A novel look at life's unfolding diversity

A review of The Ancestor's Tale: A Pilgrimage to the Dawn of Evolution, by Richard Dawkins

James Brookfield
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The Ancestor's Tale: A Pilgrimage to the Dawn of Evolution,by Richard Dawkins, Mariner Books, 2005, $16, ISBN 0-618-61916-X (paperback)

In this survey of life on earth and its evolution, Richard Dawkins adopts a rather innovative approach. Rather than beginning with the origin and proceeding forward through historical time, the author starts with modern humans and works backwards. He does so in order to dispense with the anthropocentric and essentially religious notion that evolution was somehow fated to result in human beings.

As Dawkins points out, another species, were it sufficiently conscious, could with no less justification regard itself as the "intended outcome" of evolution, whereas working backwards one can start with any living species and return to the same ultimate starting point. This approach is one that stresses the commonality of all living organisms.

The book imagines a journey back in time, punctuated by 40 narrative pauses, or "rendezvous points." At each stop, we encounter a "concestor"—an ancestor common to both our lineage and those organisms that branched off into other species.

The first concestor, for example, is the ancestor—alive six million years ago—that modern humans share with the chimpanzee; the fifth is that which we share with the old world monkeys; the twentieth is that which we share with the ray-finned fish; the thirty-ninth is that which we share with the eubacteria.

Dawkins employs the Chaucerian metaphor of a "pilgrimage," where the species that are all traveling backward in time meet up with their relatives and their concestors. Each concestor has at least one "tale" to tell, generally concerning one of the organism's modern descendants.

For the sake of clarity, we should note that this common ancestor is not the same as any of its modern descendants. Thus, the ancestor we share with the gibbons is not itself a gibbon (though it may have had a number of features that are gibbon-like) or a human (though it may have features in common with humans). Since the nodal point where the gibbon line split from ours 18 million years ago (mya), there has been considerable development and several splits into species. The concestor is akin to the branching point on a tree; the modern descendants (including human beings) are like the leaves.

The Ancestor's Tale is the first of Dawkins's works to explicitly cover the entire history of evolution. His seven earlier books have focused more on the philosophical and theoretical aspects of evolutionary biology.

Interspersed with his narrative are significant observations about the contemporary political situation. On more than one occasion, Dawkins is sharply critical of the Bush administration. These pointed remarks fit quite organically into the discussion and hardly run the risk of "dating" the book, notwithstanding objections along these lines from some.

Is it inappropriate to note, as Dawkins does while tracing the origins of modern humans, that the Fertile Crescent between the Tigris and Euphrates rivers is "the cradle of human civilisation whose irreplaceable relics in the Baghdad Museum were vandalised in 2003, under the indifferent eyes of American invaders whose priorities led them to protect the Ministry of Oil instead"?

Should Dawkins refrain from remarking that an accidentally triggered nuclear war, much like the development of a new species, is highly likely even if the odds of it happening at any given moment are small, so long as enough time passes? Especially given, as Dawkins notes, that some indication of the intellectual level of the current occupant of the White House, hand atop the trigger, is shown in his belief that the word is pronounced "nucular"?

To this reviewer the remarks seem particularly apt, considering especially the politically charged conflict over the teaching of evolution in the American public schools. Defense of the science of evolution has become a political issue.

There are, of course, some inevitable limitations in trying to survey all of evolutionary history, even in a book of more than five hundred pages. Nevertheless, one need not agree with the remark by Carl Zimmer, author of *Evolution: The Triumph of an Idea*, in a review published in the *New York Times*, that the book is "wildly lopsided" in that it devotes excessive attention to the animals at the expense of other organisms.

As one turns to ever-earlier periods, when our line splits from those that developed into plants, fungi, and ultimately bacteria, the fossil record thins. Dawkins, in focusing on the descent of homo sapiens from other animals, develops his attack on the idea, fashionable among those who try to reconcile acceptance of evolution with religion, that evolution may be responsible for modest changes within a species or among closely related species, but cannot account for the development of human beings from less complex creatures. And it should be added, in Dawkin's defense, that during the discussion in the later sections of the book covering the older concestors, his treatment of the philosophical issues at stake is particularly engaging to the general, non-specialist audience, as we shall see below.

The dates of the rendezvous points are based largely on the fossil record, which has been checked with genetic information and with measurements of the decay of certain naturally occurring radioactive constituents. The relative separation between species that are "cousins" can be approximated from the divergence in their DNA makeup. These approximations are cross-checked against the fossil record where available.

Of course, the fossil record is not complete and, given the recycling of sedimentary rock, we should not be surprised at gaps. In fact, the process of fossilization is so unusual that it is estimated that 90 percent of species will never be found as fossils. But the fossils that do exist serve, among other purposes, as known dating points that can be used to calibrate what is learned from genetic evidence.

Before reaching the first rendezvous point, Dawkins traces the development of homo sapiens. First, we meet "Cro-Magnon" man, who appears approximately 40,000 years ago during a rapid development of culture. Tools change dramatically while musical instruments and cave murals make their first appearance. Not, relatively speaking, long before that point complex reasoning and elaborate mathematics lead Dawkins to conclude that modern humans had already evolved by this point.

Leaving behind the modern homo sapiens, Dawkins draws considerable attention to *Homo ergaster*, which first emerged approximately 1.8 mya years ago. *H. ergaster* (which Dawkins, somewhat informally, refers to as ergaster), is closely related to *H. erectus*, however some scientists take the view that ergaster is actually more closely related to modern humans than erectus, whose fossil record extends much further into the modern era.

It was during the existence of ergaster that, for reasons not fully known, the brain began its explosive development. Dawkins speculates that some type of positive feedback was likely involved. He makes an interesting analogy to explain the process: just as advances in computer hardware and software seem to drive each other rapidly forward, development of the brain could have fostered cultural changes like new mating practices or other rituals that gave an advantage to those with larger brains, driving the process of brain enlargement ahead.

Late ergaster fossils had brains approximately 1,100 cubic centimeters in volume (compared with 1,400 for modern humans). Ergaster had campfires and shaped and used stone tools. Fossils indicate that ergaster lived in the Middle East and Far East. There is not yet a consensus view among biologists about ergaster's language facilities. But recent work on the language-related "FOXP2" gene reveals a major change that took place approximately 200,000 years ago.

Before leaving the hominids, and getting to the first rendezvous, Dawkins introduces a discussion of bipedality, which, it now appears to most scientists, preceded the growth of the brain. Perhaps, Dawkins suggests, the hands had to be freed for the brain to begin enlarging.

It is not possible to review even the highlights of each rendezvous point. But some of the more interesting "tales" can be noted here. Through these tales, Dawkins gives a partial portrait of the rich complexity of life as it exists today, while at the same time drawing attention to the fact that ultimately these "endless forms, most beautiful," as Darwin put it, have a common origin—are therefore our own relatives.

First, there are the species that seem particularly remarkable. The gibbon, whom we "meet" at R4 (the fourth rendezvous point, 18mya), has arms so long that it can hurl itself across a ten meter gap in the treetops. The common ancestor that we share with the gibbons is only one million generations removed from us—or, as Dawkins puts it in a way that reminds us of our shared ancestry, concestor four (C4) would be, approximately, our "1-millions-great-grandparent."

Then there are rodents and rabbits, whom we meet at R10 (75 mya). "More than 40 per cent of all mammal species are rodents," notes Dawkins, "and there are said to be more individual rodents in the world than all other mammals combined." They have penetrated almost every habitat—desert, mountain, forest canopy, river, forest floor, savannah and tundra.

The ability to branch into many habitats is not unique to the rodents, though. Amphibians have also managed it. There are even frogs in which a type of antifreeze has evolved to allow the creature to survive in subzero climates.

Then there is the quirky duck-billed platypus, whom we meet at R15 (180mya), whose bill has electrical sensors that pick up fields generated by muscle movements of its prey.

And it is hard not to feel a certain awe for the ants (found at R26, more than 500 mya). "A single nest of leaf cutter ants, *Atta*, can exceed the population of Greater London," Dawkins notes. These ants live symbiotically with a certain fungus that digests leaves and becomes food for ants and their larva—"a true example of domestication by an agricultural species other than our own."

Much later, in "Taq's Tale" (told at R39, probably more than 2 billion years ago), we learn of *Thermus aquatiqus*,which thrives in 70ºC water.

The real highlights of Dawkins' book are to be found in the historical and theoretical issues that are posed at a number of the rendezvous points, particularly those associated with the relationship between an organism and its genes. Some of these spill over into other disciplines, such as the discussion of the difficulty of constructing an historically-correct "phylogenetic tree," a diagram which shows the lineage of related organisms.

It is interesting to note that some of the techniques from genetic analysis of phylogeny have been applied with considerable success to literary study, particularly of ancient texts of which multiple copies exist. It is possible to uncover which extant manuscript of, say, *The Canterbury Tales* preceded and served as the source for another by comparing variations in the texts.

Besides certain technical problems associated with constructing phylogenetic trees in biology, there is the fundamental problem of the meaning of the phylogenetic tree itself, Dawkins argues. Students of biology are quickly familiarized with phylogenetic trees and the way in which they depict the relation of many species. But a species is also "a composite of DNA from many sources." So we can consider more than one approach to genetic descent: that of the species and that of the individual genes that are found in the species. In this sense, Dawkins argues, "My B-group gene [for blood type] relates me more closely to a B-group chimpanzee than an A-group human."

Generalizing from such specific examples, Dawkins argues: "Species trees *can* be drawn, but they must be considered a simplified summary of a multitude of gene trees. I can imagine interpreting a species tree in two different ways. The first is the conventional genealogical interpretation. One species is the closest relative of another if, out of all the species considered, it shares the most recent common genealogical ancestor. The second is, I suspect, the way of the future. A species tree can be seen as depicting the relationship among a democratic majority of the genome. It represents the result of a 'majority vote' among gene trees."

What is the value of taking such an unconventional approach? Dawkins explains it best in the passage just prior to the above. He says: "The majority of both our molecular and morphological characteristics show chimps as our closest relatives. But a sizeable minority shows that gorillas are instead, or that chimps are most closely related to gorillas and both are equally close to humans." And certainly we can think of other organisms in which morphological differences between species will not provide as great a repository of information as in the apes. In evaluating the descent of different types of bacteria (treated later), genetic analysis will be a primary tool. In such investigations, one presumes that "'majority vote' among the genome" approach will be quite essential.

Though *The Ancestor's Tale* takes as its framework the evolution of species, Dawkins adds that "something like this entire book could be written for each gene." Some examples, like the origin and development of the genes for the oxygen-carrier in our blood, hemoglobin, are considered in some detail. This "gene's eye view," for which Dawkins has become well known, does not so much lead to a reductionist view of human beings (that we are simply an assemblage of genes) as it points to the interconnectedness of all forms of life and the complex processes that led to its development over eons.

In another region of *The Ancestor's Tale*, Dawkins turns to the relationship between the phenotype and the genotype of an organism. Generally speaking, phenotype refers to the physical characteristics of an organism, and is a product of the genotype—the genes—and the organism's environment and life history.

"For a Darwinian," Dawkins writes, "phenotypes are the manifestations by which genes are judged by selection. When we say that a beaver's tail is flattened to serve as a paddle, we mean that genes whose phenotypic expression included a flattening of the tail survived by virtue of that phenotype." Those beavers that had the genes which expressed themselves in flatter tails were more likely to survive than those that did not and carry those genes into future generations. Likewise with genes for sharp teeth that could gnaw through wood. Significantly, these sets of genes developed well in each other's presence. "Genes have survived through generations of ancestral beavers because they have proved good at collaborating with other genes in the beaver gene pool, to produce phenotypes that flourish in the beaver way of life." In this sense, Dawkins speaks of organisms as gene cooperatives.

This leads to an important conclusion: "Each gene promotes its own selfish warfare, by cooperating with the other genes in the sexually stirred gene pool which is the beaver's environment." To put it another way, "Selfishness and cooperation are two sides of a Darwinian coin." In taking this approach, Dawkins is arguing for a more complex view of an organism and its environment. One can proceed from the standpoint of the organism or one can also proceed from the standpoint of one or more of its genes. In the latter case, the remainder of the genome is itself part of the environment.

Likewise, we can consider a broader idea of the gene's expression. Referring to an argument from his earlier work, *Extended Phenotype*, Dawkins argues here for the idea that not only the organism, but the products of the organism should be considered phenotypic. For example, not only should we think of the beaver and his tail as the phenotypic expression of his genes. The dam built by the beaver is part of the "extended phenotype."

Why consider both under the same heading? "The answer," according to Dawkins, "is that both have evolved to become better and better at preserving those genes; both are linked to the genes they express by a similar chain of embryological causal links."

Just as variation among beaver genes for tail flatness led to better than average survival and reproduction rates for those who possessed them, variation in the genes that controlled dam-building behavior would have led to better than average survival and reproduction rates for the best dam-builders.

The general point that Dawkins asks us to adopt is that "the phenotype of the gene, in the true sense of the word, may extend outside the skin of the individual." There are countless other examples, of which a particularly interesting group is that of parasitic species. Their genes express themselves, in part, indirectly—in the behavior of their hosts.

In arguing for greater consideration of biological phenomena at the gene level, Dawkins, it would seem, is pointing out that this theoretical framework may be a more profitable one in finding new insights. Though one need not agree with his use of the terms "selfish gene" and "extended phenotype" to recognize the validity of new methodologies that draw more heavily on genetic data, it would seem to help in comprehending these new tools.

For example, in examining speciation of a group of fishes in Lake Victoria and nearby lakes (at R20, the ray-finned fish), Dawkins points to a relatively new type of speciation diagram, the haplotype tree. A haplotype is a fragment of a gene that is long enough to be observed in many individuals. These individuals may or may not be of the same species. By drawing a diagram of a number of haplotypes and their geographic distribution, scientists can make very well-reasoned hypotheses about the geography and timing of speciation events. Here it pays to adopt the "gene's eye view."

Then there is the potential use of genetic information to provide a more precise classification scheme for species. For example, Dawkins introduces a discussion of Hox genes, which provide information about the position of a cell along the length of an animal. It turns out that only animals have them, though they have not yet been found in all organisms considered to be animals. Plants and fungi have a different type of gene to provide such spatial information.

One precise way to define an animal, therefore, may well be simply as an organism that contains Hox genes. What is the value of such an approach? "If you forget morphology and look only at the genes, it emerges that all animals are minor variations on a very particular theme." Put another way, a particular genetic development can be correctly pinpointed, in hindsight, as the point of departure for new ways of life for organisms which ultimately led to the flowering of entirely new groups.

There is much more in this book worth considering, and it is possible in a review to deal with only some of it. In "The Prologue to the Galapagos Finch's Tale," Dawkins points to the fact that Darwinian dynamics, far from being unable to explain life's diversity, "can drive evolutionary change at a rate far faster than we ever see in nature."

This can be demonstrated by artificial selection. If scientists impose conditions on a sample population of, say, fruit flies, generation after generation, they can see very dramatic changes quickly. Similar processes are employed in animal breeding. Why doesn't such rapid change happen often in nature? Because selective pressures tend to alternate rather than consistently reward one body type. Drought may follow flood, sending contradictory signals to an animal population in nearly immediate succession.

How then can rapid change in the forms of organisms take place? One means is sexual selection, which refers to selection as it relates specifically to the process of reproduction. For example, a particular feature may make a creature more attractive to would-be mates. This is considered in "The Peacock's Tale," told at R16. The brilliant plumage of the male peacock attracts mates, though it also makes him more easily seen by predators. Why are such features attractive? Dawkins refers to the argument that certain easily observable features, like the peacock's feathers, may be taken by mates as proxies for overall fitness.

A similar dynamic may have facilitated the rapid loss of most body hair in the genus *Homo* since it allowed the body to be more easily seen. Could it also have driven bipedality or brain development? Dawkins argues for some type of copying—one ape perhaps developed a *fashion* of walking upright (which would also increase his visibility to would-be mates). Others then mimicked it. Those best able to walk would have found greater reproductive success. The genes associated with the ability to walk upright would increase in frequency in the descendant population.

This may be far fetched. However, in pointing to these issues, Dawkins is drawing attention to the fact that coming to some understanding of the specific driving forces behind certain evolutionary developments is not always a straightforward operation.

The notion of a fashion leads Dawkins to introduce the concept of "meme," a term from his 1976 work, *Selfish Gene*. A meme is "a unit of cultural inheritance." It can be a fashion, a habit or an idea.

The concept is one that has found use by psychologist Susan Blackmore, philosopher Daniel Dennett and others. Dawkins suggests that memes played a part in the enlargement of the brain.

Memes developed and took advantage of variability in brain features. For example, musical practices (musical memes) could have arisen accidentally and illustrated differences in cognitive abilities involved in music in a particular group.

The value of the term "meme" is a subject of debate, but it does lend itself here to a consideration of the interrelation between cultural change (e.g., walking upright) and genetic change (predominance of genes that foster such behavior).

Dawkins addresses certain questions about the nature of the species concept at R17 (approximately 340mya), where we meet the ancestor we share with the amphibians. Here Dawkins introduces the concept of "ring species," which are collections of related organisms that live in some sort of geographic near-ring or near-circle. Each can interbreed with his neighbor until one reaches the break in the ring. At this spot the circle is broken in that the two geographically adjacent organisms cannot interbreed. Yet there is a chain of intermediates that can do so. Two populations are generally considered to be the same species if they can potentially interbreed. So is a "ring species" one species or more than one?

Though ring species are relatively rare, evolution is filled with an analogous process. It is taken as a truism that parent and child organisms are of the same species. But there exists an unbroken chain of descent from any modern species all the way back to the origin of life. Dawkins sees this paradox as a critical one. The "discontinuous mind" that cannot abide such contradictions must stumble at ring species and their evolutionary analogues. Indeed, Dawkins goes so far as to blame a tendency towards discontinuous "essentialist" thinking for the historically belated recognition of evolution. Pointing to the work of the late biologist Ernst Mayr, he faults, rather ahistorically, Plato and his discussion of "ideal forms" for setting the stage for the "discontinuous mind." This aside, the point is one which underscores the significance of a dialectical approach to the study of evolution.

In the "Flounder's Tale" told at R20 (440mya), Dawkins discuss the important point that evolution has constraints, and, in particular, that it can only operate on the foundation of existing variation in a population. This often leads to what might be considered imperfections that "mar" creatures like the teleost flatfish. In discussing the teleost flatfish, Dawkins points to the so-called "jet engine effect."

"Imagine," he writes, "how imperfect a jet engine would be if, instead of being designed on a clean drawing board, it had to be changed one step at a time, screw by screw, rivet by rivet, from a propeller engine." He goes on to explain that teleost flat fish lie on one side. The skull is distorted so that whichever eye would face down actually moves to the upper side with the other eye. "Picasso would have loved them," he suggests. A more logical approach to a flat fish would likely yield a body like the skates, with their wide, flat bellies and eyes symmetrically on top.

The later rendezvous points, where we meet the earliest forms of life, are particularly interesting for their treatment of evolutionary symbiosis, which is really a type of benevolent parasitism. Again we find here an example of the essentially interconnected nature of life.

At R37, we hear the tale of *Mixotricha paradoxa*—a microorganism that lives in the gut of an Australian termite. It is the mixotricha that actually digests the cellulose for the termite. Not only termites make use of such microorganisms: "For digesting cellulose, herbivorous mammals all rely on microbes in their gut." But there is actually another level of symbiosis at work in the mixotricha/termite. The mixotricha is a protozoan that contains hundreds of thousands of bacteria inside itself. These bacteria actually provide locomotion for the mixotricha.

This discussion of symbiosis is a prelude to what Dawkins calls the Great Historic Rendezvous. At the Great Historic Rendezvous, formerly free living mitochondria are incorporated into bacterial cells. The mitochondria, which have their own DNA separate from those of the cell's nucleus, provide energy to the cell. Likewise, the chloroplasts that absorb solar energy and create oxygen are absorbed into bacteria cells that will give rise to the plants. Deep in the foundation of most biological phenomena is an evolutionary symbiosis.

Going back still further to R39, which is not dated but probably more than 2 billion years ago, we meet the eubacteria and find a very unusual case of evolution: the creation of a wheel. The flagellum of the rhizobium bacteria is able to rotate on a sort of axle to provide locomotion.

Dawkins points out that self-described "intelligent design theorists" have pointed to the wheel as evidence for their case. The wheel design of the flagellum is, they claim, irreducibly complex. How could it have evolved in stages?

Of course, the answer is found a few pages later. It turns out that intermediates have a separate use: as means of creating round holes in the cell walls of the rhizobium's hosts.

Dawkins points out that the argument of "irreducible complexity" is often little more than an appeal to ignorance or, as he puts it, an argument from "personal incredulity." That is, the intelligent design "theorist" cannot personally conceive of an independent use of an evolutionary intermediate. From this failure of imagination, he generalizes the impossibility of the existence of such an intermediate.

We must at least briefly consider the final rendezvous point, the "Canterbury" of this tale. This, Dawkins writes, "is the singularity known as the origin of life, but we could better call it the origin of heredity."

What is meant by the use of this term? In short, for the process of life to begin, the first gene had to come in to being. By gene, Dawkins means not DNA, but some type of "replicator" or molecule that "forms lineages of copies of itself." The first replicator would have needed to possess two important properties: it would have to be amenable to being copied and it would need to find some way to regulate the rate at which it is copied.

In chemistry, agents that speed up or slow down a chemical process are known as catalysts. Biological catalysts are known as enzymes. The primeval replicator would likely need to catalyze its own production; it would serve as the enzyme for the reaction that produces it.

Experiments have shown that such replicator enzymes could be created from the materials available in the early atmosphere. Dawkins notes, "We can draw the robust conclusion that biologically important small molecules, including amino acids, sugars, and, significantly, the building blocks of DNA and RNA, spontaneously form when various versions of the Oparin/Haldane primitive Earth are simulated in the laboratory." [Oparin and Haldane were, respectively, Soviet and British biochemists working independently on this problem in the 1920s].

Dawkins points out that RNA, a "relative" of DNA used in protein synthesis, may be good enough as a replicator and enzyme. Unlike DNA, RNA does not form a double helix. Though its shape is a hindrance in that it results in a relatively high error rate when copying, it is a benefit in that it allows it to coil up, as good enzymes do. So it turns out to be a good early replicator, one that will work more than adequately for organisms with small genomes (like viruses).

Recent experiments have been able to generate RNA from raw materials plus a separate catalytic enzyme. New experiments are planned to synthesize even this catalytic enzyme from the biological precursors available in the early atmosphere.

Having read the tales of the concestors and their modern descendants, Dawkins turns to the "The Host's Return," the final "chapter" in the book and, in many ways, its most philosophically suggestive. Here Dawkins proposes to turn around and make the trip back to the present. Of course, he had taken the opposite path at the outset of the book in order to oppose an anthropocentric teleology. But is there, he now asks, a legitimate teleology? Were certain steps in evolutionary history inevitable or, at least, very likely? He points to the work of American theoretical biologist Stuart Kauffman, who takes a statistical approach. If we were able to "rerun" evolution thousands of times from the eukaryotic cell stage forward, what milestones would be common? Which rare?

Though we cannot perform such an experiment, we can look to historical analogues. "Australia, New Zealand, Madagascar, South America, even Africa, furnish us with approximate reruns of major episodes of evolution." These regions were largely isolated from each other and the rest of the world after the disappearance of the dinosaurs, when mammals began to flourish. Some modes of locomotion seem to have evolved repeatedly. Some features seem to recur—the eye, for example, has evolved 40-60 times independently in the animal kingdom. Echolocation, like the sonar used by bats, has arisen four times.

The important point, according to Dawkins, is that the contingency of human evolution can be overstated, particularly by Stephen J. Gould and those who take a lead from him. Dawkins defends "the unpopular notion of progress in evolution: not progress towards humanity—Darwin forfend!—but progress in directions that are at least predictable enough to justify the word."

Some biologists predict that a rerun would yield another "large brain biped with two skilled hands, forward pointing camera eyes and other human features." Likewise, the insect body plan—with articulated exoskeloton, compound eyes, six-legged gait, etc.—seems a likelihood.

Dawkins points out that there is another type of "progress" in evolution that has a certain inevitability: "arms races" between predators and prey or parasites and their hosts. A predator evolves better eyesight; the prey develops better camouflage. A tendency toward ever greater complexity is latent in the process. Also favored are those adaptations that increase a group's "evolvability." One example: an adaptation that allows a bird to fly further (and thus get to islands where separation followed by speciation is more likely) will increase its evolvability. "Watershed events" like the development of multi-cellular body plans also increase evolvability.

This type of approach, assisted in the future, one hopes, by elaborate computer simulations, should shed further light on the basic fact that the possibility of life and even many of its particular characteristics are latent in the development of matter itself.