Genome Research* 2004, Vol. 105, No. 2–4, pp. 316–324; Denis NOBLE, “Evolution Viewed from Physics, Physiology and Medicine”, *Interface Focus* 2017, Vol. 7, No. 5, <https://doi.org/10.1098/rsfs.2016.0159>; Benjamin P. OLDROYD and Boris YAGOUND, “The Role of Epigenetics, Particularly DNA Methylation, in the Evolution of Caste in Insect Societies”, *Philosophical Transactions of the Royal Society B: Biological Sciences* 2021, Vol. 376, No. 1826, article number: 20200115, <https://doi.org/10.1098/rstb.2020.0115>; Charles T. WOLFE, “Introduction. Vitalism without Metaphysics? Medical Vitalism in the Enlightenment”, *Science in Context* 2008, Vol. 21, No. 4, pp. 461–463.

<sup>29</sup> See J. Scott TURNER, “Termites as Models of Swarm Cognition”, *Swarm Intelligence* 2011, Vol. 5, No. 1, pp. 19–43, <https://doi.org/10.1007/s11721-010-0049-1>; J. Scott TURNER, “Semiotics of a Superorganism”, *Biosemiotics* 2016, Vol. 9, No. 1, pp. 85–102, <https://doi.org/10.1007/s12304-016-9256-5>.

grass and dung brought back to the colony by the termite foragers.<sup>30</sup> The termites' functional diet is this composted material. *Termitomyces* spp. are always found in association with *Macrotermes* colonies. To cultivate these fungi, the colony humidity must be tightly regulated at about 60% relative humidity. The fungi and termites are thus organized into an extended super-organism, nested as symbiotic fungal culture < termites < colony < soil structure < ecosystem. The 60% relative humidity is essentially this extended super-organism's βίος, toward which the super-organism continually strives, even if the environment changes (Figure 2).<sup>31</sup>



**Figure 2.** The water balance of *Macrotermes* colonies. The nest humidity is tightly regulated at 60%. In the wet season (a), the colony is in water surfeit: water percolates into the colony from surrounding soil (blue vector), which the termites transport out (red vectors), upward into the mound. In the dry season (b), the colony is in water deficit, drawing water away from the colony (blue vector), which the termites replace by mining liquid water (red vector) from deep soil horizons.

<sup>30</sup> See Lekh R. BATRA and Susane W.T. BATRA, "Termite-fungus Mutualism", in: Lekh R. BATRA (ed.), *Insect-fungus Symbiosis: Nutrition, Mutualism and Commensalism*, John Wiley and Sons, New York 1979, pp. 117–163.

<sup>31</sup> See J. Scott TURNER, "Termites as Mediators of the Water Economy of Arid Savanna Ecosystems", in: Paolo D'ODORICO and Amilcare PORPORATO (eds.), *Dryland Ecohydrology*, Springer, Dordrecht 2006, pp. 303–313; J. Scott TURNER, Eugene MARAIS, Mendes VINTE, Angela MUDENGI, and Wendy PARK, "Termites, Water and Soils", *Agricola* 2006, Vol. 16, pp. 40–45.

Through the year, the semi-arid savannas inhabited by these termites change considerably. During the winter, drought prevails and the colony is in net water deficit. During the wet summers, episodic torrential rains prevail, and the colony is in water surfeit. To keep nest humidity at 60% during the dry winter (i.e., for the βιος of the *Macrotermes/Termitomyces* super-organism to persist), termites mine water from subterranean water tables during the winter, and bring it into the nest.<sup>32</sup> During the wet summers, the termites export water from the nest, in the form of wet soil transported up into the mound.

The adaptive striving of the *Macrotermes* extended superorganism operates through a combination of collective cognition and process memory.<sup>33</sup> The termites live in a rich cognitive environment which comprises cognitive interactions both between worker termites and between worker termites and the soil environment they build and continually remodel.<sup>34</sup> With respect to the first, workers' activities are strongly driven by a subset of worker termites that act as "initiators", who prod inactive workers to move soil, and who guide their movements through various cognitive cues. With respect to the second, how workers move soil is influenced by additional cognitive cues, including how wet the local soil is (workers move soil from moist to dry), how friable the soil is (friable soils are dismantled and moved), the curvature of the tunnel surfaces (surfaces with a small radius of curvature are remodeled to create surfaces with a larger one).<sup>35</sup> Transient perturbations of the nest environment, which might follow damage to the carefully constructed mound, also elicit remodeling. The resulting soil modifications are long-lived, and so can act as a form of process memory. The modification imposed by one worker serves as a persistent cognitive cue to other workers that might come

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<sup>32</sup> See Michel LEPAGE, "Recherches écologiques sur une savane sahélienne du Ferlo septentrional, Sénégal: influence de la sécheresse sur le peuplement en termites", *La Terre et la Vie: Revue d'Ecologie Appliquée* 1974, T. 28, No. 1, pp. 76–94.

<sup>33</sup> See TURNER, "Termites as Models of Swarm...".

<sup>34</sup> See Ben GREEN, Paul BARDUNIAS, J. SCOTT TURNER, Radhika NAGPAL, and Justin WERFEL, "Excavation and Aggregation as Organizing Factors in *de novo* Construction by Mound-building Termites", *Proceedings of the Royal Society B: Biological Sciences* 2017, Vol. 284, No. 1856, article number: 20162730, <https://doi.org/10.1098/rspb.2016.2730>.

<sup>35</sup> See Daniel S. CALOVI, Paul BARDUNIA, Nicole CAREY, J. SCOTT TURNER, Radhika NAGPAL, and Justin WERFEL, "Surface Curvature Guides Early Construction Activity in Mound-building Termites", *Philosophical Transactions of the Royal Society B: Biological Sciences* 2019, Vol. 374, No. 1774, article number: 20180374, <https://doi.org/10.1098/rstb.2018.0374>.

along at a later time. In the case of the *Macrotermes* colony, these cues can persist well beyond the lifetime of a typical worker: the mound and subterranean structure have lifetimes of the order of decades, while the lifespan of a *Macrotermes* worker is a few weeks.

For the lifetime of a colony (10–20 years), the sterile workers are descended from a single queen, which makes the super-organismal adaptation as I have described it akin to adaptation in an individual organism. This interaction of cognition with process memory can extend across generations of colonies, however, with evolutionary adaptation being the result.

The persistence of *Macrotermes* populations over many generations has ecosystem-wide consequences, including long-term modifications of regional hydrology. If these modifications persist beyond the lifetime of a colony, they can also act as hereditary process memory. Furthermore, they can serve as hereditary memory of past adaptation, which is teleonomy embodied. *Macrotermes* colonies are extensive modifiers of the subterranean environment. A typical colony perturbs soil to depths of 10–12 meters, which produces a persistent termite-created lens of modified soil moisture.<sup>36</sup> In addition, an extensive array of foraging tunnels radiating from the colony promotes percolation of water into the soil. This modifies the soil environment considerably. The emission of methane from the workers' gut flora<sup>37</sup> interacts with soluble calcium and water in the soil to precipitate a calcite pavement situated roughly 1–3 meters below the ground surface. The layer of calcite runs deeper below the colony itself, forming a kind of calcite

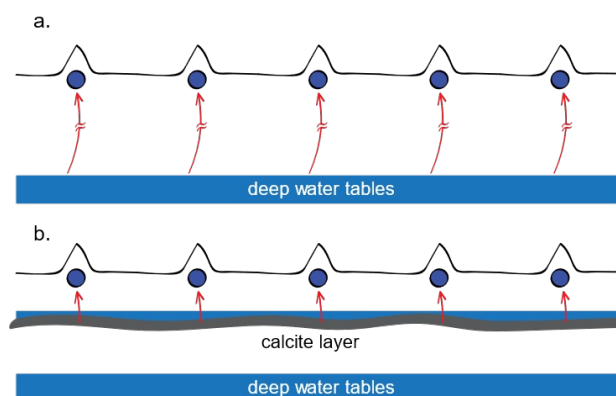
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<sup>36</sup> See Philippe BOYER, "Les effets de l'implantation destermitières des *Bellicositermes* sur la configuration des sols des savanes de la République centrafricaine", *Bulletin de Muséum National d'Histoire Naturelle* 1969, 2<sup>e</sup> Série, T. 41, No. 3, pp. 789–800; Philippe BOYER, "Différents aspects de l'action des termites sur les tropicaux", in: Paul PESSON (ed.), **La vie dans les sols. Aspects nouveaux. Etudes expérimentales**, Gauthier Villars, Paris 1971, pp. 279–334; Philippe BOYER, "Action de certains termites constructeurs sur l'évolution des sols tropicaux I. Les termites et le sol", *Annales des Sciences Naturelles Zoologie Paris 12 série* 1973, T. 15, No. 3, pp. 329–498; Philippe BOYER, "Etude particulière de trois termitières de *Bellicositermes* et de leur action sur les sols tropicaux", *Annales des Sciences Naturelles (Zoologie et Biologie Animale)* 1975, T. 17, No. 3, pp. 273–446; Philippe BOYER, "Les différents aspects de l'action des *Bellicositermes* sur les sols tropicaux", *Annales des Sciences Naturelles (Zoologie et Biologie Animale)* 1975, T. 17, No. 4, pp. 447–504; Jean-Paul WATSON, "Calcium Carbonate in Termite Mounds", *Nature* 1974, Vol. 247, No. 5435, p. 74.

<sup>37</sup> See Alain BRAUMAN, Matthew D. KANE, Marc LABAT, and John A. BREZNAK, "Genesis of Acetate and Methane by Gut Bacteria of Nutritionally Diverse Termites", *Science* 1992, Vol. 257, No. 5075, pp. 1384–1387.



saucer (Figure 3). The calcite pavement serves as a catchment for water percolating into the soil from the region's episodic torrential summer rainfalls, gathering the water into shallow perched water tables. No longer need termites venture deeply into the soil to mine water from deep water tables. Water is now easily accessible during the dry winter months from the termite-created perched water tables.<sup>38</sup> Because the calcite pavements, and the perched water tables they create, endure for much longer than the lifetime of an individual colony (centuries as opposed to decades), these modifications serve as process hereditary memory. Present adaptation is therefore shaped by the memory of past adaptation, with the proviso that the memory of past adaptation is not embedded in genes, but in defense of the termite colonies' collective βίος.



**Figure 3.** Ecosystem scale hereditary memory. (a) In the dry season, termites mine water from deep water tables. (b) The long-standing presence of a population of termites produces a calcite pavement a few meters deep, which can serve as a catchment for more accessible perched water tables all year round.

This can be construed as teleonomy, but it occurs in an entirely different framework from the Darwinian program of gene selectionism: it is driven by purpose. This has real evolutionary consequences, including enabling *Macrotermes* colonies to compete and survive in more arid environments compared to termite species that are not such adept hydraulic engineers.<sup>39</sup> All of this is shaped by modifying the environment to enable the persistence of the super-organism's

<sup>38</sup> See Jean-Claude LEBRUN, "Une construction originale hypogée pour le stockage de l'eau par les termites en régions sahélo-soudanaises de Haute-Volta", *Pedobiologia* 1976, Bd. 16, H. 6, pp. 451–456.

βίος. It is teleonomy, but now imbued with purpose. Purpose is no longer illusory, but the consequence of purpose-driven adaptation.

This has radical implications for how we think about evolution. For example, evolutionary novelty need not await the emergence of new genes that specify novel function. Rather, novelty arises from the active, continual, and *cognitively-driven* search for adaptive modification of environments: purposeful modification, to put it succinctly. The epigenetic web of feedbacks of adaptively-modified environments onto DNA structure and expression means that adaptive experience actually can shape genomes. Although there is still much to learn about epigenetic modification of genomes, what we are learning is pointing to a radical reconception of the gene. No longer are genes specifiers of form and function, adaptive or not. Rather, it is genes that are dragged along in the wake of cognitive and purposeful adaptation.

In the alternate conception I have outlined here, novelty arises from the adaptive boundary's active, continual, and cognitive search for environments to modify adaptively. In this conception, adaptation is no longer merely apparent and easily dismissed as illusion; instead, it is a profoundly purposeful and intentional shaper of lineages. Now, it is no longer novel genes which force lineages into the future to either live or die. Rather, the epigenetic web of feedbacks of adapted environments onto the genome drags genes along in the wake of the organism's adaptive (and purposeful) striving.

This has deep implications for the Darwinian idea itself — ones which are embodied in the title of this essay. Darwinism holds that species evolve through a kind of purposeless mechanism. There can be no question of purposeful striving, of wanting to evolve. The Darwinian idea rules such questions out of bounds *a priori*: only purposeless natural selection can generate new species. To quote Daniel C. Dennett:

No matter how impressive the products of an algorithm [i.e., natural selection], the underlying process always consists of nothing but a series of individually mindless steps succeeding each other without the help of any intelligent supervision.<sup>40</sup>

<sup>39</sup> See Ian DESHMUKH, "How Important are Termites in the Production Ecology of African Savannas?", *Sociobiology* 1989, Vol. 15, No. 2, pp. 155–168.

<sup>40</sup> Daniel C. DENNETT, *Darwin's Dangerous Idea: Evolution and the Meanings of Life*, Simon & Schuster, New York 1996, p. 586.

However, if adaptation and hereditary memory are purposeful phenomena, as I argue they fundamentally are, the very idea of *natural* selection is thereby nullified. If prevailing in the “struggle for existence” is purposeful and intentional, selection cannot, by definition, be “natural”. Rather, it is determined by the purposeful striving of organisms and lineages of organism to persist. Saying that species may actually, in some deep sense, *want* to evolve, is now conceivable.

*J. Scott Turner*

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