Introduction

When astronomers and astrophysicists realized that there were large unexplained anomalies in the universe, they invented an unobserved dark matter and dark energy to explain them. They still haven't observed dark matter and dark energy but are convinced that they must exist. Or could their theories about the universe be wrong?

For evolutionary biologists, random genetic mutations came to occupy a similar place in explaining biological evolution during the era of the so-called "Modern Synthesis" during the twentieth century. However, we now know that random genetic changes have had little influence in evolution. There are many far more important factors, including the actions of living systems themselves as purposeful "agents" and the many kinds of cooperative effects (synergies) in living systems.

In this volume I will draw upon our updated understanding of evolution to address our growing climate crisis and to "prescribe" a potential strategy for responding to it.

I should note that the term "agency" was imported into biology from the social sciences and philosophy, and it is entangled with theories of "mind," human cognition, intentional behavior, rationality, rational choice theory, and artificial intelligence, among other things. However, there have been some useful efforts to sort all this out for biologists. Walsh (2015), for instance, stresses that agency in biology refers to the goal-directed behavior of living organisms – their ability to pursue goals and to respond appropriately to conditions in their environments. Agency is fundamentally an "ecological phenomenon," he says, and he identifies three key properties of biological agency: (1) goals, (2) "affordances" which are determined by both the organism and its environment and (3) the organism's "repertoire" of behavioral responses. Okasha (2018), likewise, identifies three rationales for applying the term "agency" in biology: (1) goal-directed activities in organisms with a "unified" goal, (2) behavioral flexibility, and (3) traits that are adaptations serving intermediate "sub-purposes" related to the overarching goal. (For more on "agency," see the footnote.[1])

[1] I would add to this the following points: Because life is a contingent phenomenon, living organisms must actively pursue opportunities (resources) in their environments and must be able to avoid, or cope with challenges and threats of various kinds. Agency is thus an evolved capability that enables a living system to respond to the variability and changing conditions in relation to needed resources and challenges/threats in its environment. (Mobility in an organism also greatly increases this challenge, needless to say.) Agency in living systems requires: (1) the detection or "perception" of variations in internal and external conditions; (2) the ability to discriminate among these perceptions ("information"); (3) the ability to purposefully vary behavior, or actions; and (4) "control" – or the ability to link information with actions (cf., the

1 "Life Ascending"

Here I will begin with what is known about the origins of life, consider the vexed question of Vitalism in evolution, explore the role of teleonomy (evolved purposiveness) in evolution, review the evidence for the role of various kinds of cooperative effects (synergies) in evolution, consider the costs and benefits (the bioeconomics) of evolution, revisit Darwin's often misunderstood theories about evolution, reconsider the rise of humankind, and end with a prescription for our growing environmental crisis, with particular reference to Benjamin Franklin's famous warning before the American Revolution: "Unite or Die."

In his two important books on the subject, biochemist Nick Lane (2009, 2015), discussed at length the evidence for how life arose. As he put it: "Life itself transformed our planet from the battered and fiery rock that once orbited a young star . . . Life itself turned our planet blue and green, as tiny photosynthetic bacteria cleansed the oceans of air and sea and filled them with oxygen. Powered by this new source of energy, life erupted" (Lane, 2009: 1).

How life first arose has long been debated, of course. In the modern era, the debate began, perhaps, with the Nobel physicist Erwin Schrödinger's wartime lectures and famous 1944 book, *What Is Life?* Schrödinger pioneered the idea that ordered energy (now called negative entropy, or "negentropy") was an essential factor. Life is, among other things, a thermodynamic process. Today, we commonly refer to it as "metabolism." Many years later, biologists Humberto Maturana and Francisco Varela (1980/1973) identified another important property of living systems. They called it "autopoiesis" or self-making. Life has a form of autonomy, they proposed. Today the term "agency" is commonplace.

A more elaborate effort to explain the rise of living systems was provided by the little-known Hungarian theoretical biologist Tibor Gánti (1971). His three-part "Chemoton" model included an autocatalytic network for metabolism, machinery for controlling growth and self-replication, and a protective envelope to shield the system from the environment. In other words, he proposed a cooperative (synergistic) system. Some theorists, notably including John

cybernetic model of goal-oriented, "feedback" driven behavior). Agency is not dependent upon having a "brain." It can be based upon simple decision rules. However, its effectiveness can be greatly enhanced by being able to draw upon prior learning and memory, along with in situ cognitive and problem-solving skills. Agency will be favored by natural selection in relation to the degree of variability and novelty in the opportunities and threats in any given environmental context. But it is also a costly trait. It requires energy and functionally specialized biomass that must be built and maintained over time. Therefore, it will atrophy, or will not evolve at all, in conditions where it is not clearly advantageous for survival and reproduction. Illustrations of these points can be found in such diverse living entities as macrophages, bacteria at hydrothermal vents, slime molds, sea floor sponges, land plants, insects, fish, birds, and mammals.

Maynard Smith and Eórs Szathmáry (1999), argue that an additional requirement for life is the ability to evolve, when there is variation that can be differentially selected. I would add that life must also be able to respond to "feedback" and to changes in the environment. It must be sentient.

Two of the major alternative theories about the origin of life depend on yet another synergistic effect, an external catalyst. One is the "surface metabolism" theory of Günter Wächtershäuser (1988). He proposed that ancient Earth, with high concentrations of metallic compounds, may have provided important catalysts. The subsequent discovery of hydrothermal vents on the ocean floor lent credence to this idea. The other theory, proposed by geochemist Mike Russell (2006) and his colleagues (Martin & Russell, 2003; Koonin & Martin, 2005), involves a different kind of "metabolism first" theory, namely, deep-sea alkaline vents and the CO_2 in the ancient oceans. In effect, this provided an abundant source of free energy. It is a compelling idea. Most recently, biochemist Addy Pross (2024) has suggested that consciousness in evolution may have a biochemical basis.

These and other theories advanced in recent years, like the proposal that life was "seeded" by compounds brought from outer space by the once abundant meteors (see Powner, Gerland & Sutherland, 2009), make it seem even more likely that a synergistic combination of elements for the catalyzing life arose together in the early environment.

The Evolution of Prokaryotes

The evolution of prokaryotes (bacteria and their cousins, archaea) perhaps 3.7 billion years ago (some theorists say even earlier) was another major step in biological evolution. The prokaryotes were the first complete organisms, and they are still with us today. Indeed, they are the most productive form of life on Earth, with an estimated total biomass that outweighs all other fauna and flora combined (see Corning, 2018). Prokaryotes are also highly creative and adaptable. They invented many important biotechnologies, including photosynthesis, nitrogen fixing, fermentation, and cellular damage repair, and they can synthesize many different kinds of minerals. More important for our purpose, they invented various forms of collective action, from the division of labor to pack-hunting behaviors. It was the primordial "collective survival enterprise" (Corning, 2018: 102–104). As Baluśka, Miller, and Reber (2023a, 2023b) have stressed in detail, sentience and cognitive abilities can be found in all living organisms. Some theorists even see evolution as a cognition-based process (e.g., Miller, 2023).

The next major transition in evolution was the emergence, some 1.8–2.0 billion years ago, of eukaryotes – complex single-celled organisms with an array of specialized internal organelles and with genes in a sequestered nucleus. But the most important innovation was the role played by their symbiotic partners, the mitochondria, which provide the eukaryotes with an abundant source of energy. This enabled them to grow vastly larger than the prokaryotes – an important synergy of scale – and to become specialists in even larger multicellular organisms, another transition in biological size and complexity. "Symbiogenesis" represented an important cooperative partnership (Margulis, 1970, 1981, 1998; Margulis & Fester, 1991; Margulis & Sagan, 1995, 2002). (See the footnote.[2])

The emergence of multicellular organisms was another synergistic innovation. Among the innumerable examples, consider the human body. It involves an extraordinary combination of labor by an estimated 30 trillion cells of some 210 different kinds that are organized into an extraordinarily complex system of functionally differentiated parts, including 10 different specialized organ systems (Corning, 2018: 112–113). A human being, or any other multicellular organism (from earthworms to elephants), is fundamentally a cooperative effect, a synergistic system.

Finally, the synergies were raised to a new level with the emergence of behavioral cooperation and social organization among individuals of the same species – including everything from pack hunting to joint nesting, collective migration, collective defense against predators, and much more. One well-known example is the so-called leaf-cutter ants (pictured on the cover of my 2018 book, *Synergistic Selection: How Cooperation Has Shaped Evolution and the Rise of Humankind*). Another example is the recent discovery of underground cooperative systems among forest trees (see especially Shilthuizen, 2018).

2 Designers versus Tinkerers in Evolution

"Vitalism" is the doctrine that proceeds from the premise that living organisms are fundamentally different from nonliving entities because they contain some nonphysical element or are governed by different principles than inanimate things. Frequently used are such terms as *élan vital* (coined by Vitalist Henri Bergson) or a "vital spark." Among other things, this doctrine has come to be associated with the Intelligent Design movement, as well as various therapeutic medical treatments. Since the mid-twentieth century, though, Vitalism has been considered a pseudoscience. Evolution can be characterized as a process of

[2] Although the basic idea of symbiogenesis, and even the term itself, traces back to a school of nineteenth- and early twentieth-century Russian botanists, including A.S. Famintsyn (1907a, 1907b, 1918), Konstantin Mereschkovsky (1909, 1920), and B.M. Kozo-Polyansky (1924, 1932), their pioneering work was generally not known to Western scientists until recent decades.

biological "tinkering" (or trial-and-error) over eons of time, in Nobel biologist François Jacob's (1977) classic term.

Now it seems that Vitalism is being revitalized. Daniel Witt (2024), a persistent advocate for the idea of Intelligent Design, has suggested that recent publications on purposiveness (teleonomy) in living systems show that Vitalism is "making a comeback." Witt does not seem to believe that teleonomy in living systems could be an evolved biological trait – a product of natural selection. Perhaps he did not read my extensive introductory/overview chapter: "Teleonomy in Evolution: "The Ghost in the Machine" in P. A. Corning et al., eds. *Evolution "On Purpose": Teleonomy in Living Systems.* (Cambridge, MA. The MIT Press, 2023). As the eminent twentieth-century biologist Theodosius Dobzhansky long ago explained:

> Purposefulness, or teleology, does not exist in nonliving nature. It is universal in the living world. It would make no sense to talk of the purposiveness or adaptation of stars, mountains, or the laws of physics. Adaptedness of living beings is too obvious to be overlooked . . .. Living beings have an *internal*, or natural, teleology. Organisms, from the smallest bacterium to man, arise from similar organisms by ordered growth and development. Their internal teleology has accumulated in the history of their lineage. On the assumption that all existing life is derived from one primordial ancestor, the internal teleology of an organism is the outcome of approximately three and a half billion years of organic evolution . . .. Internal teleology is not a static property of life. Its advances and recessions can be observed, sometimes induced experimentally, and analyzed scientifically like other biological phenomena. (Dobzhansky, 1977: 95–96)

In sum, purposiveness (or teleonomy) in living systems is a product of evolution and natural selection. It has nothing to do with any purported external Vitalism.

3 Teleonomy in Evolution

The Ghost in the Machine is the title of a provocative book by the polymath and famed twentieth-century novelist Arthur Koestler (1967), in which he disputed the then-fashionable view, often attributed to Descartes, that the human mind is a dualistic, non-material entity. (Koestler's ironic title was borrowed from the philosopher Gilbert Ryle.) Koestler argued that, on the contrary, the mind is embedded in and is a product of the natural world.

This distinctive title underscores the cardinal fact that teleonomy (or evolved purposiveness) in biological evolution is not simply a product of natural selection. It is also an important cause of natural selection and has been a major shaping influence in evolution over time. Natural selection is not an exogenous force or "mechanism." It is an outcome of the relationships and interactions between purposeful living organisms – agents if you will – and their lived-in environments, inclusive of other organisms.

The term "teleonomy" was originally coined by the biologist Colin Pittendrigh in connection with the landmark 1957 conference on behavior in evolution (Roe & Simpson, eds., 1958). Pittendrigh was seeking to draw a contrast between an "external" teleology (Aristotelian or religious) and the "internal" purposiveness and goal-directedness of living systems, which are products of the evolutionary process and of natural selection.

Many theorists over the years have expressed supportive views, as Samir Okasha (2018) has documented in his book-length study, *Agents and Goals in Evolution* (see also Walsh, 2015). For instance, the Nobel biologist Jacques Monod (1971: 9) concluded that "one of the most fundamental characteristics common to all living things [is] that of being endowed with a project, or a purpose." Likewise, the biologist Ernst Mayr, one of the founding fathers of the so-called Modern Synthesis in evolutionary biology, wrote, "goal directed behaviour … is extremely widespread in the natural world; most activity connected with migration, food-getting, courtship, ontogeny, and all phases of reproduction is characterized by such goal orientation" (Mayr, 1988: 45; see also Mayr, 1963).

Over the years, many theorists have interpreted teleonomy broadly. Pittendrigh (1958) himself characterized it as a "fundamental property" and defining feature of all biological phenomena, including behavior. Similarly, Monod, in his influential book, *Chance and Necessity*, concluded: "All the structures, all the performances, all the activities contributing to the essential project [of life] will hence be called 'teleonomic' … . It is the very definition of living beings" (Monod, 1971: 9,14). As an example, he pointed to the central nervous system.

However, Mayr (1974), in his classic essay on "Teleological and Teleonomic: A New Analysis," opposed such a broad definition. Mayr framed teleonomy as requiring a preexisting goal and "something material" that guides and controls a "process" to a "determinable end." In living organisms, he said, this a priori goal entails a "program" – an analogy Mayr borrowed from computers. It is the teleonomic program that is responsible for directing the process of developing a phenotype and its behavior, although an "open program" (as Mayr called it) allows for the influence of learning and experience (and other "disturbances"). To illustrate his definition, Mayr alluded to the science of cybernetics, or goal-directed control systems. He also insisted that a teleonomic program – an obvious euphemism for the genome – could only have a one-way flow of information, and that developmental influences are highly restricted. "The inheritance of acquired characters becomes quite unthinkable." (In fact, we now know this is not true.)