

Evolution As Opinion Versus Fact: A False Dichotomy With True Consequences

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ABSTRACT

Evolution is fundamental to the understanding and contextualization of all of the life sciences. However, widespread public confusion and denial surround evolutionary theory. To better illuminate some of the issues concerning evolutionary misinformation, an abbreviated review of the fundamentals of modern evolutionary theory, a discussion and clarification of prevalent misconceptions therein, and a prominent case study highlighting the importance of basic understanding of evolution are provided. The information here may serve as an introductory piece prior to lectures on the subject of evolution and/or its relation to society.

KEYWORDS

Evolution, Education, Misconceptions, Belief, MRSA

"Nothing in Biology Makes Sense Except in the Light of Evolution" (Dobzhansky, 1973). The famous statement by the late geneticist Theodosius Dobzhansky has become so commonplace in evolutionary biological circles to the point of nearing cliché. And for good reason - it is true. Evolution ultimately underlies all life science concepts and has the potential to unify all biological disciplines (Wilkins, 2000; Blackstone, 2009). However, despite evolution's influence on life science and medical fields, public perception of evolution is still turbulent. While public perception has improved over the years, a persistent minority of evolution deniers and the pervasive lack of understanding of the theory manifest themselves in wide-ranging consequences. Here, an abbreviated review of the fundamentals of modern evolutionary theory, prevalent misconceptions regarding evolution, and a prominent case study highlighting the importance of basic understanding of evolution is provided.

WHAT IS EVOLUTION: BARE-BONES ESSENTIALS

The basic premise of neo-Darwinian (modern) evolution is a simple concept readily intellectually comprehensible to the vast majority of individuals with a basic genetics background. Prior to the discovery of genes as the fundamental unit of heredity,

Charles Darwin himself noted that evolution involved heritable variation. Knowing now that genes are indeed the basic unit of heredity, evolution can be defined as the change in allele frequency in a population over time (e.g. Kutschera and Niklas (2004); an allele is a variant form of some gene; see Wilkins (2001) for a more in-depth discussion of the definition and history of the term evolution). The definition tells us that frequencies of alleles will change through time from Generation A, to B, to C, and so on rather than remaining absolutely constant. We as humans, for instance, are not all clones of one another, as a result of genetic change over time through various mechanisms. The mechanisms influencing evolution include: selection (the cross-generational propagation of beneficial alleles at rates greater than neutral or deleterious alleles), genetic drift (stochastic fluctuations in allele frequency), mutation (changing of gene structure), migration (that is, gene flow, or movement of individuals between populations), and non-random mating (selective mating among individuals of a population) (Kimura and Ohta, 1974; Reece et al., 2011, Wilkins, 2000).

Evolution is sometimes divided into *microevolution* and *macroevolution*. The former implies minor allelic change on short time scales, whereas the latter entails significant allelic change over greater time scales, sometimes manifest in hierarchical taxonomic splitting (Hendry and Kinnison, 2001). Unless specified, the term evolution refers to *microevolution* which, over time, can lead to macroevolution. For a more in-depth review of evolution and evolutionary mechanisms, see Kutschera and Niklas (2004). Most widely used university-level biology textbooks are also appropriate sources of information on basic principles of evolutionary biology.

PUBLIC UNDERSTANDING AND MISCONCEPTIONS

Evolution is empirically evident in many forms, including an extensive fossil record, observational studies, manipulative studies, comparative anatomy and physiology, and developmental biology, among others (e.g. Dawkins, 2009). To roughly quantify the body of scientific support for evolution upon writing this review, a Google Scholar search of the phrase "evidence for evolution" yields 1.82 million results in the scientific literature. Mirroring this figure, a 2014 Pew Research poll of scientists affiliated with the American Association for the Advancement of Science found that 98% of those surveyed accept evolution (Pew Research Center, 2014).

Despite the overwhelming scientific consensus on evolution, public perception of the topic is lagging. From the same 2014 survey, this time directed at American adults, only 35% accepted evolution driven by natural processes (Pew Research Center, 2014). Some 24% of those surveyed maintained the notion that evolution is occurring but is being guided by a supernatural being or god, a

perception firmly rooted in scientific misunderstanding (Pew Research Center, 2014). Additional national and international surveys have yielded similar results (see Garvey (2008) for commentary). Other cultures (many in Latin America, for example) are often less accepting of evolution (e.g. Pew Research Center, 2014). Even more startling is the view of evolution by science teachers. For instance, Rutledge and Mitchell (2002) found that 19% of Indiana high school biology teachers rejected evolution and 27% were undecided on its validity. Of those surveyed, only 43% avoided or only peripherally mentioned evolution in the classroom. Even those that accept evolutionary theory often harbor misconceptions, with 60% of high school biology teachers having a less than exceptional understanding of the topic (Berkman and Plutzer, 2011), almost certainly perpetuating students' own misconceptions. The same study reports that 13% of teachers present creationism as an alternative to evolutionary theory (Berman and Plutzer, 2011). Additionally, these patterns largely transcend national borders to varying degrees (e.g. Papadopoulou et al., 2011; Coleman et al., 2015). Excluding religious objections (see Scott (2000), Wilkins (2006), and Berkman and Plutzer (2011) for discussion on this topic), these statistics highlight several pervasive misconceptions of basic evolutionary theory. A partial list of some of the more common and influential misunderstandings surrounding evolution are briefly discussed:

1. *Evolution is "just a theory"*: Scientific theory is vastly different than the colloquial use of the word. Unlike the use of theory in laymen speech to mean conjecture or speculation, a scientific theory denotes a well substantiated explanation of some aspect of the natural world that incorporates facts, laws, inferences, and tested hypotheses (e.g. National Academy of Sciences, 2008). Additionally, a theory does not transform from a hypothesis or into a law depending on amount of evidence; all three are distinct scientific terms. Some additional theories include Cell Theory, Germ Theory, Theory of Special Relativity, and the Theory of Gravity. Indeed, just like gravitation, evolution is a fact (it is true) and a theory (it is explainable).
2. *Evolution is improvement*: Evolution is not goal-oriented. The process does not necessitate improvement and is not synonymous with "survival of the fittest". A change in allele frequency in a population over time (that is, evolution) may be functionally adaptive, maladaptive, or neutral. Indeed, there is no end to evolution (barring a population's extirpation).
3. *Evolution is the mechanism*: Evolution is a process and not in itself a mechanism. The mechanisms that govern evolution of a population include selection, genetic drift, mutation, migration, and non-random mating.

4. *Evolution is a linear process*: Evolution is in fact a branching process, mapped in phylogenetic trees (see Baum and Smith (2013) for an introduction to phylogenetics). Just as your family tree is branching (hence "tree"), so is the evolutionary tree of life (Figure 1). For example, humans *Homo sapiens* did not descend from chimpanzees (*Pan spp.*), but rather from a common ancestor of the two taxa between 4 and 6.3 million years ago (Patterson et al., 2006).

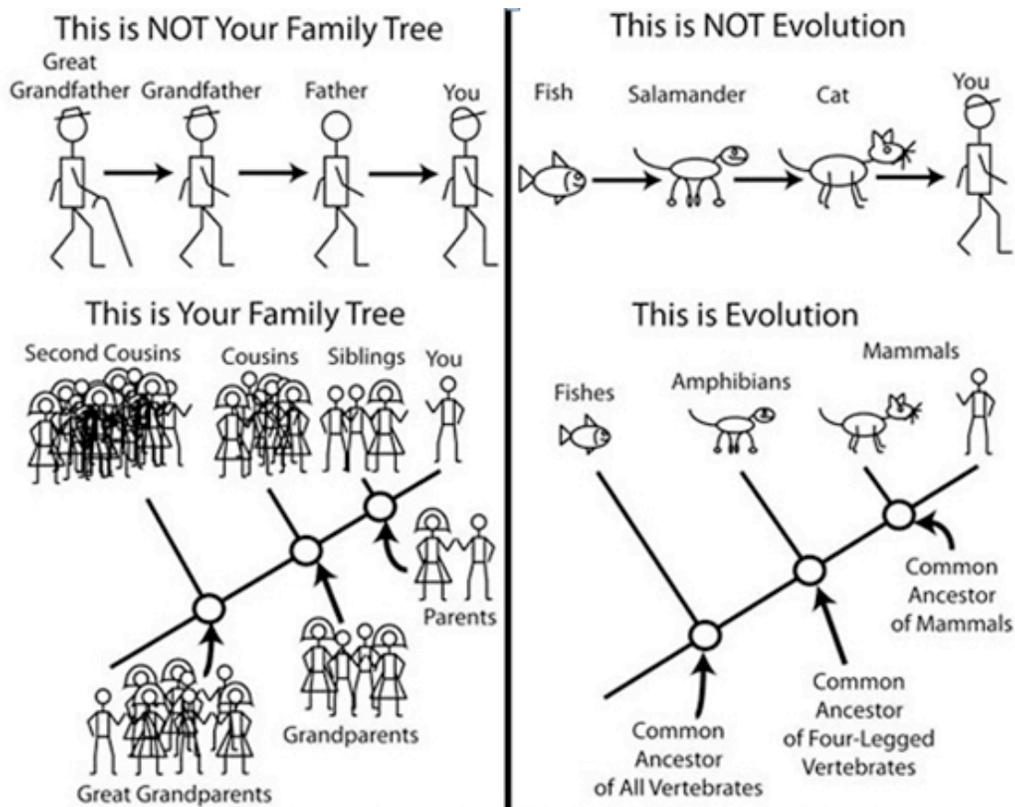


Figure 1: Evolution (right) is analogous to a family tree (left) in that it is a branching rather than a linear process. Image used with kind permission of the artist, Dr. Matthew Bonnan.

5. *Evolution is a belief, much like special creation*: Evolution is neither an opinion nor a belief, but rather an observable fact backed by substantial evidence. As with other scientific phenomenon, it is to be accepted or rejected based on available evidence. For this reason, it is completely independent of special creation, which seeks to explain dynamics of life through supernatural, non-testable ideologies. Therefore, comparing the two is non-productive.

6. *Evolution is speciation*: Speciation, or the splitting of a clade resulting in new species, is one of many possible outcomes of evolution, but certainly not the only

one. Evolution is generally considered to occur on the level of populations, not at the levels of genes, individuals, species, and so on (however, see Stanley (1975) and Wilkins (2001) for discussion of the potential for evolution on other hierarchical levels).

7. *Evolution explains the origin of life*: Evolutionary theory does not seek to explain the origin of life on earth, but rather how life changes over time. While evolution is intimately intertwined with the origin of new species, subspecies, and populations, and is certainly informative to the study of the origin of life on earth, it is in itself independent of any explanation of life's origins.

Case Study: MRSA

Why should it matter that evolution is so widely misunderstood or written off as a hand-waving opinion? While science and society face many consequences of denial and misunderstanding of evolution (Enright et al., 2002), the rise of antibiotic resistant bacteria is one of the best characterized (Brooks et al., 2008; Davies and Davies, 2010).

Methicillin-resistant *Staphylococcus aureus*, or MRSA, consists of gram-positive strains of *Staphylococcus aureus* that are resistant to a wide array of antibiotics (Enright et al., 2002). Historically, with the advent of readily available penicillin and other antibiotics in the 1940s, *Staphylococcus* bacteria were readily treatable with appropriate antibiotic use (Schentag, et al., 1998; Davies and Davies, 2010). However, by the 1980s, increased rates of resistance became evident in large hospitals and, later on, in smaller hospitals and clinics (Schentag et al., 1998). The bacteria are not more virulent *per se*, but are less treatable than their non-resistant counterparts. In fact, from 1999 to 2005, the estimated number of MRSA related hospitalizations in the United States more than doubled, from 127,036 to 278,203, with approximately 5,500 deaths per year (Klein et al., 2007).

What caused the rampant increase in MRSA? Resistant strains of this pathogenic bacterium have evolved via selective pressure of antibiotic use (Enright et al., 2002). The vast majority of bacteria that were susceptible to antibiotics perished upon treatment while those that were resistant survived. Over time, the resistant phenotypes become common due to their advantage over non-resistant phenotypes, rendering the antibiotic useless for the pathogen. Much of the blame has been placed solely on medical practitioners, but in reality antibiotics are overused and misused in both human and veterinary medicine, farming (as growth promoters), aquaculture, and agriculture, with little regard to evolutionary consequences (Hart, 1998).

Fortunately, we can learn from our collective mistakes. Antibiotic resistance is inevitable through selective pressures applied by the prescription of antibiotics (Pray, 2008). However, the rate at which resistance evolves in different bacteria can be greatly reduced. By prescribing antibiotics more effectively (e.g. selecting the appropriate antibiotic per infection, not prescribing antibiotics for viral infections, completing antibiotic regimens, et cetera), the growing threat of antibiotic resistant pathogens can be greatly slowed. Responsible antibiotic use can buy time for developing alternative approaches, such as the development of novel vaccines.

CONCLUSION

It is evident that there is a persistent disconnect between scientific knowledge and public understanding. The discussion of evolution provided here is largely symptomatic of this gap between the scientific community and the general public across scientific topics (e.g. global climate change, see Weber et al, 2011). However, the state of scientific understanding seems to be improving. For example, in 1982, 9% of Americans accepted natural evolutionary origins of humans; the figure steadily rose to 19% in 2014 and continues to do so (with distinct trends according to religious and political affiliations; Gallup Poll, 2014).

Despite this positive trend, public scientific literacy could and should be higher. Political debate persists on all levels, largely revolving around the relative merits of creationism versus evolution in the science classroom, despite the mountain of evidence in favor of the latter. The quality and quantity teaching of evolution in schools is a priority, particularly in the face of religious antagonism in the science classroom (see Berkman and Plutzer (2011) for commentary). After all, evolution is not a belief system. Evolution is a process that occurs in natural systems regardless of one's opinion. Ultimately, then, it is best to take advantage of that fact by encouraging evolutionary understanding in and out of the classroom, even if only for mankind's sake.

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