

Fact of evolution accounts for much: Why anti-evolutionism is fundamentally an attack on all of science

Graham Mark

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A number of anti-evolution letters have recently appeared in the Monitor. These letters should not go unanswered. Anti-evolutionism is fundamentally an attack on all of science, not just on evolutionary biology. Science rests on the proposition that the best way to understand the physical world is to assume that it operates according to mechanistic, natural, observable, and uniform principles. Anti-evolutionists reject that proposition.

Anti-evolutionism rests on misunderstanding and fear that will, if unchallenged, erode public confidence in science. It will weaken the school's efforts to promote scientific literacy. Lowering the level of scientific activity in this country will eventually lower our standard of living. If religious groups are able to degrade science, we must wonder about their ability to degrade our civil liberties.

Consider the words that John Baumgardner used in his letter of Feb. 23. He described evolutionary theory as fraudulent, dishonest, deceitful, "one of the most outrageous hoaxes ever perpetrated on the human race." He evidently believes that evolutionary biologists have conspired to deceive the world.

This belief would be laughable if it did not reveal tremendous misunderstanding. Evolutionary biology, like other scientific disciplines, requires open discussion, criticism, and debate. Its publications are publicly available. It is an international science. Evolutionary biologists are heterogeneous in politics, culture, ethnic background, nationality, language, and religious persuasion. To imagine that this diverse group has, for the past 140 years, secretly conspired to defraud the world is to imagine the impossible.

Anti-evolutionists fear evolution because they believe it is evil. In their minds, evolution is irreconcilable with belief in a supreme creator. In their minds, evolution is incompatible with the existence of transcendent ethical values. In their minds, the science of evolution rests on morally impoverished and corrupt metaphysics. Thus, although anti-evolutionists usually frame their attacks on evolution in technical terms their real objections are not technical. Their fundamental objections, and the roots of their fears, are religious.

This being the case, answering their technical objections is not likely to convince them of the errors of their ways. Pointing out that their objections lack technical merit may, however, help other people understand the issues. This letter is offered for that purpose. The following is necessarily an impressionistic outline rather than a complete development. For a fuller discussion with documentation, I suggest the book *Science on Trial* by Douglas J. Futuyma.

It is important to distinguish the theory of evolution from the fact of evolution. Just as the theory of gravity is different from the fact that massive bodies attract each other, so the theory of evolution is distinct from the fact that evolution has occurred. The best evidence of this fact is the fossil record.

The fossil record is not a random mixture of the relics of organisms. It is instead a temporally ordered sequence. In this sequence, particular assemblages of fossils that is, the remains of particular sets of organisms occur only at particular and unique times. There are no mammals, for example, in Cambrian fossils. Many of these fossil assemblages occur at locations widely separated over the planet, indicating that the corresponding assemblages of organisms lived at particular times across the world.

Ages of fossils can be established by stratigraphic and by radiometric means. The oldest known fossils, of "simple" single celled organisms, are well over 3 billion years old. No fossils of nucleated cells have been found with age of more than about 2 billion years. Progressively more recent fossils are larger, more complex, and more diverse. By the beginning of the Cambrian, about 570 million years ago, representatives of many modern phyla existed. The record since that time shows the appearance of new groups, which typically resemble preceding groups with modifications. As the age of fossil assemblages approaches zero, the fraction of fossils that resemble modern organisms increases. The record shows that well over 99 per cent of all species that have ever lived are now extinct.

The fossil record thus shows that the kinds of organisms living on the planet have changed over time. Further, the kinds of organisms that lived at any particular time were modified models of organisms of earlier times. Evolution is the only scientifically plausible interpretation of these facts. This interpretation is so firmly supported by the fossil record that it is regarded as scientific fact. (Like any empirical "fact," this one consists of interpretation of observations.) The fact of evolution is not scientifically in question.

The fact of evolution accounts for a huge variety of seemingly unrelated phenomena in addition to features of the fossil record: vestigial organs; taxonomic hierarchies; past and present distributions of organisms; the universality of the genetic code; structures in embryonic development; ecological vicars; the universality of basic physiological processes like the Krebs cycle this list could go on for pages. As the great geneticist Theodosius Dobzhansky said, "Nothing in biology makes sense except in the light of evolution ."

The theory of evolution by natural selection provides a mechanism that explains the fact of evolution. According to the theory, all organisms live in a constant struggle for existence. Each adult on the average produces many more than one offspring, but in a stable population each adult is replaced in the next generation by exactly one adult. (The theory applies also to unstable populations; the stable case is used here for simplicity.) Variations among the offspring will cause variations among the offspring's success in survival and reproduction. To the degree that these variations are inherited, variations that contribute to success will increase in frequency from one generation to the next, and variations that reduce success will decrease in frequency. This is natural selection.

The theory holds that mutations, which are the source of inherited variations, occur at random with respect to natural selection. This means that mutations are not guided by any plan, they do not occur in response to selective pressure, and they are not associated with phenotypic traits that the parents acquired during their lifetimes.

According to the theory, adaptation to a particular environment is a common result of natural selection. It is not the only possibility, however. Sexual selection, for example, is a form of natural selection that results in nonadaptive or maladaptive traits, like the male peacock's tail.

This is the theory as Darwin proposed it. The so-called "modern synthesis" or "neo-Darwinism" is Darwin's theory extended and clarified by the inclusion of modern genetics, systematics, and paleontology. Current theory also recognizes that evolution can sometime occur in the absence of selection. Genetic drift in populations, caused by sampling effects, is one example of non-selective evolution. Accumulation of apparently innocuous mutations in DNA -- the so called "neutral theory" -- is another. These refinements, while significant, in no way challenge the central theoretical importance of natural selection.

The modern synthesis has been accepted by virtually all biologists since its formulation, more than 50 years ago. It is accepted because of its strong empirical support, its wide applicability, its utility in guiding research, and its power in rationalizing observations. Of all scientific theories ever devised, neo-Darwinism is among the most successful.

Mr. Baumgardner raises the following technical objections to evolutionary theory: the earth is too young to have allowed evolution to occur as the theory describes it; the theory is unable to account for macroevolution; the fossil record does not show gradual change from one species to another, as the theory requires; complex information systems like bacterial genomes could not have arisen spontaneously, nor could they have evolved by neo-Darwinism mechanisms; catastrophes were more common in the geological past than has been recognized. With the possible exception of the last, these are standard creationist objections. (I fail to understand the relevance of the last one, but I suspect that it has to do with the Noachian Flood.) Let us consider Mr. Baumgardner's other claims.

There is no serious debate among experts that the earth is at least 4.5 billion years old. Ibis age, which coincides well with estimated ages of other objects in the solar system, poses no problem to neo-Darwinism. Mr. Baumgardner claims that, if the world were really as old as that, the oceans would be much saltier than they are. This claim was first made in the last century, and it has been long refuted. Salt has been repeatedly removed from the oceans by the formation of salt deposits, which exist all over the planet. (A deposit in Texas, for example, is estimated to contain 2,500 cubic miles of salt.)

Mr. Baumgardner asserts that microevolution -- that is, changes in gene frequencies within populations -- cannot account for macroevolutionary events such as the appearance of new species. Since neo-Darwinism describes microevolutionary mechanics, it cannot, says Mr. Baumgardner, account for the appearance of new species.

There is a great deal of evidence to show that Mr. Baumgardner is mistaken. Modern theories of speciation rest largely on the work of Ernst Mayr. Mayr proposed the "biological species" concept, which underlies the usual definition of species: a species is a group of organisms with a common gene pool. This implies that members of different species do not successfully interbreed; species are genetically isolated from each other. The formation of a new species thus requires the development of reproductive isolating mechanisms.

Mayr proposed that the most common origin of reproductive isolation is geographic isolation. If part of a species becomes geographically cut off from the rest, microevolution will occur independently in each group and cause them to diverge. This divergence may become sufficient over time to bring about reproductive isolation if the two populations eventually reestablish contact.

Mayr developed his theory on the basis of extensive field studies of living populations. He found numerous examples of geographically isolated populations that had undergone various degrees of microevolutionary divergence from the parental population. Such examples are particularly common on islands, where small populations, founded by chance colonization, are effectively cut off from the mainland population. Mayr also documented many examples of various stages of the development of reproductive isolation. Microevolution is thus entirely adequate to constitute the genetic basis of speciation. This conclusion, to repeat, rests neither on theory nor on fossils, but on field observations of living populations.

Direct genetic measurements give further evidence that microevolution is sufficient to cause macroevolution. The genetic variation that exists within a species is not qualitatively different from the variation that exists between related species. This indicates that the process that generates genetic variation within species that is, microevolution is the same as the process that generates genetic variation between species.

Mr. Baumgardner says that evolutionists resort to "major handwaving" when they attempt to account for macroevolution. He proceeds to quote some vigorous anti-Darwinian handwaving by a professor of linguistics at MIT. This professor, according to Mr. Baumgardner, claimed that, in a formal language like the genetic code, meaning is "almost invariably" destroyed by random changes. The professor concluded that random mutation could never generate adaptively useful genetic change.

Given the proper equipment and training, it is easy to demonstrate empirically that the professor's conclusion is incorrect. Begin with a genetically uniform, insecticide sensitive population of fruit flies and split it into some number of subpopulations. Maintain each subpopulation separately for 10 generations in an environment that contains a low level of DDT. At the end of that time, most subpopulations will have evolved some degree of resistance to DDT. This resistance will have a genetic basis. The physiological mechanism of resistance will be different in each subpopulation.

This result shows that at least one resistance-conferring mutation took place in each resistant subpopulation. The fact that the mechanisms of resistance varied means that different mutations took place, and none of them was selectively deleterious. Once a resistance-conferring mutation occurred, it provided a selective advantage and its frequency in the population increased.

Experiments like this have been performed many times with consistent results. Some of these experiments have shown further that mutations occur at random with respect to the presence of insecticide. Besides demonstrating natural selection in action, these experiments show that random mutations are in fact not "almost invariably" fatal. It turns out that some mutations are highly deleterious or fatal in a given environment; some are highly beneficial; some are intermediate; and some have very little detectable effect, or none at all.

Mr. Baumgardner's claim regarding the absence of intermediate forms in the fossil record is based on ignorance of the fossil record and on misunderstanding of neo-Darwinism. A great many intermediate fossils have in fact been found. (Three examples of reasonably complete sequences that each contain numerous intermediates: the hominid lineage; the reptile to mammal lineage; and the bacitrid to ammonoid lineage.) Current theories of species formation -- Mayr's theory, and the fashionable "punctuated equilibrium" model derived from it, for instance -- indicate that speciation is highly unlikely to be shown in fossils. These theories state that speciation usually occurs rapidly (in geological time) and in small peripheral populations. The speciating population's smallness, both numerical and geographical, together with the rapidity of the event -- perhaps as fast as a few hundred generations -- mean that the likelihood of fossilization is very small, as is the likelihood of the fossils being discovered.

Mr. Baumgardner is surely correct in saying that even a "primitive" bacterial genome has never sprung fully formed from an abiotic environment. No evolutionary biologist would claim that it has. Mr. Baumgardner evidently fails to realize that the central thrust of evolutionary theory is precisely to explain how such a complex object could naturally

come into existence. He seems not to understand that evolutionary theory provides a plausible, mechanistic explanation of how bacterial genomes (and all other genomes) have come to be: neither by spontaneous generation nor by miraculous creation, but through evolution by natural selection.

The origin of life is not, strictly speaking, part of evolutionary biology, but it is a closely related issue. It is well known that numerous kinds of organic compounds form easily in conditions thought to resemble those of the pre-biotic earth. Although no detailed and definite pathway of biogenesis has been generally accepted by people in the field, there is no scientific reason to reject the hypothesis that life originated through natural and repeatable biochemical processes.

Despite the success of neo-Darwinism, it is important to remember that science, unlike revealed religion, does not provide absolute truth. Scientific understanding is inherently tentative and incomplete. Even well established theories must always remain open to criticism and change. It should therefore be no surprise that various facets of neo-Darwinism have been and continue to be openly questioned and debated by evolutionary biologists. Anti-evolutionists point to these debates and claim that they show the decay or death of evolutionary theory. In reality, of course, they indicate an active and dynamic science. They are also proof, incidentally, that evolutionary theory is not the product of a conspiracy.

Suppose for a moment that neo-Darwinism could be convincingly refuted. A scientist would respond by attempting to devise an alternative theory to account for the fact of evolution. To be scientifically useful, the alternative theory would have to rely on explanations based on natural, mechanistic causes, and it would have to be open to disproof by empirical means. It would also have to rely on the assumption, subject to contrary evidence, that physical laws were the same in the past as they are now. Scientifically acceptable alternatives could not include accounts that, like the Book of Genesis, rely on miracles.