

Darwin's Tree of Life

In the first edition of his book *On the Origin of Species*, Charles Darwin included one, and only one, illustration: a taxa chart, which helps in conceptualizing his idea of evolution. Darwin visualized the evolutionary process as a Tree of Life. I will describe Darwin's Tree of Life and show how its features explain the observations made by geologists and taxonomists in Darwin's time. I will then show that Darwin's Tree of Life illustrates the revolutionary idea that design can emerge without a designer but with time, from the mindless processes of descent with modification and natural selection.

Darwin's taxa chart is a diagram in two dimensions showing the evolution of species. The vertical axis represents time, with later times on top of earlier times, the direction of time being the opposite of its direction in the expression "descent with modification". The horizontal axis represents some abstract design space, so that the horizontal distance between two organisms roughly represent their morphological differences. Darwin uses the same diagram to discuss evolution at different resolutions: organisms to varieties, varieties to species, species to genera, genera to families, families to order. Indeed, the tree structure is scale-invariant. At the finest resolution, each organism would be represented on the chart as a tiny straight vertical line, starting at the time of its birth and extending for the short duration of its life. The tiny line of an organism would be very

close in time and space to the lines of its direct ancestors, below, and of its descendants, if any, above. Through descent with modification, as variations accumulate, the tiny lines would horizontally drift from the lines of their ancestors. Through natural selection, some lines would go extinct, leaving no offspring. The living organisms are all at the top of the Tree of Life, being the descendant of generations of organisms that successfully reproduced. Contemplating the diagram from a lower resolution, organisms of the same species living at the same time might appear like a dot, being so close together. Their offspring might appear as nearby dots, and so on, until, many thousands generations later, the descendants might appear as dots sufficiently apart to be classified as varieties. By the same processes at different resolutions, varieties might diverge enough to give rise to sub-species, which might diverge enough to give rise to genera, then families, then even orders, etc. The Tree of Life explains how each genus, each family, and even each order, shares a common ancestor in a once living species. “The green and budding twigs may represent existing species; and those produced during each former year may represent the long succession of extinct species. At each period of growth all the growing twigs have tried to branch out on all sides, and to overtop and kill the surrounding twigs and branches, in the same manner as species and groups of species have tried to overmaster other species in the great battle for life. The limbs divided into great branches, and these into lesser and lesser branches, were themselves once, when the tree was small, budding twigs; and this connexion of the former and present buds by ramifying branches may well represent the classification of all extinct and living species in groups subordinate to groups. Of the many twigs which flourished when the tree was a mere bush, only two or

three, now grown into great branches, yet survive and bear all the other branches; so with the species which lived during long-past geological periods, very few now have living and modified descendants.”¹

The Tree of Life helps making sense of the observations coming from geology and taxonomy. The fossil records of a geological period should map to a slice of corresponding time in the Tree of Life. Therefore, as Darwin says, “those groups, which have within known geological periods undergone much modification, should in the older formations make some slight approach to each other; so that the older members should differ less from each other in some of their characters than do the existing members of the same groups; and this by the concurrent evidence of our best paleontologists seems frequently to be the case. Thus, on the theory of descent with modification, the main facts with respect to the mutual affinities of the extinct forms of life to each other and to living forms, seem to me explained in a satisfactory manner. And they are wholly inexplicable on any other view.”² The hierarchical organization of organisms into varieties, species, genera, families and orders can also be explained by the Tree of Life. Each group maps to a branch of the Tree, rooted in a common ancestor: “Natural selection [...] leads to divergence of character and to much extinction of the less improved and intermediate forms of life. On these principles, I believe, the nature of the affinities of all organic beings may be explained. It is a truly wonderful fact—the wonder of which we are apt to

¹ Darwin, Charles. *On the Origin of Species* 1st ed. (1859). Cambridge, Mass.: Harvard University Press, 1975. (p. 129)

² Darwin. (p. 333)

overlook from familiarity—that all animals and all plants throughout all time and space should be related to each other in group subordinate to group, in the manner which we everywhere behold—namely, varieties of the same species most closely related together, species of the same genus less closely and unequally related together, forming sections and sub-genera, species of distinct genera much less closely related, and genera related in different degrees, forming sub-families, families, orders, sub-classes, and classes. The several subordinate groups in any class cannot be ranked in a single file, but seem rather to be clustered round points, and these round other points, and so on in almost endless cycles. On the view that each species has been independently created, I can see no explanation of this great fact in the classification of all organic beings; but, to the best of my judgment, it is explained through inheritance and the complex action of natural selection, entailing extinction and divergence of character, as we have seen illustrated in the diagram.”³ Finally, the gradual emergence of a branch in the Tree of Life justifies Darwin’s reluctance to give a sharp definition of the word “species”. Indeed, a speciation event is a “retrospective coronation” as the philosopher Daniel Dennett puts it: “There is not *and could not be* anything internal or intrinsic to the individuals – or even to the individuals-as-they-fit-into-their-environment — from which it follows that they were – as they later turn out to be – the founders of a new species. We can imagine, if we want, an extreme (and improbable) case in which a single mutation guarantees reproductive isolation in a single generation, but, of course, whether or not the individual who has that mutation counts as a species-founder or simply as a freak of nature depends on nothing in

³ Darwin. (pp. 128-129)

its individual makeup or biography, but on what happens to subsequent generations – if any – of its offspring.”⁴ Again, because the Tree of Life is scale-invariant, “the same moral applies to the creation of new genera, families, and even kingdoms, of course. The major branching that we would retrospectively crown as the parting of the plants from the animals began as a segregation of two gene pools every bit as inscrutable and unremarkable at the time as any other temporary drifting apart of members of a single population.”⁵

Darwin’s Tree of Life depicts the shape of the evolutionary process, an iterative bottom-up process arising from the principles of descent with modification and natural selection. As such, Darwin’s Tree of Life embodies the revolutionary implications of his theory of evolution, not only in the realm of biology but also in the realm of philosophy. I will now discuss a few of these implications: the Tree of Life as a counterexample to the Argument from Design, the Tree of Life as an undermining of Locke’s deduction of the primacy of Mind, the Tree of Life as an argument for the possibility of artificial intelligence and consciousness.

The Argument from Design is perhaps the favorite argument of natural theology, which aims to give religious beliefs a scientific basis. It can briefly be stated as:

⁴ Dennett, Daniel. *Darwin’s Dangerous Idea*. New York: Simon & Schuster, 1995. (pp. 99-100)

⁵ Dennett. (p. 100)

1. Parts of this world, such as living beings, cannot have occurred by accident and must have been designed.
2. Design implies a designer.
3. Therefore, a designer, God, must exist.

William Paley exposes the most influential version of this argument in his *Natural Theology*, which Darwin read and enjoyed. Paley introduces the famous analogy of a watch implying a watchmaker. In *Dialogues Concerning Natural Religion*, David Hume's character Cleanthes defends a version of the Argument from Design: "The curious adapting of means to ends, throughout all nature, resembles, exactly, though it much exceeds, the productions of human contrivance – of human design, thought, wisdom and intelligence. Since therefore the effects resemble each other, we are led to infer, by all rules of analogy, that the causes also resemble, and that the Author of Nature is somewhat similar to the mind of man, though possessed of much larger faculties, proportioned to the grandeur of the work which he has executed. By this argument *a posteriori*, and by this argument alone, do we prove at once the existence of a Deity and his similarity to human mind and intelligence."⁶ Hume's skeptic character Philo gives many counter-arguments to the Argument from Design, ranging from the problem of infinite regress (who designed God?) to the possibility of order and design emerging from chaos. At the end, though, Philo agrees with Cleanthes, because he cannot taken his own objections seriously: "What can the most inquisitive, contemplative, and religious man do more than give a plain,

⁶ Hume, David. *Dialogues Concerning Natural Religion* (1779). London: Penguin Classics, 1990. (p. 53)

philosophical assent to the proposition, as often as it occurs; and believe, that the arguments, on which it is established, exceed the objections, which lie against it?”⁷

Darwin’s theory of evolution provides a strong objection to the Argument from Design by convincingly showing how organisms seemingly adapted to their environment can emerge from a mindless evolutionary process through the principles of descent with modification and natural selection. Darwin showed that design, though it needs an explication, doesn’t imply a designer.

In his *Essay Concerning Human Understanding*, Locke wanted to prove *a priori* the primacy of Mind, which is essentially what the Argument from Design aims to infer *a posteriori*. Philo, in his final concessions, acknowledges as a legitimate conclusion: “if we are not contended with calling the first and supreme cause a GOD or DEITY, but desire to vary the expression; what can we call him but MIND or THOUGHT, to which he is justly supposed to bear a considerable resemblance?”⁸ Locke asks: “If, then, there must be something eternal, let us see what sort of Being it must be. And to that it is very obvious to Reason, that it must necessarily be a cogitative Being.”⁹ Locke’s summarizes his proof as follow: “So if we will suppose nothing first, or eternal: Matter can never begin to be: If we suppose bare Matter, without Motion: Motion can never begin to be: If we suppose only Matter and Motion first, or eternal: Thought can never begin to be. For it is impossible to conceive that Matter either with or without Motion could have originally in

⁷ Hume. (p. 138)

⁸ Hume. (p. 128)

⁹ Locke, John. *Essay Concerning Human Understanding* (1690). (Book IV, Chapter x, §10)

and from itself Sense, Perception, and Knowledge, as is evident from hence, that then Sense, Perception, and Knowledge must be a property eternally inseparable from Matter and every particle of it.”¹⁰ Darwin’s theory inverts the standard way of thinking. In the standard way, mind comes first, and designs are effects of mind. In Darwin’s theory, minds are a recent outcome of evolution. A contemporary reviewer attacked Darwin’s theory precisely for “this strange inversion of reasoning”: “In the theory with which we have to deal, Absolute Ignorance is the artificer; so that we may enunciate as the fundamental principle of the whole system, that, IN ORDER TO MAKE A PERFECT AND BEAUTIFUL MACHINE, IT IS NOT REQUISITE TO KNOW HOW TO MAKE IT. This proposition will be found, on careful examination, to express, in condensed form, the essential purport of the Theory, and to express in a few words all Mr. Darwin’s meaning; who, by a strange inversion of reasoning, seems to think Absolute Ignorance fully qualified to take the place of Absolute Wisdom in all the achievements of creative skill.”¹¹

Today, the debate on Mind continues in the realm of the machines: can machines ever be “truly” intelligent or conscious? In a way, the Tree of Life shows that the answer is trivially yes, since we, humans, are proof that intelligence and consciousness can evolve from a mindless process. As Richard Dawkins puts it, we are “survival machines – robot

¹⁰ Locke. (Book IV, Chapter x, §10)

¹¹ MacKenzie, Robert Beverley, 1868, *The Darwinian Theory of the Transmutation of Species Examined* (published anonymously “By a Graduate of the University of Cambridge”), London: Nisbet & Co. Quoted in a review, *Athenaeum*, no 2102, Feb 8, p217.

vehicles blindly programmed to preserve the selfish molecules known as genes”¹². Less trivially, the proponents of strong Artificial Intelligence (AI) believe that intelligence and consciousness could arise in sufficiently complex computational systems. This is a heated and fascinating debate, beyond the scope of this essay, with proponents and opponents of strong AI equally persuaded of their position. For now, I would modestly like to point out a parallel between the Tree of Life as the shape of Darwin’s evolutionary process and trees as the typical shape of AI search algorithms. This parallel is not a coincidence, because Darwin’s evolutionary process can be cast in the mould of a generate-and-test AI algorithm: starting with a population, generate variations, select individuals according to some fitness function and iterate. In practice, it usually tricky to design a good fitness function, not surprisingly given the complex role of natural selection in evolution.

In conclusion, Darwin’s Tree of Life helps in conceptualizing the complexities not only of the Darwin’s theory itself but also of its revolutionary implications. The Tree of Life illustrates how the mindless little steps of evolution accumulate to create a seemingly magical adaptation of means to an end, the hallmark of design. Before Darwin described the mechanism by which design could emerge from mindless steps, many philosophical ideas were inconceivable. For example, Locke’s “proof” of the primacy of Mind stems from his impossibility of conceiving how mind could emerge from matter. By including man in the Tree of Life, Darwin gives the beginning of an answer – or rather the crux of an answer, growing in details over the next century and a half. For example, Darwin

¹² Dawkins, Richard. *The Selfish Gene* (1976). New York: Oxford University Press, 1989. (p. vii)

treated the mechanism of modification with descent as a black-box. Perhaps more telling, in his diagram, Darwin starts in the middle, showing how new species and groups can evolve from a set of existing species. He cautiously speculates that these species might themselves have evolved from a common ancestor, until the beginning of life. Today, scientists are still speculating on the origin of life, speculating on how a molecule gained the remarkable capability of producing copies of itself, thus triggering an increasingly and irregularly complex “struggle for life and survival of the fittest”.