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Thirteen Misunderstandings About Natural Selection

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Introduction

The theory of evolution by natural selection is the unifying paradigm of biology and indeed of all the life sciences – it explains and integrates a huge diversity of known findings and predicts an astonishing number of new ones (Alcock 2009; Coyne 2009). It has been famously suggested that nothing in biology makes sense except in the light of evolution (Dobzhansky 1973). Prominent philosopher Daniel Dennett has said "If I were to give an award for the single best idea anyone ever had, I'd give it to Darwin, ahead of even Newton and Einstein and everyone else" (Dennett 1996, p. 21). Indeed, scientists, historians of science, and philosophers of science generally regard evolutionary theory as one of the most predictively powerful and explanatorily successful theories in the history of science (Alcock 2009; Coyne 2009; Dawkins 2009; Dennett 1996).

And yet, despite the simplicity of the core idea and its universal acceptance in the scientific community (e.g., Pew Research Center 2015), misunderstandings regarding natural selection abound. Such misconceptions even appear in college textbooks and among students who have taken college-level evolutionary biology courses (Alters and Nelson 2002; Gregory 2009; Nehm and Reilly 2007; Nehm et al. 2008; Winegard et al. 2014). A review of ten textbooks in social psychology revealed at least one factual error about inclusive fitness theory in *each*, and typically two to three (Park 2007). In this entry, we briefly identify and dispel 13 of the most pervasive misunderstandings of evolutionary theory.

Misunderstanding 1: Natural Selection Is a Random, Chance-Driven Process

Probably the most pervasive misunderstanding about natural selection is that it is a chance process.

In simplified form, evolution takes place in two steps: mutation and natural selection (in reality, the process is more complicated than this). In the first step, random genetic mutations arise. These mutations may turn out to be beneficial, detrimental, or neutral. This step is random, involves no foresight, and does not take into account what the organism "needs" or would benefit from. Indeed, more mutations turn out to be detrimental than beneficial. In the second step, mutations with

T. K. Shackelford, V.A. Weekes-Shackelford (eds.), *Encyclopedia of Evolutionary Psychological Science*,
https://doi.org/10.1007/978-3-319-16999-6_2158-1

harmful effects on reproduction are filtered out by natural selection, which acts like a sieve (Dawkins 1982). By contrast, those that have beneficial effects on reproduction are more likely to be passed on and increase in frequency over time.

This second step is quintessentially *nonrandom*: some mutations make it past natural selection's filter precisely because they are beneficial, and others fail to make it past the filter precisely because they are harmful. This is the opposite of randomness: it is an orderly and predictable process in which there is a logical connection between the effect a mutation has and its likelihood of making it past the filter of natural selection. By contrast, a random process would be unpredictable and would have no systematic connection between the effects of a mutation and its likelihood of making it into the next generation.

The problem seems to be that people sometimes confuse mutation (which is random) with natural selection (which is not random). To make matters worse, they may conflate one or both of these processes with evolution, which is the *outcome* of these processes (see Misunderstanding #11 for more detail on the distinction between evolution and natural selection).

To avoid these errors, it helps to remember that natural selection is the *nonrandom sorting of randomly mutated genes*. Finally, because natural selection is not random, the process it drives – evolution – is also not random.

The misunderstanding that natural selection is a chance process is particularly pernicious because of its downstream effects. It is nearly impossible that a random, chance-driven process could explain the complexity, utility, and apparent purposiveness of the adaptations we see in the biological world. As a result, falling into the erroneous belief that natural selection is a random process might lead some people to reject evolution altogether on the basis of a conceptual mistake.

Misunderstanding 2: Natural Selection Is Primarily About Survival

It is common to think of natural selection as being primarily about survival, but in truth, it is primarily about reproduction. *Differential reproductive success* – not survival – is the driving engine and the "bottom line" of evolution. It is possible to illustrate this point using both logic and empirical evidence.

To illustrate the point logically, imagine two genes, each of which has two distinct effects (these are called "pleiotropic effects"). Gene A leads the animal in which it resides to live to be 100 years old, but makes it infertile. Gene B leads the animal in which it resides to die at 25 years old, but after having had several offspring. Which gene will have greater representation in the next generation? The answer is that gene B will be well represented, whereas gene A will be entirely absent. This thought experiment helps to demonstrate that when the two conflict, reproduction trumps survival.

It is also possible to illustrate empirically that when survival and reproduction conflict, survival takes the backseat. Examples abound. The peacock's tail is a massive burden to survival but is crucial in seducing peahens (Darwin 1871; Cronin 1993). Human testosterone is a powerful immunosuppressant but human females are attracted to testosterone-dependent traits such as a strong jawline and a high shoulder-to-hip ratio (Buss 2015; Al-Shawaf & Lewis 2018). Male redback spiders willingly offer themselves to their mates for cannibalization – they die, but in doing so, they double their paternity relative to noncannibalized males (Andrade 1996, 2003).

In other words, when it comes to evolution, reproduction is more important than survival. Many species take this to an extreme, living only long enough to reproduce and then dying immediately thereafter. This is so common in nature that the phenomenon has a recognized name – *semelparity* – and examples of species that do it range from desert agave plants to butterflies to bamboo plants to Pacific salmon (Quammen 1985). Perhaps even more morbid are those species that successfully reproduce – only to be promptly devoured by their offspring. The matricidal gall midge *Miastor* does this, producing larvae that eat it alive from the inside out (Quammen 1985). The key point is that in evolution, survival is important only insofar as it eventually leads to reproduction. Both logical thought experiments and an abundance of empirical examples illustrate that when survival and reproduction conflict, it is invariably reproduction that wins (Alcock 2009; Dawkins 1976; Hamilton 1964; Williams 1966).

Misunderstanding 3: "Natural Selection" Refers to an Agent That Actively "Selects" the Best Organisms for the Next Generation

"Natural selection" is an unfortunate misnomer. It gives the impression that some kind of causal agent is actively "selecting" traits for inclusion in the next generation. Nothing could be further from the truth: there is no agent and there is no selection. Stated differently, there is no guiding hand in the process of natural selection – the process is blind, mechanistic, and passive.

"Differential reproductive success by virtue of heritable differences in design" is a much more accurate description of the process: some organisms reproduce more than others, and this simple fact is the key driver of evolution by natural selection. But because "differential reproductive success" is a mouthful, scientists and laypeople alike often use "natural selection" as shorthand. That is perfectly fine as far as it goes, but it is helpful to remember that this is just shorthand for a longer and more cumbersome phrase.

In sum, "differential reproductive success" is a little wordy, but it is more accurate in that it (a) describes what is actually occurring, (b) does not suggest the presence of a hidden causal agent, and (c) does not misleadingly imply some form of active selection. It may therefore be beneficial for readers and writers to bear in mind that "natural selection" is a linguistic shorthand rather than a descriptively accurate term for the process that drives evolutionary change.

Misunderstanding 4: Natural Selection Is Teleological – It Is Working Toward a Goal or Final Purpose

Natural selection does not have a final goal or *telos*. It also has no foresight – in other words, it is impossible for natural selection to take into account future conditions. Though the products of selection can be beautiful and complex, the process itself is blind and mechanistic.

For example, if a certain species of mammal would benefit from evolving a slightly thicker coat of fur, this does not mean that natural selection will guide it toward that goal. First, a beneficial mutation must arise that contributes to said trait. This stage of the process is entirely random and is not affected by what the animal "needs" or would benefit from. In fact, harmful mutations are much more common than beneficial mutations (because there are many more ways to disrupt a functioning biological machine than to improve it). Second, if the new mutation happens to confer a survival or reproductive advantage, natural selection will favor it, and it will tend to increase in frequency as the generations pass. But it is impossible for natural selection to *anticipate future needs* and lead species toward a distant goal state, as natural selection cannot look ahead and does not have goals.

Nor does natural selection inevitably lead to "progress" in the sense of greater intelligence or greater complexity. A common misconception is to think of evolution as progressive – always improving or moving toward greater complexity. In reality, there is no predetermined direction to evolution. Natural selection can easily cause a species to lose complexity when the environment demands it (see e.g., Misunderstanding #6 and Al-Shawaf and Zreik 2017). For example, several species have slowly evolved to lose their sight after moving into pitch-black caves. Since sight is no longer useful in such an environment, natural selection led these species to lose their vision and channel the metabolic resources previously used for sight to other physiological needs such as immune function or cell repair.

Natural selection is a tinkerer, not an engineer (Jacob 1977). An engineer can look ahead to her final goal and implement changes that help her get closer to that final goal. She can also return to the drawing board any time she pleases to fix a mistake. By contrast, natural selection cannot look ahead, has no goal, and can only build adaptations based on the genetic variants already available in the population at the time. In short, natural selection has no *telos* or endgame.

Misunderstanding 5: Natural Selection Favors the Survival of The Species

One of the most common misconceptions about evolution is that natural selection favors the survival of the species. In reality, natural selection works primarily at the level of the gene and the individual bodies in which genes reside – not at the level of groups, subspecies, or species (Hamilton 1964; Williams 1966).

George Williams, one of the most important evolutionary biologists of the twentieth century, showed several decades ago that group selection is theoretically possible – but likely to be extremely rare in nature. For group selection to work, several preconditions must be in place – and these preconditions are themselves very rarely met in nature (Williams 1966). Recent years have witnessed a resurgence of interest in group selection (e.g., Wilson and Sober 1994; Henrich 2004), but most evolutionary biologists and psychologists agree on the following: (1) group selection is theoretically possible, but (2) genic-level and individual-level selection are considerably stronger than group-level selection, (3) there is no clear empirical evidence that group selection applies to humans, and (4) group selectionist thinking does not appear to have led to any testable new hypotheses (Delton et al. 2011; Krasnow et al. 2012, 2015, 2016; Krasnow and Delton 2012; Pinker 2012). By contrast, orthodox genic-level and individual-level selectionist thinking have led to many hundreds of testable hypotheses, which have in turn led to thousands of empirical studies. This suggests that, unlike genic-level and individual-level thinking, group selectionist thinking may not be especially generative or fruitful as a scientific theory (Alcock 2017).

An important sidenote is worth mentioning: even if group selection turns out to be more widespread in nature than we previously thought, it would still not be the case that adaptations evolve for the good of the *species*. Even dyed-in-the-wool group selectionists are primarily focused on small, local groups – not whole species. It is therefore incorrect, for example, to think we have sex “to perpetuate the species”. We have sex because we are the descendants of ancestors whose sex led to reproduction, and so we inherited their tendency for sexual motivation. An incidental side effect of this is that the species as a whole may sometimes benefit. Outcomes that are beneficial to groups can indeed occur, but they are not the proper biological function of adaptations, they are incidental side effects.

Misunderstanding 6: Natural Selection Builds Perfectly Designed Biological Mechanisms

There are several constraints that limit natural selection’s ability to craft optimally designed mechanisms. These include (a) time lags, (b) historical constraints, (c) constraints due to available genetic variation, (d) unavoidable trade-offs, (e) imperfections at one level due to selection at a different level, (f) mistakes due to environmental unpredictability, and (g) antagonistic pleiotropy (Al-Shawaf and Zreik 2017; Dawkins 1999). We highlight only three of these in this entry: time lags, historical constraints, and unavoidable trade-offs (for a more thorough discussion, see Al-Shawaf and Zreik 2017).

Time lags refer to the fact that natural selection is a slow and gradual process. Animals are adapted to *past* environments, not current environments (Dawkins 1999). If the environment changes rapidly, natural selection may be too slow to catch up. For example, human taste preferences for fat, sugar, and calorie-dense foods were adaptive when food was scarce during the evolution of our species. By contrast, in today's world of cheap and ubiquitous fast food, these same taste preferences lead to obesity, type II diabetes, and cardiovascular diseases (Buss 2015). The environment has changed too quickly for the slow, cumulative process of evolution to catch up. Time lags have rendered our previously adaptive taste preferences maladaptive.

A second important constraint on natural selection comes from a species' *evolutionary history*. Once a species has evolved a certain nervous system or body plan, this constrains what it is capable of evolving next. Given their current body plan, it would be difficult or impossible for elephants to now begin to evolve wings, say, or an exoskeleton. Once a species finds itself on a certain evolutionary trajectory, this limits where it can go next. In other words, the phylogenetic background of a species affects what it is capable of evolving next – history constrains evolution.

Unavoidable trade-offs impose a third constraint on natural selection. Gazelles under predation pressure from wolves may evolve longer legs, enabling them to run faster and increasing their likelihood of escape. But longer leg bones are more brittle and more likely to break. The gazelles therefore face an unavoidable trade-off: longer, more gracile bones with enhanced capacity to flee but increased likelihood of breaking, or shorter, more robust bones with a lower likelihood of escape. The key point is that every adaptation comes with a cost, and this leads to unavoidable trade-offs. Trade-offs, in turn, make it impossible to optimize every parameter simultaneously.

These constraints, along with several others, make it impossible for natural selection to build perfectly designed biological mechanisms (see Al-Shawaf and Zreik 2017; Dawkins 1999, for an extended treatment of the constraints on natural selection). It is because of these constraints on natural selection that we are left with suboptimal designs such as the vertebrate eye (which has a blind spot) and the human esophagus and trachea (whose inelegant setup poses a serious choking hazard). Natural selection can build complex and functional mechanisms. It can even build mechanisms so sophisticated and impressive that engineers are studying them in an attempt to replicate their structure and function in artificial systems (e.g., the luminescence of fireflies, the sonar of bats, and the adhesive abilities of geckos; Bhushan 2009; Kim et al. 2012; Murr 2015). Nonetheless, despite these impressive feats, the constraints on natural selection limit its ability to craft truly optimal biological mechanisms.

Misunderstanding 7: Evolution Implies Genetic Determinism

One of the most widespread misunderstandings is that *evolution implies genetic determinism*. That is, many are under the impression that naturally selected behaviors or psychological mechanisms are genetically determined – that the claim "X is a product of natural selection" is equivalent to the claim "X is genetically determined." It is emphatically not.

First, evolution by natural selection is an environmentally driven process, and it would not exist at all without the environment. Adaptations (the products of natural selection) require environmental input at every stage of their emergence: (a) initial evolution, (b) ontogenetic development, and (c) immediate activation (Buss 1995). Stated differently, adaptations only evolve in the first place because of an environmental challenge, often referred to as an "adaptive problem" (Buss 1995; Tooby and Cosmides 1992). Subsequently, adaptations require environmental input for their proper development during an organism's lifespan. And finally, adaptations require environmental input for their immediate activation in the present. This means that the environment is crucial to every product of evolution at every stage of the evolutionary process.

The second problem with the idea that natural selection implies genetic determinism has to do with the fact that nothing is determined by genes or environment alone. Genes and environment, working together, jointly codetermine every aspect of an organism – from its ears to its personality. Neither genes nor environment is capable of doing this alone. After all, genes are like a recipe for making a body, and environmental input is like the raw ingredients. The ingredients alone are impotent, and the recipe alone is equally impotent (e.g., Dawkins 1976; Ridley 2003). As such, no credible scientist thinks the products of evolution are genetically determined, and the claim that a psychological mechanism is a product of natural selection is *not* in any way equivalent to the claim that it is genetically determined.

It might be worth adding here that the often-misunderstood concept of *heritability* (percentage of variance in a phenotypic trait due to genetics) does not refer to a single individual; it refers to how much of the *differences* between individuals are due to *differences* in their genes as opposed to *differences* in their environments. For example, if the personality trait of extraversion has a heritability of 60%, this does not mean that Bob's extraversion is 60% due to his genes and 40% due to his environment. Instead, it means that 60% of the *differences* between individuals in their extraversion is due to differences in their genes, and 40% is due to differences in their environments. For a single organism, every single trait is jointly codetermined by genes and environment. This even includes traits with 0% heritability or 100% heritability – there is simply no other way to build an organism. Stated differently, we must distinguish between two levels of analysis: the individual level (in which we are concerned with individual organisms) and the population level (in which we are concerned with the differences between organisms). Partitioning an outcome like height, IQ, or extraversion into percent due to genes and percent due to environment is meaningful at the population level of analysis but meaningless at the individual level of analysis. A quip by Donald Hebb illustrates this point well: when asked whether nature or nurture makes a greater contribution to personality, he replied, "Well, which contributes more to a rectangle's area – its length or its width?" (Meaney 2001).

In sum, there are two key points about the relationship between evolution, genes, and environment. First, environmental input is essential to the emergence and activation of all evolved mechanisms. Second, genes and environment jointly codetermine everything from an organism's morphology to its behavior. For both of these reasons, it is wrong to think that evolution bears any relationship to genetic determinism.

Misunderstanding 8: Adaptations Must Be Present at Birth (or Must Emerge Very Early in Life)

An odd but widespread assumption is that adaptations – the products of natural selection – must be present at birth or must emerge very early in life. Features not present early in life are automatically assumed to be "learned," not the product of natural selection. One key problem with this line of reasoning is that it mistakenly pits learning and evolution against each other as if they are competing explanations, when in fact they are not (for an extended discussion of the compatibility between learning and evolution, see e.g., Al-Shawaf et al. 2018; Lewis et al. 2017; Symons 1979; Tinbergen 1963). The other key problem is that there is simply no basis for the arbitrary assumption that the products of natural selection must be present at birth.

Teeth and breasts illustrate what is wrong with this principle: they are both adaptations *par excellence*, but they are not present at birth. Instead, they emerge at the appropriate developmental stage of the organism's life. Natural selection builds adaptations that emerge at the correct point in ontogenetic development, not adaptations that are necessarily present at the moment a baby is born. Teeth and breasts (and pubic hair and facial hair, etc.) emerge later, when they are needed, during the appropriate life stage. The same goes for walking and bipedalism: newborn infants cannot walk, but nobody doubts that bipedalism is a biological adaptation. Similarly, nobody doubts that flight or vision are exquisite biological adaptations, despite the fact that many newly hatched bird offspring can do neither.

In sum, adaptations – the products of natural selection – can "come online" during the prenatal phase, shortly after birth, or much later in life. There is no theoretically principled reason to stipulate that they must be present at birth. That is not how natural selection works – it works to produce adaptations that come online during the developmental phase in which they are needed, not ones that are present at a particular arbitrarily selected moment.

Misunderstanding 9: The Products of Evolved Mechanisms Are Fixed and Unchangeable

A key misconception is that if a certain behavior is the output of a mechanism built by natural selection, it is fixed and unchangeable. For example, people worry that if there is evidence of an evolutionary basis for aggression, warfare, or sexual infidelity, this somehow means that these undesirable outcomes are inevitable.

In reality, evolved mechanisms are flexible and their outcomes are rarely fixed. All evolved mechanisms require environmental input. Often, changing the input is enough to change the output. For example, all humans have callus-producing mechanisms in their hands. These evolved physiological mechanisms are designed to produce calluses in response to repeated friction of the skin. But this does not mean that the outcome – calluses – is unavoidable: simply remove the friction by wearing gloves, and these mechanisms will no longer produce calluses. By modifying the input, you have successfully changed the output (Buss 2015).

Behaviors produced by natural selection are no more fixed or set in stone than calluses. Indeed, evolved psychological mechanisms are exquisitely context-dependent and environmentally sensitive (see Al-Shawaf et al. 2018, for an extended treatment of the centrality of context in evolutionary psychology). Even if socially undesirable behaviors such as aggression, warfare, or romantic infidelity have an evolutionary basis, this does not mean that we are stuck with them forever. Indeed, a wealth of evidence shows that war, violence, and other forms of aggression have been steadily declining throughout human history (Pinker 2011). In fact, our best chance of changing or eliminating socially undesirable behaviors will come from understanding them more deeply. Only when we understand the inputs, evolved decision rules, and outputs involved in an undesirable outcome will we have the information necessary to try to change it.

Misunderstanding 10: You Can Use the Principles of Natural Selection to Bypass the Psychological Level of Analysis and Predict Behavior Directly

It is common to think – especially among evolutionists who do not have a background in psychology – that there is nothing wrong with going directly from the principles of natural selection to predictions about behavior, skipping the psychological or information-processing level of analysis. But skipping the level of psychological adaptations – the information-processing machinery built by natural selection – can lead one astray (Cosmides and Tooby 1987).

Consider incest aversion. Studies suggest that the mind uses a few key cues during childhood to tag individuals as siblings, marking them as unsuitable sexual partners. Chief among these are childhood co-residence (years spent growing up with the other child in the same house) and maternal perinatal association (if you are the older sibling, observing your mother breastfeeding the other child). The human mind uses these two key informational inputs to tag someone as a sibling and consequently produces incest aversion at the thought of having sex with them. Normally, siblings encounter these cues during childhood and nonsiblings do not. But sometimes there is a mismatch – and these mismatches are revealing. For instance, in the phenomenon of Taiwanese minor marriages, a young female child is betrothed to a young male child, and they are both raised by the boy's parents in the boy's parents' house. Because they grow up together in the same household (childhood co-residence), their brains mistakenly tag each other as siblings, producing incest aversion. As a consequence, the individuals involved in Taiwanese minor marriages report less sexual interest in one another, lower fertility rates, lower relationship satisfaction, and higher divorce rates (Lieberman et al. 2007; Lieberman and Symons 1998). In essence, the mind mistakenly coded a nonrelative as a sibling because it received the key informational input of childhood co-residence (Lieberman et al. 2003, 2007).

This process can fail in the opposite way, too: genetic siblings who do not receive the key informational inputs of childhood co-residence and maternal perinatal association may fail to psychologically tag each other as siblings, leaving open the possibility of being sexually attracted to each other later in life. This is exactly what happened to some siblings who were separated at birth, grew up apart, and later in life found each other and fell in love (Childs 1998). This outcome makes no sense unless you take into account the information-processing level of analysis. If you attempt to go directly from the principles of natural selection to behavior, the phenomenon appears incomprehensible – they are genetic siblings, so why are they sexually attracted to each other? By contrast, if you *do not* skip the information-processing level of analysis, the difficulty immediately disappears: these siblings were reared apart, so their minds did not receive the key informational inputs needed to produce incest aversion. That is why they are capable of being sexually attracted to one another.

In short, if you leapfrog the psychological level of analysis and attempt to go directly from the principles of natural selection to statements about behavior, you will make mistakes in both prediction and explanation (Cosmides and Tooby 1987). This brings to mind two quotes from foundational evolutionary thinkers, one by Donald Symons and the other by John Tooby and Leda Cosmides. To paraphrase Don Symons, the evolutionist should focus on psychology and information processing. When he ignores these in favor of observable behavior, he is like the drunk looking for his key under the lamppost: he knows he dropped it in the dark, but under the lamppost the light is better (Symons 1979).

And as Tooby and Cosmides wrote so eloquently, "The fact that the brain processes information is not an accidental side effect of some metabolic process. The brain was designed by natural selection *to be* a computer. Therefore, if you want to describe its operation in a way that captures its evolved function, you need to think of it as composed of programs that process information" (Tooby and Cosmides 2005, pp. 16–17). In short, if you want to maximize the accuracy of your evolution-based predictions and explanations, you would do well not to skip the information-processing level of analysis.

Misunderstanding 11: Natural Selection Is the Only Driver of Evolutionary Change

Another important misconception is that natural selection is the only driver of evolutionary change. A variant of this misunderstanding is the erroneous belief that the terms "evolution" and "natural selection" are more or less interchangeable.

In reality, evolution is the *outcome*, and there are four evolutionary forces that drive it: mutation, genetic drift, gene flow, and natural selection (e.g., Futuyma and Kirkpatrick 2017). Mutation is a random heritable change in a gene or chromosome and constitutes part of the raw material on which natural selection works. Genetic drift is the random, chance-driven change in allele frequency from one generation to the next. Gene flow, sometimes called admixture or migration, is the movement of genes from one population to another. Natural selection, the fourth evolutionary force and the subject of this entry, is most accurately described as nonrandom differential reproductive success (see Misunderstandings #1 and #2).

To be clear, while natural selection is not the only driver of evolutionary change, it is a key one – and most scientists agree that it is the most important one (Alcock 2009; Dawkins 1976; Dennett 1996; Williams 1966). It is also the *only* evolutionary force capable of fashioning adaptations or creating the appearance of design, the explication of which is the central explanatory task of evolutionary biology (Darwin 1859; Williams 1966).

This is an important point: while there are four different evolutionary forces, only one of them – natural selection – can create adaptations designed to solve environmental problems. The other three forces can cause evolution – defined as a change in allele frequencies in a population over time – but only natural selection can fashion complex specialized mechanisms like the porcupine's quills, the turtle's shell, or the angler fish's bait, all exquisitely designed to solve key environmental problems in these animals' lives.

In sum, natural selection is only one of four evolutionary forces, but it is the only one capable of fashioning adaptations.

Misunderstanding 12: Evolutionary Hypotheses Are Primarily Post-Hoc Storytelling – Also Known as "Just-So" Stories

One of the most widespread misunderstandings of evolutionary science – and of evolutionary psychology in particular – is that evolutionary hypotheses are post-hoc storytelling, also known as "just-so stories" (Gould and Lewontin 1979). Nothing could be further from the truth. There are two ways to appreciate why this is a mistake.

First, as in all sciences, evolutionary psychologists can proceed in two ways: using the top-down or bottom-up approach. In the top-down approach to science, researchers generate hypotheses and predictions directly from theory and subsequently go out and test their hypotheses. Since hypotheses and predictions in this approach are made *a priori* on the basis of theory, it is impossible for the top-down approach to be open to the charge of just-so storytelling.

By contrast, in the bottom-up approach, researchers first make an observation, and then generate a hypothesis to explain why that observation might have occurred. This approach to science is *potentially* open to the charge of post-hoc storytelling, but only if the researcher *stops* after generating a hypothesis and fails to derive or test any new predictions from that hypothesis. Whether or not a proposed explanation counts as just-so storytelling depends entirely on this last step: if the researcher in question simply chooses to believe her hypothesis without generating and testing any novel predictions, then she is guilty of just-so storytelling. If, by contrast, the researcher uses the proposed hypothesis to generate novel, testable predictions, the charge falls flat. A cursory look at published evolutionary psychological papers makes it clear that most evolutionary psychological hypotheses are not open to this accusation, either because they used the top-down approach to generate *a priori* predictions (e.g., see Al-Shawaf 2016), or because they used the bottom-up approach but subsequently generated and tested novel predictions.

A concrete way of remedying the confusion here is simply to list examples where an evolutionary approach started from theory, generated novel hypotheses, and then used those hypotheses to derive new predictions which were subsequently tested in the lab and the field. There are literally hundreds of such examples, and many of them have been included in easy-to-read tables in previous journal articles. We therefore do not replicate them here but instead direct the reader to three articles where they can find plenty of such examples – as well as much more detailed discussions of why evolutionary hypotheses are eminently falsifiable. Key papers that include such tables and discussion are Buss et al. (1998), Ketelaar and Ellis (2000), and Lewis et al. (2017).

The underlying mistake seems to be thinking that if a discipline is partly *historical* in nature (as are the evolutionary sciences), that makes the discipline unfalsifiable and prone to just-so storytelling. But if that were the case, *all* disciplines with a historical component – including, for example, astrophysics, cosmology, and geology – would be exercises in just-so storytelling. This is obviously incorrect. Whether or not a scientific discipline includes a historical component is not relevant in differentiating good science from just-so storytelling. What *is* relevant is whether the scientists in a given discipline – regardless of whether that discipline includes a historical component – use their hypotheses to *generate novel predictions that can be tested in the present day*. If they skip this crucial step, they may be engaged in just-so storytelling. By contrast, if they use their hypotheses to generate and test novel predictions about previously unobserved phenomena, they are engaged in normal, productive science. It is the latter that characterizes most evolutionary psychological research (for full discussions, see Buss et al. 1998; Confer et al. 2010; Ketelaar and Ellis 2000; Lewis et al. 2017).

Misunderstanding 13: Natural Selection Has Stopped for Our Species, So Humans Are No Longer Evolving

The thirteenth misconception is that humans have stopped evolving because natural selection has ceased operating on our species. This erroneous line of reasoning points out that we have eradicated many diseases, and that modern medicine keeps humans alive when they would have surely died in ancestral populations. There are at least three reasons why this does not warrant the conclusion that humans have stopped evolving.

First, we have not eradicated all diseases. People still die of cardiovascular problems, sexually transmitted diseases, respiratory diseases, cancer, and plenty of other illnesses. Every year, about 800,000 children die from diarrhea-related problems *alone* (Center for Disease Control and Prevention 2015). It is true that WEIRD societies (Western, Educated, Industrialized, Rich, and Democratic; Henrich et al. 2010) have made great medical progress, but as a species, we are far from having eradicated all sources of death and disease. The vast majority of the world still suffers from many illnesses, some of which are fatal. And of course this is to say nothing of warfare, homicide, and other causes of death.

Second, even if we *had* eradicated all sources of disease, this would not imply the cessation of evolution. Recall that it is differential *reproduction*, not survival, that is the bottom line of evolution (see Misunderstanding #2). As long as some humans are still reproducing more than others, natural selection is still operating. This means that, putting survival aside, there are plenty of sources of selection still operating on our species: mate competition, mate selection, mate retention, romantic infidelity, childrearing, investment in genetic relatives, grandparenting, altruism, social betrayal, free-riding, status hierarchy negotiation, and more. Eradicating disease does not remove important selection pressures related to social processes, mating processes, and differential reproductive success. Indeed, not only are humans still evolving but the pace of our evolution has *sped up* over the last 10,000 years (Cochran and Harpending 2009).

Third, it is important to remember that there are three prerequisites for evolution: (1) variation (organisms in a population vary), (2) inheritance (some of this variation is passed on to offspring), and (3) differential reproductive success (as a result, some of these organisms reproduce more than others). As long as ingredient #3 (differential reproductive success) still obtains, natural selection is still operating. And as long as *all three* prerequisites are still in place – as is the case among humans – evolution is still occurring. Consequently, humans are still evolving, and will be for the foreseeable future.

Conclusion

The theory of evolution by natural selection is regarded by scientists as one of the most parsimonious, explanatorily successful, and predictively powerful theories in the history of science (Alcock 2009; Coyne 2009; Dawkins 2009; Dennett 1996; Dobzhansky 1973). Its parsimony and simplicity suggest that it should not be difficult to understand, but misconceptions still abound, even among scientists. There are likely several reasons for this, including insufficient educational exposure to the principles and findings of evolutionary biology as well as social and ideological biases that serve as impediments to understanding (e.g., Von Hippel and Buss 2017). Ironically, some of these errors may also be rooted in the fact that our evolved cognitive systems make it difficult for us to understand evolution correctly (e.g., Evans and Lane 2011; Legare et al. 2013; Shtulman and Schulz 2008).

This entry has tackled what we see as the 13 most important misunderstandings about evolution and natural selection (see Table 1). This list is not exhaustive. For example, due to space considerations, we were unable to discuss such misunderstandings as the notion that something is good because it is natural, the intuition that natural selection must always lead to change, or the idea

Thirteen Misunderstandings About Natural Selection, Table 1 Misunderstandings about natural selection vs. accurate alternatives

Misconception	Accurate alternative
Natural selection is random and so is evolution	Mutation is random, natural selection is nonrandom, and as a consequence, evolution is also nonrandom
Survival is the bottom line of evolution by natural selection	Differential reproduction is the bottom line of evolution by natural selection. Survival is tributary to reproduction, and when the two conflict, reproduction trumps survival
There is an agent doing the "selecting" in natural selection	There is no agent and no active "selection". The process is blind and passive, and a more accurate term for natural selection would be "differential reproductive success"
Evolution is teleological – the process has a final goal, endgame, or *telos*	Evolution is not teleological and has no final goal, endgame, or *telos*. Natural selection is blind and cannot peer into the future
Evolution favors the "survival of the species"	Most evolutionists agree that group selection is a much weaker force than genic-level and individual-level selection. Adaptations do not routinely evolve to benefit groups, and the survival of species is not a goal of evolution
Natural selection builds perfectly designed biological mechanisms	Natural selection builds functional mechanisms that are often impressive but are nonetheless suboptimal. This is because there are several unavoidable constraints on the power of selection (e.g., time lags and trade-offs)
Evolution implies genetic determinism	Evolution does not imply genetic determinism. An evolutionary perspective highlights the centrality of the environment at every stage: the initial evolution of adaptations, their ontogenetic development, and their immediate activation in the present
Adaptations must be present at birth (or must develop very early in life)	Natural selection builds adaptations that "come online" at the appropriate developmental stage of life, not adaptations that are necessarily present at birth. Teeth and breasts illustrate this principle
The products or outputs of adaptations are fixed and unchangeable	Evolved mechanisms are flexible. Because environmental input is crucial to the products of adaptations, it is often possible to change the output by simply modifying the input (e.g., calluses)
You can use the principles of evolution to predict behavior directly, bypassing psychological adaptations	Information processing is the key intervening step between the principles of evolution and predictions about behavior. Skipping this step can lead to errors in both prediction and explanation
Natural selection is the only driver of evolutionary change	There are four drivers of evolutionary change: mutation, migration, genetic drift, and natural selection. Natural selection is very important, and it is the only viable explanation for the structure and function of *adaptations,* but it is only one of four drivers of evolutionary change
Evolutionary hypotheses are inherently unfalsifiable "just-so" stories	Most evolutionary hypotheses are eminently falsifiable. When researchers use the top-down approach to generate *a priori* predictions, the "just-so" charge falls flat. When researchers use the bottom-up, observation-driven approach, whether the charge falls flat depends on whether the researchers use their hypotheses to generate novel, testable predictions. For an extended discussion, see Buss et al. 1998; Confer et al. 2010; Ketelaar & Ellis 2000; Lewis et al. 2017
Humans have stopped evolving because natural selection has ceased for our species	Humans are still evolving and natural selection is still ongoing in our species. We have not eradicated all sources of death and disease – and even if we had, the bottom line of evolution is differential reproduction, not survival. As long as some humans still reproduce more than others, natural selection is still ongoing in our species

that evolution is "just a theory" (e.g., Dawkins 2009). Nevertheless, we have attempted to clear away the most common impediments to an accurate understanding of natural selection. We hope this entry helps readers to avoid these misunderstandings and to think about the process of evolution in a rigorous and clear-headed manner.

Cross-References

- ▶ Adaptations
- ▶ Falsifiability
- ▶ Genetic Determinism
- ▶ George Williams
- ▶ Natural Selection
- ▶ Problems With Group Selection
- ▶ Richard Dawkins on Constraints on Natural Selection
- ▶ The Handicap Principle

Acknowledgments We do not mean to imply that behavior is unimportant and can be ignored. Behavioral outputs are a key part of evolved psychological mechanisms, and an analysis that ignores them is necessarily incomplete. Our point is that skipping the information-processing level of analysis also leads to incomplete and often mistaken analyses.

References

Alcock, J. (2009). *Animal behavior: An evolutionary approach*. Sunderland: Sinauer Associates.
Alcock, J. (2017). Human sociobiology and group selection theory. In M. Tibayrenc & F. J. Ayala (Eds.), *On human nature* (pp. 383–396). New York: Elsevier.
Al-Shawaf, L. (2016). The evolutionary psychology of hunger. *Appetite, 105*, 591–595.
Al-Shawaf, L., & Zreik, K. (2018). Richard Dawkins on constraints on natural selection. In T. K. Shackelford, & V. A. Weekes-Shackelford (Eds.), *Encyclopedia of evolutionary psychological science* (pp. 1–5). Springer.
Al-Shawaf, L., & Lewis, D. M. G. (2018). The Handicap Principle. In T. K. Shackelford & V. A. Weekes-Shackelford (Eds.). Encyclopedia of Evolutionary Psychological Science.
Al-Shawaf, L., Lewis, D. M. G., Wehbe, Y. S., & Buss, D. M. (in press). The importance of context in evolutionary psychology. In T. K. Shackelford, & V. A. Weekes-Shackelford (Eds.), *Encyclopedia of evolutionary psychological science*. Springer.
Alters, B. J., & Nelson, C. E. (2002). Perspective: Teaching evolution in higher education. *Evolution, 56*(10), 1891–1901.
Andrade, M. C. (1996). Sexual selection for male sacrifice in the Australian redback spider. *Science, 271*, 70–71.
Andrade, M. C. (2003). Risky mate search and male self-sacrifice in redback spiders. *Behavioral Ecology, 14*(4), 531–538.
Bhushan, B. (2009). Biomimetics: Lessons from nature – An overview. *Philosophical Transactions. Series A, Mathematical, Physical, and Engineering Sciences, 367*(1893), 1445–1486.
Buss, D. M. (1995). Evolutionary psychology: A new paradigm for psychological science. *Psychological Inquiry, 6*(1), 1–30.
Buss, D. M. (2015). *Evolutionary psychology: The new science of the mind*. New York: Routledge.
Buss, D. M., Haselton, M. G., Shackelford, T. K., Bleske, A. L., & Wakefield, J. C. (1998). Adaptations, exaptations, and spandrels. *American Psychologist, 53*(5), 533–548.
Center for Disease Control and Prevention. (2015). *Global diarrhea burden: Diarrhea: Common illness, global killer*, Atlanta.
Childs, R. M. (1998). Genetic sexual attraction: Healing and danger in the reunions of adoptees and their birth families. Dissertation Abstracts International, B: *The Sciences and Engineering*, 59, 1843.
Cochran, G., & Harpending, H. (2009). *The 10,000 year explosion: How civilization accelerated human evolution*. New York: Basic Books.
Confer, J. C., Easton, J. A., Fleischman, D. S., Goetz, C. D., Lewis, D., Perilloux, C., & Buss, D. M. (2010). Evolutionary psychology controversies, questions, prospects, and limitations. *American Psychologist, 65*(2), 110–126.
Cosmides, L., & Tooby, J. (1987). From evolution to behavior: Evolutionary psychology as the missing link. In J. Dupre (Ed.), *The latest on the best: Essays on evolution and optimality*. Cambridge, MA: The MIT Press.
Coyne, J. A. (2009). *Why evolution is true*. New York: Penguin.
Cronin, H. (1993). *The ant and the peacock: Altruism and sexual selection from Darwin to today*. Cambridge: Cambridge University Press.
Darwin, C. (1859). On the origin of species by natural selection. London, UK: Murray.
Darwin, C. (1871). *The decent of man, and selection in relation to sex* (Vol. 1). New York: D. Appleton and Company.
Dawkins, R. (1976). *The selfish gene: 30th anniversary edition*. New York: Oxford University Press.
Dawkins, R. (1982). *The extended phenotype*. New York: Oxford University Press.
Dawkins, R. (1999). *The extended phenotype: The long reach of the gene*. Oxford: Oxford University Press.
Dawkins, R. (2009). *The greatest show on earth: The evidence for evolution*. New York: Simon and Schuster.
Delton, A. W., Krasnow, M. M., Cosmides, L., & Tooby, J. (2011). Evolution of direct reciprocity under uncertainty can explain human generosity in one-shot encounters. *Proceedings of the National Academy of Sciences, 108*(32), 13335–13340.

Dennett, D. C. (1996). *Darwin's dangerous idea: Evolution and the meanings of life*. New York: Simon and Schuster.

Dobzhansky, T. (1973). Nothing in biology makes sense except in the light of evolution. *National Association of Biology Teachers, 35*(3), 125–129.

Evans, E. M., & Lane, J. D. (2011). Contradictory or complementary? Creationist and evolutionist explanations of the origin (s) of species. *Human Development, 54*(3), 144–159.

Futuyma, D., & Kirkpatrick, M. (2017). *Evolution*. Sunderland: Sinauer Associates.

Gould, S. J., & Lewontin, R. C. (1979). The spandrels of San Marco and the Panglossian paradigm: A critique of the adaptationist programme. *Proceedings of the Royal Society of London B, 205*(1161), 581–598.

Gregory, R. T. (2009). Understanding natural selection: Essential concepts and common misconceptions. *Evolution: Education and Outreach, 2*(2), 156–175.

Hamilton, W. D. (1964). The genetical evolution of social behaviour. II. *Journal of Theoretical Biology, 7*(1), 17–52.

Henrich, J. (2004). Cultural group selection, coevolutionary processes and large-scale cooperation. *Journal of Economic Behavior & Organization, 53*(1), 3–35.

Henrich, J., Heine, S. J., & Norenzayan, A. (2010). The weirdest people in the world? *Behavioral and Brain Sciences, 33*, 61–83.

Hippel, W., & Buss, D. M. (2017). Do ideologically driven scientific agendas impede understanding and acceptance of evolutionary principles in social psychology? In J. T. Crawford & L. Jussim (Eds.), *The politics of social psychology* (pp. 7–25). New York: Psychology Press.

Jacob, F. (1977). Evolution and tinkering. *Science, 196*(4295), 1161–1166.

Ketelaar, T., & Ellis, B. J. (2000). Are evolutionary explanations unfalsifiable? Evolutionary psychology and the lakatosian philosophy of science. *Psychological Inquiry, 11*(1), 1–21.

Kim, J. J., Lee, Y., Kim, H. G., Choi, K. J., Kweon, H. S., Park, S., & Jeong, K. H. (2012). Biologically inspired LED lens from cuticular nanostructures of firefly lantern. *Proceedings of the National Academy of Sciences, 109*(46), 18674–18678.

Krasnow, M. M. & Delton, A. W. (2012). Is there evidence for special design of a group-selected psychology? Comment on Steven Pinker's The false allure of group selection. *Edge*. Retrieved from http://edge.org/conversation/the-false-allure-of-group-selection#mkad

Krasnow, M. M., Cosmides, L., Pedersen, E. J., & Tooby, J. (2012). What are punishment and reputation for? *PLoS One, 7*(9), e45662.

Krasnow, M. M., Delton, A. W., Cosmides, L., & Tooby, J. (2015). Group cooperation without group selection: Modest punishment can recruit much cooperation. *PLoS One, 10*(4), e0124561.

Krasnow, M. M., Delton, A. W., Cosmides, L., & Tooby, J. (2016). Looking under the hood of third-party punishment reveals design for personal benefit. *Psychological Science, 27*(3), 405–418.

Legare, C. H., Lane, J., & Evans, E. M. (2013). Anthropomorphizing science: How does it affect the development of evolutionary concepts? *Merrill-Palmer Quarterly, 59*, 168–197. https://doi.org/10.1353/mpq.2013.0009.

Lewis, D. M. G., Al-Shawaf, L., Conroy-Beam, D., Asao, K., & Buss, D. M. (2017). Evolutionary psychology: A how-to guide. *American Psychologist, 72*(4), 353–373.

Lieberman, D., & Symons, D. (1998). Sibling incest avoidance: From Westermarck to wolf. *The Quarterly Review of Biology, 73*(4), 463–466.

Lieberman, D., Tooby, J., & Cosmides, L. (2003). Does morality have a biological basis? An empirical test of the factors governing moral sentiments relating to incest. *Proceedings of the Royal Society of London B: Biological Sciences, 270*(1517), 819–826.

Lieberman, D., Tooby, J., & Cosmides, L. (2007). The architecture of human kin detection. *Nature, 445*(7129), 727–731.

Meaney, M. J. (2001). Nature, nurture, and the disunity of knowledge. *Annals of the New York Academy of Sciences, 935*(1), 50–61.

Murr, L. E. (2015). Biomimetics and biologically inspired materials. In *Handbook of materials structures, properties, processing and performance* (pp. 521–552). Cham: Springer.

Nehm, R. H., & Reilly, L. (2007). Biology majors' knowledge and misconceptions of natural seclection. *Bioscience, 57*(3), 263–272.

Nehm, R. H., Poole, T. M., Lyford, M. E., Hoskins, S. G., Carruth, L., Ewers, B. E., & Colberg, P. (2008). Does the segregation of evolution in biology textbooks and introductory courses reinforce students' faulty mental models of biology and evolution? *Evolution: Education and Outreach, 2*(3), 527–532.

Park, J. H. (2007). Persistent misunderstandings of inclusive fitness and kin selection: Their ubiquitous appearance in social psychology textbooks. *Evolutionary Psychology, 5*(4), 860–873. 147470490700500414.

Pew Research Center. (2015, July 23). An elaboration of AAAS scientists' views: A deeper examination of views about key science topics by members of the American Association for the Advancement of Science. Retrieved from http://www.pewinternet.org/2015/07/23/an-elaboration-of-aaas-scientists-views/.

Pinker, S. (2011). *The better angels of our nature: Why violence has declined*. New York: Penguin Books.

Pinker, S. (2012). The false allure of group selection. Retrieved from https://www.edge.org/conversation/steven_pinker-the-false-allure-of-group-selection.

Quammen, D. (1985). *Natural acts: A sidelong view of science and nature*. New York: W. W. Norton & Company.

Ridley, M. (2003). *Nature via nurture: Genes, experience, and what makes us human*. New York: HarperCollins Publishers.

Shtulman, A., & Schulz, L. (2008). The relation between essentialist beliefs and evolutionary reasoning. *Cognitive Science, 32*, 1049–1062. https://doi.org/10.1080/03640210801897864.

Symons, D. (1979). *The evolution of human sexuality*. New York: Oxford University Press.

Tinbergen, N. (1963). On aims and methods of ethology. *Zeitschrift für Tierpsychologie, 20*, 410–433. https://doi.org/10.1111/j.1439-0310.1963.tb01161.x.

Tooby, J., & Cosmides, L. (1992). The psychological foundations of culture. In J. Barkow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind: Evolutionary psychology and the generation of culture*. New York: Oxford University Press.

Tooby, J., & Cosmides, L. (2005). Conceptual foundations of evolutionary psychology. In D. M. Buss (Ed.), *The handbook of evolutionary psychology* (pp. 68–95). Hoboken: Wiley.

Williams, G. C. (1966). *Adaptation and natural selection: A critique of some current evolutionary thought*. Princeton: Princeton University Press.

Wilson, D. S., & Sober, E. (1994). Reintroducing group selection to the human behavioral sciences. *Behavioral and Brain Sciences, 19*(4), 585–654.

Winegard, B. M., Winegard, B. M., & Deaner, R. O. (2014). Misrepresentations of evolutionary psychology in sex and gender textbooks. *Evolutionary Psychology, 12*(3), 474–508.