Understanding Creationism

An insider's guide by former YEC (Young-Earth Creationist)

David Starling MacMillan

0 *Introduction to* Understanding Creationism

In this book, David MacMillan explains how misinformation and misconceptions allow creationists to maintain their beliefs even in the face of overwhelming evidence to the contrary. A former creationist blogger and writer, Mr. MacMillan earned his BS degree in physics from the University of North Alabama and now works as a technical writer when he isn't frequenting the PT comment boards. Since leaving creationism, he has written several columns discuvssing the public dialogue between creation and evolution. This series will outline the core beliefs creationists use as the basis for their reasoning while pointing out the challenges faced in re-educating against creationist misconceptions.

`http://www.huffingtonpost.com/david-macmillan`

1 *Philosophy of pseudoscience*

During my tenure as an active young-earth creationist, I never once heard other creationists accurately describe what evolutionary theory is or how it is supposed to work. Nor did I understand it myself. Creationists often seem familiar with a lot of scientific terminology, but their understanding is filled with gross misinformation. Thus, a host of misconceptions is believed and taught throughout creationist circles, making it almost impossible for actual evidence to really sink in.

There are plenty of comprehensive lists of creationist claims with exhaustive refutations, such as the TalkOrigins archive. Rather than try to replicate those, I will attempt to explain *why* creationist claims persist in the face of contrary evidence, even when individuals are otherwise well-educated. To do so, I'm going to go over the major areas where creationists get the science itself completely wrong. My list doesn't represent all such misconceptions, of course. These are the misconceptions I personally recall hearing or using myself. I've chosen not to provide specific examples of each misconception from the creationist literature, though they are all easy to find. Citations for my explanations can be found online by anyone who wants to see them; this series is not about any particular facts so much as it's about how false beliefs are used to support false conclusions.

`http://talkorigins.org/indexcc/list.html`

Real scientists understand the theory of evolution to be a series of conclusions drawn from over a century of research, predictions, and discoveries. This theory allows us to understand the mechanisms in biology and make further predictions about the sort of evidence we will uncover in the future. Its predictive power is vital to success in real-life applications like medicine, genetic engineering, and agriculture.

However, creationists don't see it the same way. Creationists artificially classify medicine, genetic research, and agriculture as "operational science", and believe that those disciplines function in a different way than research in evolutionary biology. *They understand the theory of evolution, along with mainstream geology and a variety of other disciplines, as a* ***philosophical construct*** *created for the express purpose of explaining life on Earth apart from divine intervention.* Thus, they approach the concept of evolution from a defensive position; they believe it represents an attack on all religious faith.

This defensive posture is reflected in nearly all creationist literature, even in the less overt varieties such as intelligent-design creationism. It dictates responses. When creationists see a particular argument or explanation about evolution, their initial reaction is to ask, "How does this attack the truth of God as Creator? What philosophical presuppositions are dictating beliefs here? How can I challenge those underlying assumptions and thus demonstrate the truth?" Recognizing this basis for creationist arguments is a helpful tool for understanding why such otherwise baffling arguments are proposed.

In reality, we understand that although various philosophical implications may

be constructed around evolution, it is not driven by any atheistic philosophy. The fundamental principle undergirding the theory of evolution is the same as the fundamental principle behind all science: that hypotheses can be tested and confirmed by prediction. But creationists instead insist that evolution arises out of explicitly atheistic axioms. This series will look at the arguments and objections which flow from this worldview in six different areas.

Creationists accept certain aspects of variation, adaptation, and speciation, but they artificially constrain the mechanism for adaptation to produce an imagined barrier between "microevolution" and "macroevolution" (Part 2). They conceptualize evolutionary adaptation as a series of individual changes, missing the entire mechanism provided by the population as a whole (Part 3). They make the extraordinary claim that no transitional fossils exist, simply by redefining "transitional" into something that could not possibly exist (Part 4). Creationists attempt to rewrite the last two centuries of scientific progress in order to avoid dealing with the multiple lines of evidence all independently affirming common descent and deep time (Part 5). They have far-reaching misapprehensions concerning microbiology and DNA (Part 6). On top of all this, they assign ethical and moral failings to evolutionary science in order to make evolution seem dangerous and anti-religion (Part 7). I will address each of these topics in the coming posts.

2 Variation and adaptation

The majority of modern creation science freely admits the existence of biological variation, adaptation, and speciation. Indeed, the recent-creation model—particularly the belief that all extant life descended from a small group of "kinds" present on Noah's Ark which diversified into all families on Earth after a global flood—requires enormous adaptive variation and near-constant speciation. Creationists estimate that fewer than 10,000 pairs of land-dwelling, air-breathing animals on the Ark diversified to represent all families alive today. There are around 6.5 million land-dwelling species today, so millions of speciation events would have needed to take place over the past 44 centuries since their global flood.

http://preview.tinyurl.com/putplgw

As a side point: in order to go from 10,000 primordial "kinds" to 6.5 million species in less than 5000 years, the number of species would need to double every 385 years. If the rate of evolutionary development and speciation really were this rapid, few species would endure for more than four or five centuries without undergoing drastic and noticeable adaptation, and we would presently see about 45 new species emerging every single day. To explain this inconsistency, creationists will sometimes imagine an even more rapid period of hyper-evolution immediately following the Flood, after which adaptation and speciation would supposedly stabilize to their presently-observed levels. Apart from being utter special pleading, this explanation is even more problematic: each species would have to undergo a speciation event every few generations.

So creationists most certainly accept the existence of biological variation and speciation. Creationists call this rapid diversification from "kinds" down to modern species "micro-evolution." *However, the mechanism they propose as the basis of "microevolution" differs broadly from the mechanism accepted and taught as part of the theory of evolution.*

Creationist literature—particularly curriculum, though this is the rule in apologetics and journals as well—typically presents Mendelian inheritance as the sole mechanism for biological variation. Almost all biological variation is believed to come through this process: the recombination of whole genes (examples usually tracing the familiar-but-oversimplified dominant/recessive system) from parental chromosomes to produce offspring with a blend of traits from each parent. They propose that this new blend of pre-existing traits is subject to natural selection and can cause those traits (and their associated genes) to become more or less prevalent in the population as a whole. Eventually, the concentration of these genes in subsets of the population is expected to lead to a split and the emergence of a new species. Creationists also point out that the *loss* of genetic information due to mutation can produce similarly selectable results, accelerating the diversification process. However, they will invariably add that this process works in only one direction; mutations can remove genetic information, but they cannot (in the creationist mindset) add it.

The creationist model claims that the variation provided by Mendelian inheritance and genetic loss—this "microevolution" mechanism—is responsible for all the variation we ever observe in nature. They claim that this observed level of variation is sufficient for the diversification of the 10,000 kinds represented on the Ark, but—they claim—not sufficient to produce the new genetic information needed to produce all life from a single common ancestor (what they term "macroevolution"). By erroneously supposing that Mendelian recombination is the exclusive source of genetic variation, they neatly exclude any viable mechanism for universal common descent.

Correcting this misconception can be difficult. It is not enough to explain that macroevolution is the accumulation of microevolution over time, because creationists define these as two distinctly different processes. They actually *are* correct in arguing that their "microevolution" could never accumulate into "macroevolution" because their definition of "microevolution" is much more limited than we see in reality. *They must be made to understand that the genetic variation we actually observe on a daily basis is* ***fundamentally different*** *than what their "microevolution" allows for.*

The misconception depends on a lack of information about microbiology and sexual reproduction in general, but there is a conceptual foundation at play as well: the idea that God is the prime creator of information, including genetic information. This idea is philosophical: the assumption that no new information can arise without an intelligence.

The creationist needs to understand two things. First, he should understand the scientific fact of just how much variation is actually observed in microbiology. There is no "limit" to genetic recombination; chromosomal crossover can take place at any base pair, and this process can alter or transpose or duplicate entire genes without loss of function. A common creationist claim is that any mutation large enough to make a difference will ruin the organism's chances at survival. But this claim is simply false. First of all, genotype (the information in our DNA) is distinct from phenotype (the expression of traits based on DNA). Each generation has two copies of every chromosome (one from the mother and one from the father), so a given organism can use the maternal gene if the paternal one is scrambled, and vice versa. Moreover, it is not uncommon for chromosomal crossover to duplicate whole genes, so the old gene can retain its original function while the new gene develops a new function. Mendelian recombination can be the source of visible changes from generation to generation, but new genetic combinations are continually being generated within the genome itself.

More fundamentally, the creationist must realize the flaw in his philosophical argument. Our DNA does not contain abstract information, like a book filled with human language. Abstract information almost certainly requires a conscious mind to interpret it, but that is not what DNA represents. Using the idea of a code to represent DNA is our abstraction; the actual function of DNA is purely chemical. There is no interpretation required; the alignment and connection is the same sort of process by which snowflakes form into crystals. The evolution of our genetic code is not driven by some conscious intelligence constantly adding new information, but by the environment, which continually forces life to adapt in order to survive.

3 *You don't evolve, your species does.*

Creationists often conceptualize evolution as something which is purely vertical: successive changes from parent to child to grandchild to great-grandchild accumulating over time. They can hardly be faulted for this misconception, because this view seems to be shared by the general public and even reinforced by the sometimes-imprecise explanations and depictions of evolution by museums and science educators.

Evolutionary adaptation, however, does not happen in a straight line from parent to child. Rather, adaptation takes place *throughout a population* as different genetic sequences spread outward from parents to all their offspring and are recombined and reshuffled in many different individuals each successive generation. Evolution is wibbly-wobbly, timey-wimey stuff. It is the combination of changing genetic material across an entire population that makes major evolutionary adaptation possible; without this constant mixing and recombination from the entire population, evolution would grind almost to a halt. Evolution is a phenomenon that functions not at the level of the individual, nor at the level of individual lineages, but across the entire population within the species (Figure 1).

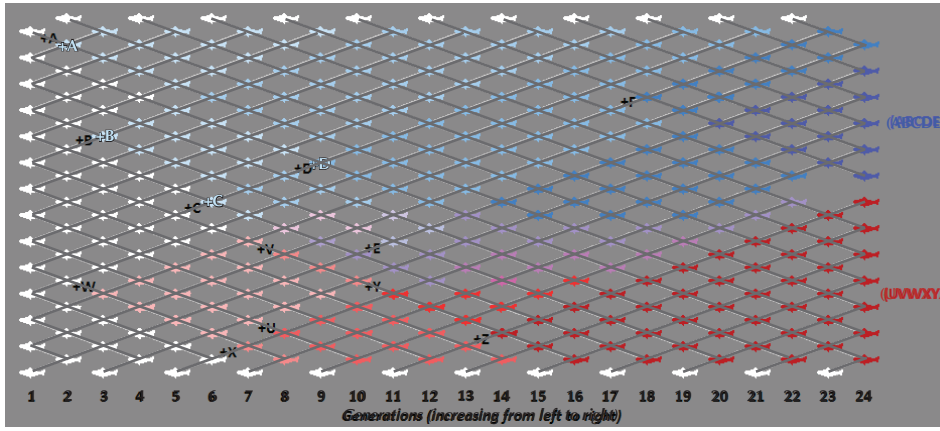

Figure 1: *This hypothetical example depicts evolutionary change as an emergent property of the entire population. Both the "ABC" combinations (in shades of blue) and the "XYZ" combinations (in shades of red) offer a survival advantage and are passed on, while combinations of the two (shown in shades of purple) are detrimental and are removed from the population. No specific mutation order is required; as long as the selection pressure remains steady, the mutations accumulate together (essentially "finding" each other) and two separate genotypes emerge.*

Unfortunately, depictions of evolution often show individual specimens arranged linearly in ascending order: apes to humans, theropods to birds, and the like (Figure 2). Such representations make it easy to miss the population aspect. Even an accurately depicted branching tree of evolution can still be misunderstood to represent individuals rather than whole populations.

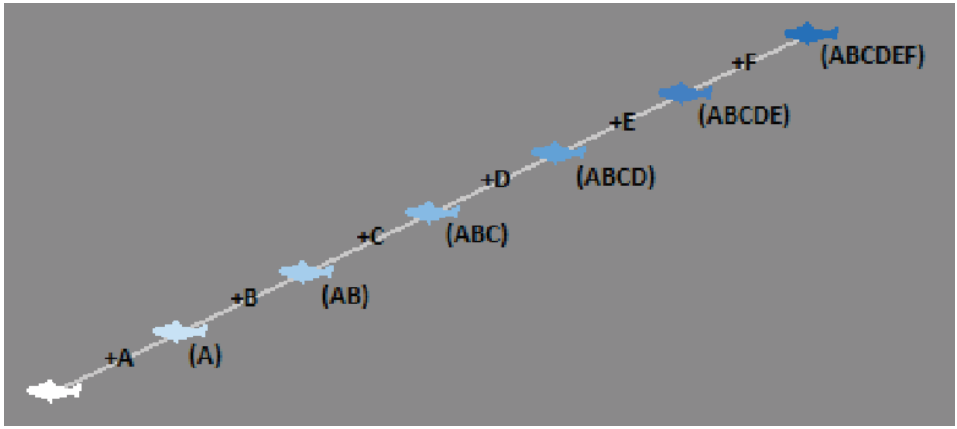

Figure 2: *In this common but mistaken depiction of evolution typically adopted by creationists, individual changes occur in simple sequence within a single lineage. With this view, it is easy to wrongly assume that individual mutations must occur one after another in a specific order, something that seems intuitively improbable.*

Biologist PZ Myers explains it very well in a recent blog post:

> *Evolution isn't sequential. It's massively parallel. Massively. Humans have about 20,000 genes, and all of them are evolving at once, with trial runs in about 7 billion individuals. New variants are arising all the time, and then they're tested to destruction in multiple combinations over time. Scrap your weird idea that the pieces of a complex system must be developed one at a time—they can't, and all of them are being constantly tinkered with. It is the most badly designed scientific experiment or engineering program ever, with no controls and every variable getting randomly tweaked at random intervals. So don't be surprised that multiple elements are getting juggled.*

`http://preview.tinyurl.com/ld4jl5v`

Understanding and addressing the misconception (Figure 2) is vital because it determines how plausible common descent seems (as well as how plausible objections to evolution will seem). In a game of cards, it would be incredibly rare to draw four aces on the first try. But if you have hundreds of card players all trading cards back and forth between their hands, it's virtually certain that someone in the group will end up with four aces almost right away.

Even when creationists with professional scientific training understand that evolution is supposed to happen at the population level, they will still (wittingly or unwittingly) reinforce this misconception because it fits better with their philosophical presuppositions. This approach is seen particularly in statistical or probabilistic arguments, especially among intelligent-design creationists. Demonstrating the difference between the misconception of "individual" evolution and the reality of "population" evolution quickly displays the fallacy in this sort of reasoning.

For example, a creationist may calculate that the probability of a fish arriving at a particular DNA sequence by chance mutation is some astronomical number like 1 in 10^{30}. This number, he believes, is far beyond the limits of what he thinks is reasonable.[1]

1 Some of the smallest protein-coding genes are around 22 codons in length, or 66 nucleotide base pairs; the chance of arriving at a specific 22-codon sequence by pure chance is roughly 1 in 10^{30}. Note, however, that the size of the genome plays a major role here. Even as few as 4-5 different species with genomes roughly the size of our own are likely to have matching sequences of this length in their junk DNA,

Now, his estimate is probably suspect, but that's beside the point, because evolution doesn't happen in just one fish; it happens in a population of fish. A school of fish like sardines may contain 100 billion individuals, each with around 25 chromosome pairs. During meiosis, each maternal and each paternal chromosome can undergo a simple crossing-over recombination two or three or even more times. A single breeding pair of sardines can produce 20,000 eggs in one clutch. And this is just one school; there may be multiple schools of the same species.

If we suppose five separate schools, there is the potential for 1.4 million trillion trillion (2.1×10^{30}) newly recombined genotypes[2] for this species in a single breeding season. Now, this is just a very generalized example; using different numbers would of course generate different results, and a rigorous examination of this question would require analysis of mutation rates and much more. But my rough example illustrates how seemingly astronomical odds can turn out to be much less challenging once a shift is made from thinking in terms of individual evolution to thinking in terms of population evolution.

For individuals who are not interested in learning about the underlying microbiology, the card game example from earlier is probably sufficient: the chance of one lone individual drawing one exact hand off the top of the deck is very low; the chance of somebody getting the desired hand when there are hundreds (or thousands) of players all constantly exchanging cards is very high.

Easy-to-understand examples are vitally important. At heart, these sorts of probabilistic arguments usually advanced by intelligent-design creationists are nothing more than arguments from incredulity: "I can't imagine how it's possible, so it must not be." Although this is an obvious logical fallacy, it doesn't usually do any good to point it out—"just because you can't imagine it doesn't mean someone else can't"—because creationists will merely assume such imaginings are only wishful thinking by atheist evolutionists determined to defend a theory that would otherwise fall apart. That's why it's vital to have straightforward examples to demonstrate the fallacies inherent in the creationist understandings.

---

simply by statistical accident. Also keep in mind that creationists often wrongly assume a gene must be complete and fully functional before natural selection can begin selecting for it and developing it further, but they are wrong. Selection doesn't require the emergence of some new major advantage; selection requires only a functional difference. Even a change in a single codon can alter a protein enough to cause a division to form between the original genotype and the altered genotype. For example, a small mutation that alters the start of the breeding season by even a couple of days can cause a population to divide into two overlapping groups which will continue to evolve both separately and in concert.

2 In ordinary sexual reproduction, each parent contributes half its genetic material by selecting one chromosome from each of its chromosome pairs to donate. Each of the offspring's chromosomes is thus an exact match to an individual chromosome in one of the parents. A crossing-over recombination takes place when pieces of both chromosomes in a given parental pair are spliced together to produce a new donated chromosome. Not only does crossing-over result in a newly arranged package of genes to be passed on to the next generation, but it also creates an entirely new genetic sequence at each splice point. This event is not technically a mutation in the same way as substitution, insertion, deletion, and transposition, but it still generates new genetic information. Fortunately, crossing-over recombinations rarely interfere with any existing functions, simply because it is very unlikely for any given splice point to intersect a functioning protein sequence. When a recombined chromosome is combined with the chromosome from the other parent, the result is a new, complete genotype which is both heritable and selectable.

4 Transitional fossils

One of the most common and most frustrating creationist objections to evolution is the claim that there are no "missing links" or "transitional fossils" required by evolution. This claim is made without qualification, particularly in presentations to lay or church audiences. As unthinkable as it might seem, creationists really do believe that transitional fossils simply do not exist. On this basis, they conclude that evolution must be false.

They maintain this completely erroneous view by consistently misrepresenting what a transitional fossil actually is. Creationists don't deny that *Archaeopteryx, Pakicetus, Tiktaalik, Australopithecus*, and similar prominent examples of transitional fossils exist; they rather argue that these are not "true" transitional fossils.

The last section dealt with misconceptions about evolution on the population level: the "where" of evolutionary change. This installment will focus on misconceptions about how evolutionary change happens over time. Evolution is properly understood as "descent with modification", where the critical word is "descent". The life on earth today is not the same as the life which was once on earth, the life we descended from. As this series has already illustrated, creationists do not dispute the concept of change; rather, they dispute the concept of descent in the way it is described by the theory of evolution.

Young-earth creationists believe that all life, living and fossil, can be grouped into a series of families—they call them *baramins*, a made-up Hebrew word for "created kinds"—which all existed together at the same time from the very beginning. They use this completely artificial understanding of our planet's biosphere in generating their concept of a "missing link": in order for something to be a "true" transitional form under their model, it would have to be something halfway between two separate created "kinds". Because they automatically assign every species to a particular created kind and only to that created kind, their "transitional form" is something that could never exist.

The usual parodies of evolutionary transitional fossils, like Ray Comfort's infamous crocoduck, are openly tongue-in-cheek. But because creationists see all animals as belonging to individual, immutable kinds, they represent evolution as "change from one 'kind' to another" claiming that evolution predicts we should see transitions *between* their "created kinds": for example, a fossil that is midway between a dog and a cat. Just as with living species, all fossil species are placed within strict "created kinds", allowing creationists to maintain the illusion that nothing is ever "in-between".

http://en.wikipedia.org/wiki/Crocoduck

This characterization is a complete misunderstanding of what evolution actually predicts. No one expects one existing species to evolve into another. The "kinds" alleged by creationism simply do not exist in the evolutionary model; there is no line between one family and another that a transitional form needs to straddle.

What creationists don't recognize is that *the theory of evolution does not predict "transitional" fossils at all*—at least, not in the way creationists expect. Evolutionary theory does not predict that there will be "normal" fossils most of the time, while chimaera-like "transitional" fossils will appear tucked in-between. Evolution has no general prediction about a unique class of transitional fossils. Instead, evolution makes predictions about the specific morphology, age, and location of the *individual* fossils it expects to discover. *It bases these individual predictions on other specific fossils that have already been discovered.*When morphology and a variety of other factors indicate that one particular species is the distant ancestor of another particular species, evolutionary principles can be used to predict the attributes of one or more intermediate species.

These predictions can be directly employed to make new discoveries; *Tiktaalik*, the transitional form between lobe-finned fish and all tetrapods, was found in the exact region in the exact range of strata that evolution had predicted it would be found. Adding to the confusion, creationists also erroneously assume that in order for a species to be truly intermediate, it must contain parts that are only partly functional—half-working lungs in fish, half-formed wings in theropod dinosaurs, and so forth. This assumption is another misunderstanding about evolutionary descent. In order for a new trait to become fixed in a population in the first place, the trait must be maximally adapted to the environment. Evolution thus does not predict functionless or half-functioning intermediate organs and morphologies, but rather organs which are fully optimized to their environment but are *repurposed* by a later organism as part of a different design. For example, the human appendix is evidence for evolution not because it is functionless (it does, in fact, have a function), but because it was adapted from the cecum, which provided a different function to our ancestors. All life is full of little bits and pieces showing how evolution has adapted different structures for different purposes in its universal descent. Yet to creationists, none of this is "true" evidence for evolution, because they imagine that "true" evolution would produce functionless structures. Functionless structures, of course, are the one thing evolution *cannot* manufacture.

http://tiktaalik.uchicago.edu/meetTik.html

In applying this belief, creationists invariably move the goalposts. Any hypothetical function, no matter how minor or speculative, is taken to mean that the morphology in question couldn't have been transitional. Even if they can't think of a function, they'll still hold out that there could be a function, and so it's not proven to be transitional—all while completely misunderstanding what a transitional form really is.

These two objections—that a given fossil isn't "really" transitional because it's "not in-between two kinds" or because all its organs are fully functioning—are recycled over and over every time a new intermediate fossil is discovered. Even when a new species is discovered exactly matching a specific evolutionary prediction, it is still discounted using these two objections. Alternatively, creationists announce that the new species is a new "kind" and then point out the two spaces on either side of it as further "missing links". In their eyes, every new link means there are twice as many holes to fill.

Sometimes this misconception can be dismantled by inquiring exactly what sort of transitional fossils the creationist thinks evolution expects. "Describe the specific attributes of a fossil which you would consider evidence for evolutionary common descent." The creationist will either fail to come up with anything (demonstrating that his model is set up to explain away all evidence, no matter how obvious), or will describe something that evolution would not predict in the first place.

5 Evolution of evolution.

Most creationists believe that the theory of evolution was developed out of an ideological commitment to explaining life apart from God. Explanations of the history of evolutionary theory often point out personal struggles in the lives of prominent scientists—Darwin most often, of course—in support of this belief. "Secular scientists wanted a way of explaining a world that didn't require God, so they invented this ridiculous theory." To creationists, this foundation offers an easy way of dismissing all the theoretical and observational bases of evolution. If evolution is just wishful thinking born of anti-theistic extremism, then all the "evidence" is reduced to *ad hoc* speculation.

Because of this misconception, creationists rarely understand the actual history of how geology, paleontology, and biology built upon each other to provide us with our understanding of the world. Mainstream geology emerged significantly ahead of Darwin's work; many early geologists were Christians. Studying the distribution of rock layers around the globe allowed geologists to construct a complete geologic column and begin appreciating the incredible amount of time the column represents. Moreover, the regular progression of extinct species fossilized throughout the geologic column had been well-catalogued.

However, creationism requires that the development of evolutionary theory be ad hoc, driven by presupposition rather than by observation. As a result, they often assert that the geologic column doesn't actually exist: that it's cobbled together from bits and pieces around the world and that the layers aren't actually consistent. It is true that there are few places in the world where all layers of the column (the Hadean and Archean and Proterozoic and Cambrian and Devonian and Permian and Triassic and Cretaceous and Paleocene and Miocene and Pleistocene and Holocene) are visible simultaneously, but this fact does not prevent geologists from identifying them. The layers of the geologic column are identified relative to each other using clear and consistent markers which function the same way no matter where you are in the world. Constructing and identifying the components of the geologic column is not the random guesswork creationism makes it out to be.

In the creationist worldview, the ideas proposed by Darwin came from a desire to explain the existence of life apart from God. They believe all "evolutionary science"

came out of this particular worldview. But that is simply not the case. Darwin was not setting out to explain life apart from divine creation; he was discovering the mechanism behind the already well-established progression of life on Earth. Naturalists already understood that life had existed for millions of years at the very least; they already knew that the geologic record showed innumerable species living and flourishing and going extinct all one after another. Creationists like to frame the story as though Darwin invented the theory of common descent and then looked for evidence to fit it, when in fact his theory explained the evidence that already existed.

The idea that evolution is ideologically driven obscures its very straightforward history giving creationists an excuse to believe the development of evolutionary theory has been entirely *ad hoc*. This belief often manifests in accusations of circular reasoning, like the infamous, "You use the fossils to date the rocks, and then you use the rocks to date the fossils!"

In reality, of course, the established order of the geologic column had already placed stringent constraints on the design of the emerging evolutionary tree. The geological column is not just a bunch of fuzzy layers identified on the basis of the fossils discovered in them. Rather, each layer has specific properties which can identify its place in the complete column regardless of where it is in the world. The placement and distribution of fossil species within this column was already well-understood prior to the formulation of Darwin's theory. Yet creationists insist, based on their preconceptions about the atheistic basis of evolutionary science that the tree is fictitious and is thus completely arbitrary. To creationists, the placement of fossils within the tree of life is haphazard; creatures are just shoved in wherever they might fit, with no constraints whatsoever.

Creationists will make use of any evidence they can find that seems to support their beliefs about the *ad hoc* development of the evolutionary tree. They will go to great lengths in discussing the slightest revisions or alterations to the tree. Any change, however slight, is taken to mean that the whole tree is arbitrary. They will hunt down obscure speculations from fringe scientists suggesting changes to the evolutionary tree, just so they can support their belief that the tree is constantly in flux. Even the most tentative suggestions of a different interpretation of the evidence will be seized, quoted, and re-quoted.

This misconception comes from a lack of understanding of how the scientific community functions. With hundreds of thousands of research scientists in the United States alone and over a million journal articles published worldwide each year, new hypotheses are constantly being proposed. But just because something shows up in a research journal doesn't make it part of the scientific consensus. Ideas enter the realm of established science only when the initially proposed hypothesis is confirmed by subsequent research and discovery. All the major facets of common descent have been challenged numerous times, but they have remained constant within the scientific community for well over a century.

Creationists with formal training in the research sciences may be more familiar with this process, but laypeople—especially laypeople with existing skepticism toward science—will be harder to reach. Either way, the best approach is usually to start from the ground up, showing that the great age of the geologic column was well-established long before evolutionary theory emerged and that the fossil record isn't nearly as malleable as they typically assume it to be.

Often, creationists will point to what seem like large shifts in the dating of fossils

as proof that evolutionary theory is simply adapted to fit the evidence rather than making any consistent predictions. Admittedly, a change of 1-2 million years seems huge. But in comparison to the 4.5 billion year lifespan of Earth, it's not so big. A shift of 2 million years in a 4.5 billion year history is like changing the time of a weekly meeting by four and a half minutes.

The idea of an arbitrary evolutionary tree produces two major objections from creationists. The first objection is that if evolution can adapt to match new evidence, it must not be very certain about anything. This argument is easily addressed by pointing out that there are limits to what evidence evolution can adapt to. Numerous discoveries would invalidate evolution: the famed Precambrian rabbit, the existence of completely unique morphologies with no evolutionary precursors, or any sort of true chimaera with body parts from unrelated species.

The other objection is purely philosophical and much more difficult to address. Creationists equate science's dependence on the explanatory power of evolutionary theory with their dependence on doctrine and dogma in religion. Because they feel that religious truth must be static and unchanging, they deride evolutionary theory as "not trustworthy" simply because it can change to accommodate new evidence. They demand an authoritarian source of Absolute Truth which will not change or adapt.

Absolute certainty may be a comforting foundation in the sphere of religious dogma, but science doesn't work that way. In fact, it can't work that way; science is predicated on the supposition (the real underlying "assumption") that ideas must constantly change and adapt to reflect new evidence so that we can continue to better predict processes in the world around us. The truths obtained in science are based in experience, trial, and error; the truths people seek through religion are based in revelation, faith, and trust.

Obviously, the scientific model of evolutionary common descent does not make any claims about morality (though this has not prevented many people, scientists and nonscientists alike, from using evolution or pseudo-evolutionary ideas as the justification for certain ethical or moral claims). Ideally, it would be possible to simply explain that evolution makes no necessarily or intrinsic moral judgments, but many creationists will insist that it does. This misconception is entirely separate and will be addressed further later.

6 Genetic evidence

Perhaps one of the clearest and most obvious confirmations of evolution is the convergence between the evolutionary paths of descent determined by fossil evidence and the phylogenetic tree generated by algorithms analyzing genetic information. Because the tree of universal common descent is real, not invented, it leaves the same fingerprint in every part of nature that life touches. Matching trees can be found in global fossil distribution, in analysis of skeletal morphologies, in chromosome length, count, and banding, and in numerous common genetic sequences.

Not every genetic sequence yields a perfect branching tree. Evolutionary theory would not predict perfect branching trees, because random mutations scramble the relationships over time. Even though mutations provide the variation needed for diversification, their accumulation throughout that diversification can eventually obscure the evidence needed to reconstruct those relationships.

Reconstructing phylogenetic relationships is made more difficult because the number of combinations in any given sequence is finite. Every three letters of our DNA codes for only one of twenty different amino acids. Just four or five species with a genetic code as long as our own will have sequences of 60 or 70 base pairs in common—enough to code for simple proteins—simply due to the laws of probability[1]. Such coincidences can also make it more difficult to resolve perfect phylogenetic trees.

It would be a grave mistake, however, to suppose that these difficulties render phylogenetics useless. Just because certain sequences have become corrupted does not mean that a useful tree cannot be constructed. In fact, hopelessly corrupted sequences are the exception, not the norm. When we compare many trees from many different sequences, the accurate phylogeny converges rapidly.

Creationists are fully aware that the match between fossil evidence and genetic evidence is damning. If they match so closely, then common descent must be valid—how else would such agreement be possible? In order to avoid this inevitable conclusion, they seek to invalidate either fossil evidence, genetic evidence, or both, and claim that the apparent convergence is identified only through persistent confirmation bias.

Confirmation bias, of course, takes place when a particular piece of evidence is selected from among many contradictory pieces of evidence because it alone confirms

1 As mentioned in an earlier section, we have about 3 billion base pairs comprising 1 billion codons, each of which can code for up to around different 20 amino acids. Only 1-2 % of our genome codes for proteins at any given time, so even though the rest of our DNA can participate in the regulation of certain cell functions, it's pretty malleable. A simple protein may only be a couple of dozen amino acids long, corresponding to about 66 base pairs of length. There are still just under a billion possible 66-base-pair sequences in a 3-billion base-pair genome, meaning that just five different species will have 10^{36} chances (1 billion to the 4^{th} power) to have two matching 66-base-pair sequences. Since there are 2^{30} possible 66-base-pair nucleotide sequences, those five species will have hundreds of thousands of 66-base-pair sequences in common.

the researcher's presuppositions. This is almost never a conscious process; someone affected by confirmation bias rarely realizes it. The accusation of bias, then, fits perfectly within the creationist paradigm that mainstream scientists are simply too blinded by their assumptions to see the truth. They don't even have to accuse scientists of actual dishonesty; it's all presumed to be part of a nearly innocent, unwitting bias.

Earlier sections have explained how creationists attempt to invalidate the match between the fossil record and the predictions of the evolutionary tree. If they cannot challenge the tree, they will challenge the genetic evidence in whatever way possible.

The most common claim made by creationists unfamiliar with phylogenetics is that the sorting algorithms are somehow "set up using evolutionary assumptions". This objection reflects a clear lack of understanding. True, the phylogenetic algorithms are set up to produce a branching tree—but the whole purpose of the test is not to establish whether a tree exists but rather to determine whether it is an accurate tree. Creationists imply that there's some hidden evolutionary guideline built into the algorithm to make it yield the desired result. But that implication is flatly false. The algorithm has no guidance; it has no means of distinguishing between sequences apart from their contents.

Creationists who understand a little more about the subject will instead argue that not all portions of the genome consistently produce the same tree, so researchers are merely picking a tree that just happens to match their expectations. Like many creationist arguments, this simple argument unfortunately makes some intuitive sense. It's wrong because it doesn't take statistical probabilities into account.

The more items you have in a given collection, the more ways they can be arranged. Just five items can be arranged in 120 different ways, and ten items can be arranged in a staggering 3.6 million ways. Arranging them in a rooted tree makes the task more complex, so there are many many possible trees; it's not feasible to simply cherry-pick the one that "happens" to match expectations. In order for any meaningful phylogeny to show up at all, there has to be a legitimate pattern, an actual phylogenetic symbol. If geneticists were just cherry-picking whatever tree matched their expectations, we would never expect to learn anything from phylogenetic analysis. However, phylogenetic analysis *does* yield new information. Details are often updated or revised due to the results of genetic studies. The science works. Moreover, it's vital to understand that phylogenetic analysis is not limited to one sequence at a time. Phylogenetic analysis is performed on many different gene sequences, allowing researchers to compare results from multiple sources and weed out corrupted data. Corruption is possible, but it never happens the same way more than once, so when multiple sequences generate the same tree over and over researchers can have a high degree of confidence in the result. All of these essentials details about this scientific process are missing from the creationist understanding.

Once they cannot deny that both the fossil record and the genetic evidence are unassailably valid, creationists unveil one more argument: "common design".

Common design—that morphological and genetic similarities are the result of a designer re-using the same parts—is the perfect creationist argument because it can apply to absolutely anything. No matter how obvious the path of descent is, creationists can simply claim it was intentional. They may also use it in combination with the other objections. For example: "Common design created genetic similarities in creatures with similar environments, similar diets, or similar appearances. These similarities reduce the number of phylogenetic trees to the point that researchers can simply pick whichever one happens to match their evolutionary assumptions."

The obvious problem is that common design is unfalsifiable. There's no limit to what it can explain, no level of commonality it cannot be used with. We recognize that an explanation which can fit literally anything is useless; it doesn't tell us anything. Unfortunately, creationists don't care whether their explanations are falsifiable. Their presuppositionalist background tells them that it doesn't matter whether explanations are falsifiable—it's just necessary to make sure they have the right presupposition at the outset, and everything else flows from that. As long as their denial of mainstream science seems vaguely plausible, they are okay.

So instead of pointing out the unfalsifiability of common design, it's better to let them use it, but challenge them to take it to its logical conclusion. If their divine common design can really produce the observed levels of genetic similarity, then it should also produce clear and obvious genetic similarities in species that aren't anywhere close on the evolutionary tree. Not just small sequences in common, but entire gene suites. If God is in the practice of re-using the exact same gene sequences in creatures that happen to show up close together, then we should see the same thing in distant species. Species identified in mainstream science as examples of convergent evolution—the same traits or abilities having evolved separately—should have perfectly matching gene sequences placed there by the creator. For example, bats and birds evolved echolocation separately using different genes, but the "common design" argument would predict the same exact gene sequences.

Any discovery of this nature would be strong evidence for common design. Evolution can explain convergent abilities or small convergent sequences, but not convergent gene suites. Offering creationists this opportunity to demonstrate what they're claiming puts the onus on them rather than leaving you to try to falsify an unfalsifiable claim.

7 The religion of evolution

The final set of creationist misconceptions about evolution surrounds its supposed religious, moral, and ethical implications. These objections prove difficult to address, simply because they have little or no objective basis and are almost purely philosophical or religious. This section will concentrate mostly on explaining the relationships and connections between these arguments, as systematically refuting them would delve deep into philosophy and theology and is far beyond the scope of a single post.

Many creationists assume as self-evident that evolution precludes the existence of God, not because of any qualities intrinsic to evolution, but because their concept of God is dependent on creationism. Officially, creationists usually teach that the Bible is our only infallible revelation of God's existence, but in practice the "fact" of special creation is treated as a primary basis for belief in God. The "testimony of nature" is implicitly held up as proof of God's existence. Every time a particular piece of purportedly creationist evidence is described, the underlying implication is that God's existence depends on six-day special creation. Thus, to even propose that evolution *could* be true is automatically a "challenge to the evidence" for God's existence.

The assumption that "evolutionism" and "secular science" denies God's existence applies not only to the suggestions that evolution might be possible, but more generally to any challenge to creationist arguments. While some creationists take pains to discard the more outlandish arguments, others will fiercely defend obsolete and ridiculous theories simply because of their perceived apologetics value. This stubbornness is the source of animosity and division between the various creationist movements; each group points to "concessions" and "compromises" the other groups make, because any compromise is considered a tacit admission that maybe the evidence for God isn't quite as strong as it would otherwise be. Such arguments are all God-of-the-gaps arguments, of course, but this fact goes unnoticed.

Creationists often make this argument more explicit by quoting Romans 1:20, the atheism/agnosticism clobber text:

> *…since the creation of the world His invisible attributes are clearly seen, being understood by the things that are made, even His eternal power and Godhead, so that [men] are without excuse.*

To a creationist, this verse means that the testimony of nature is sufficient to establish God's existence, God's attributes, and God's nature even without revelation. Thus, it is claimed, atheists and agnostics have no excuse for unbelief. Embarrassingly, I once hosted a (short-lived) Internet radio show called "Without Excuse" predicated on this idea.

Creationists believe that if common descent is even a remote possibility, then God's existence is no longer demonstrated by nature. Even the discussion of whether evolution is possible challenges their "testimony of nature", so it challenges their certainty about the existence of God.

Certainty is a major theme in much creationist theology. A false dichotomy is set up: either you are absolutely certain about God and the Bible and the gospel, or you are doomed to wallow in doubt and probably end up lost. This dichotomy combines personal pride with fear of the unknown. Creationists will typically admit doubt about their own salvation long before they will dream of admitting doubt about special creation. Because their narrative of absolute certainty is something science obviously doesn't offer (science embraces and depends on doubt and questions), they must preserve it at all costs.

If a person's primary reason for believing in God is special creation, then it is a tenuous faith at best. The majority of Christians accept that God could have used common descent to bring about life on Earth without any hazard to their faith. More importantly, Romans 1:20 is not a polemic against atheism at all; it is rather a polemic against Roman idol-worship. Reading on in the chapter:

Professing to be wise, they became fools, and changed the glory of the incorruptible God into an image made like corruptible man–and birds and four-footed animals and creeping things. [Romans 1:22-23]

Modern atheistic humanism obviously did not exist in Rome, and this passage did not, in fact, address atheism. It was warning against something else entirely: using the natural world as a basis for religion, making gods patterned on men and birds and animals. Worshiping these sorts of gods, argued the author, effectively replaces the Creator with the creation, reversing the proper order of things. In spreading out of Judea and into Rome, fledgling Christianity sought to overcome the perception that Jesus was nothing more than another regional deity. So they preached a Creator God who was not known based on imagery taken from creation, as with the many gods worshiped in Rome, but through the revelation they had received from Jesus.

Ironically, creationists who define their God's existence as dependent on the doctrine of special creation are tying their theology to their perceptions of nature, committing the very mistake this passage warns against. Of course, they won't recognize this irony. They'll insist that merely admitting the possibility of evolution goes against the Bible. In pursuit of further confirmation of this prejudice, they dream up moral problems with evolution and common descent.

One objection to the idea of God's using evolution is that it would somehow be inconsistent with God's nature to use any process depending on "chance". As we've already seen, this objection depends on misconceptions about evolution being a "chance" process. Creationists suppose that "natural processes" are random and chaotic, and are thus somehow "beneath" the ways of a God who they argue must order everything perfectly. A more common, strident objection is that God would not use death or suffering as part of his creative process, therefore excluding evolution. To propose evolution as a possibility is to associate death and suffering with God's intent for the world, something young-earth creationists argue should be immediately rejected. This view may seem incongruous; after all, creationists have no difficulty believing that God sent a global flood to wipe out nearly every living thing on the planet. But the objection to the process of evolution should be understood as coming from a particular theological doctrine, not a generalized opposition to struggle and suffering. These creationists believe (based on Genesis 1:31 and Romans 5, along with other passages) that physical death could not have existed during the six days during which God completed the creation of the world. Obviously, this objection begs the question whether the six days are literal days: theistic evolutionists already see the six-day creation week as metaphorical.

Moreover, even in periods of church history where a six-day creation week was universally considered historical, the *theological significance* of Genesis was still primarily spiritual. The assignment of *physical* theological significance to creation, the fall, the flood, and so forth—the idea that death itself is a physical abnormality resulting directly from a single physical human action in history—is only a very recent and very sectarian doctrine. The Church has historically interpreted the Curse and Original Sin in many different ways, only a handful of which bear any resemblance at all to the YEC dogma.

Insistence on specific physical events as necessary for spiritual or theological models is rampant throughout evangelicalism. Some denominations insist on various spiritual signs like healings or speaking in tongues. Others attach vital significance to the event of baptism or to the verbalization of a particular prayer. Virtually all evangelical denominations insist that the Crucifixion achieved its purpose by meeting some predetermined set of physical conditions for sacrifices.

This practice of assigning essential spiritual significance to particular physical events has been around for a long time. It is the basic pattern of religion: making certain rituals and events and beliefs necessary components of salvation offers a more tangible object of faith, strengthening religious fervor. In the case of creationism, faith in the "scientific evidence" of a young planet and a global flood bolsters faith in the doctrines supposedly defined by those events. Of course, this practice inevitably backfires; when the faithful realize that the "science" is a con, they lose their sole basis for belief in the doctrines and jump ship. Rather than recognizing that they are responsible for creating this problem, creationists and other evangelicals take offense at the doubt and start insisting all the more strongly on the very arguments that are disillusioning their followers.

Additional objections remain. Creationists may argue that without God, we have no reason to trust logic or science. Of course, this claim begs the question as well, as it presupposes that God is the source of logic. And since evolution is not intrinsically atheistic, it's not really relevant; the antagonism comes from the creationist theology. Finally, we don't use logic because we have faith that it's true; we use logic because it provides useful results.

Often, scientists suggest evolutionary explanations for the genesis of certain behaviors or traits. Some creationists erroneously assume that, in consequence, evolution can be used to justify any sort of behavior. This, too, comes from their theology; they believe that all sin and death and suffering arise from a series of physical events in history - the Fall - so they naturally assume that an evolutionary history would give rise to an evolutionary morality. On the contrary, derivations of morality from evolutionary history are idiosyncratic; evolution is a description of what happens, not what ought to happen. Supposed "evolutionary morality" comes from the application of an essentialist philosophy, not from the study of natural history itself.

The final area of philosophical objection to evolution deals with the supposed implications of natural selection: that it supposedly demands "survival of the fittest" and thus leads people to commit selfish or immoral acts. Similarly, other creationists allege that the idea of higher or lower animals will prompt racism or lead us to treat other people "like animals". Yet this accusation only goes back to the creationist mindset that historical events dictate present moral imperatives - a view which is specific to that particular Christian group. Likewise, there are no higher or lower animals in properly understood evolutionary theory; all extant species are equally modern because they have all adapted to their present modern environments. The notion of treating people

differently because they are related to animals comes not from evolutionary ideas, but from the creationist belief that animals and humans are separated by essential physical differences, humans being in the "image of God". Creationist moral frameworks are so ingrained that they end up being applied illegitimately to the evolutionary model. Such essentialist philosophies are the reason things like eugenics were taught and believed: eugenics originated with the idea that, because survival of the fittest got us here, we ought to continue the process and cull out the weak. Creationists suppose that such ideas are somehow intrinsic to evolutionary theory, when in fact they require broad philosophical leaps that in no way derive from evolution itself.

All of these religious and ethical objections are, of course, problematic at the outset. Even if they were accurate (and they aren't), they wouldn't change the truth value of evolutionary theory. They are examples of *argumentum ad consequentiam*, a logical fallacy in which a proposition is deemed true or false because of its purported implications. Creationists suppose that evolution is accepted because of its philosophical implications and argue against it on the basis that it has immoral implications, but neither of those things are true. Evolution is accepted because it accurately describes reality. No more, no less.

8 New perspective.

I think there are several different varieties of creationism activists. Some are obsessed with the presumed negative effects of evolution and secular humanism. Some are driven by suspicion for science and the certainty that a conspiracy must be afoot. Some use creationist apologetics to make themselves feel smarter and better-informed than the general public. Some are genuinely interested in science and want to know the truth.

I'd be lying if I said my motivations for arguing creationism were firmly in the last camp. I wasn't much of a conspiracy theorist, but I certainly believed that there were inevitable negative consequences from the acceptance of evolution. I was definitely stuck-up about my "special" expertise. But deep down, I really did want to know the truth about the world. I loved being right, but I loved learning new things more.

As prior posts have explained, fundamentalist evangelicalism buttresses itself against criticism at every conceivable level. Not only must the existence of God be treated as evident from nature; the existence of God must be treated as beyond any doubt. To the fundamentalist YEC, no overall view of natural history can be even remotely possible unless it can be used as evidence to prove the existence of God.

I maintained young-earth creationism without much difficulty through college. The major objection to creationism encountered in earning a physics degree is the starlight-and-time problem, and I believed that the gravitational-well time-dilation model proposed by Russell Humphreys solved this problem. It never really came up in my classes. My ongoing exposure to the evidence against creationism came mostly in the form of continued argumentation and debate in various online forums, just as I had done before college.

I still wanted to maintain intellectual honesty, but I felt constrained by my religious belief. When I encountered questions and evidence I didn't know how to answer, I retreated to a position of false humility: "Well, I don't know how that works, but I'm sure that if I was an expert in that area, I could figure out how the evolutionary argument is wrong." I knew that there were physicists and biologists and geneticists working for creationist organizations who rejected evolution; surely they understood how it all worked.

There's not much you can do to challenge that particular approach. It's the same response I get now from creationists after I've answered all their objections. "Well, fine, but science is always changing, and scientists have been wrong before, and so you never can be sure about any of this."

As frustrating as this response can be, it's difficult to counter because it's sincere. They really believe (and, at one time, I really believed) that the scientific process is constantly in flux, that evolution is "just a theory", that scientists are just taking guesses in the dark. They really think that science can't provide truly useful answers.

In the recent debate, Bill Nye strongly implied that creationism hinders the teaching and progress of science. While this may be the case in some situations, I believe

the opposite is far more true: a lack of scientific literacy and misplaced skepticism of the scientific method enable pseudoscience like creationism to flourish. This is the problem I believe we need to address. Otherwise we are simply seen as making an appeal to authority right alongside the creationists.

Thankfully, my ability to maintain the "science could be wrong" excuse wore thin. I learned about research methods, about confidence intervals, about peer review. I learned to isolate variables, to vet sources, to establish controls. I learned that the scientific process is designed to weed out mistakes and that when mistakes are made, the process will tell where and why and how to correct them. The more actual science I learned, the more I could simply examine the evidence myself, and the more difficult it became to continue unchecked skepticism.

Though I still firmly maintained a belief in young earth and special creation, it became more and more apparent that evolution was not, after all, a theory in crisis. The evidence lined up and made sense; the model worked; the predictions were good. I kept looking for the smoking gun, the telltale traces and shortcuts I would expect to see if evolution were really the junk science I had always believed it to be—but I found nothing. Evolution was, to all appearances, rock-solid science.

I didn't feel like this discovery was something I could admit. I still claimed confidence in the whole young Earth creationism worldview. But I had confidence in the scientific process, too, and they seemed to clash rather strongly. Moreover, while creationism had only *demanded* my confidence, science had *earned* my confidence. It was a distinction I wasn't terribly comfortable with.

About this time, I came across this brief essay by noted biologist Todd Wood:

http://tinyurl.com/ye9xmku

> *Evolution is **not** a theory in crisis. It is **not** teetering on the verge of collapse. It has **not** failed as a scientific explanation. There **is** evidence for evolution, gobs and gobs of it. It is **not** just speculation or a faith choice or an assumption or a religion. It **is** a productive framework for lots of biological research, and it has amazing explanatory power. There is **no** conspiracy to hide the truth about the failure of evolution. There has really been **no** failure of evolution as a scientific theory. It works, and it works well.* [Emphasis in original.]

Yet Todd Wood was, like me, a strident creationist. Hearing another creationist say all the exact same things I had been unwilling to admit was suddenly liberating. It was all right to acknowledge that the science worked. It was all right to acknowledge that the evidence fit together. It was all right to acknowledge that "evolutionists" were in fact sincere. My faith in God wasn't going to instantly disintegrate just because I admitted that common descent was a feasible model.

The essay went on:

> *There is evidence for evolution, and evolution is an extremely successful **scientific** theory. That doesn't make it ultimately true, and it doesn't mean that there could not possibly be viable alternatives. It is my own faith choice to reject evolution, because I believe the Bible reveals true information about the history of the earth that is fundamentally incompatible with evolution. I am motivated to understand God's creation from what I believe to be a biblical, creationist perspective. Evolution itself is not flawed or without evidence. Please don't be duped into thinking that somehow evolution itself is a failure.*

This, too, resonated with me. I didn't have to keep trying to convince myself that evolution was a patent absurdity, fraught with problems and utterly indefensible. Instead, I could embrace evolution's strengths in pursuit of a better understanding of the world, looking toward a new theory that would better explain the evidence while also explaining how evolution had achieved such success.

To that end, I stopped listening to ill-informed people who continued to insist that evolution was absurd and hopelessly flawed. What could they teach me? I wanted to understand the evidence, not listen to people ridicule a theory they clearly didn't understand.

The new perspective began yielding results almost immediately. Suddenly, the fallacies in creationist arguments and rhetoric seemed breathtakingly obvious. The more I learned, the more distance I felt from creationists, who only ever seemed interested in mocking.

I studied pseudogenes and phylogenetics and endogenous retrovirus insertions. I researched genetic clocks and homology and morphology. I looked at endemic species and fossils; I read studies on observed mutations and novel genes. The deeper I dug, the more creationist answers seemed not only unsatisfying, but patently ignorant of the subject matter. I tried formulating my own explanations that made testable predictions, but they inevitably fell flat.

All the while, I still maintained that even if evolution *could* work, it wasn't fact, because the planet wasn't old enough. Granted, I could see how the planet *could* be billions of years old—flood geology was wearing a little thin—but I was still constrained by religious belief to a 6,000-year-old universe. I think I really did know the truth at this point, deep down, but I didn't feel like I could admit it.

Then I started learning about the history of creationism, and that's where things started to crack. I learned that the age of the earth had never been a dividing issue in Christianity, not until Morris and Whitcomb plagiarized flood geology from the Seventh Day Adventists in the 1960s. I realized that not even the church fathers saw Genesis 1 as speaking of six actual days. Martin Luther was one of the only six-day creationists in church history, and he also believed geocentrism for the same reasons, so that wasn't very encouraging. I began to see how there might be problems with the "historical-grammatical" approach to interpreting Genesis. *If the creationist leaders were so far wrong about science, why should I expect their treatment of the Bible to be reliable?*

And finally, one day, I was reading about transit times for cosmic rays and stumbled onto an article about stellar streams. When a small galaxy or a star cluster passes by the Milky Way, the tidal effects of the Milky Way's gravity rips away a stream of stars, which are left floating in space to mark the path taken by the cluster. The stellar wakes crisscrossing our galaxy are all many tens of thousands of lightyears long.

I realized that no matter how creatively one might spin it, there's no way any structure 20,000 or 30,000 lightyears long can form in 6,000 years[1]. It's simply

1 It's probably possible to come up with an explanation for stellar streams that sounds vaguely plausible. The prevailing creationist cosmological model features the entire universe being created out of water and God causing runaway inflation while simultaneously transmuting the water into stars and galaxies and everything else. A creative creationist could probably posit that the overall shapes of macrostructures like stellar streams (and galaxies themselves, for that matter) formed rapidly while everything was still extremely compact, and that the creative process "stretched out" these structures as their constituent material was supernaturally transmuted into stars. Of course, stellar streams aren't the only macrostructures we see. My favorite example is ESO 137-001, a galaxy

http://tinyurl.com/knck2k9

absurd. And while I had no problem with the notion of God creating a universe "in motion", so to speak, it simply didn't make sense that he would need to create dozens of completely phony wakes all over our sky. I immediately realized that the universe had to be very, very old.

As I continued reading, I toyed with the idea of a young solar system inside an otherwise very old universe. This stage lasted about six minutes, if I remember correctly: the floodgates had opened and everything I had ever read or learned about the age of the earth came rushing back. It was all so obvious. Orbital mechanics clearly matched observed climate shifts. Independent lines of radiometric dating worked just fine. Cosmic expansion fit observations. The cosmic microwave background really was the afterglow of the recombination epoch. Geology made sense. Plate tectonics made sense. Erosion rates and geomagnetic reversals and everything else fell together in a perfectly aligned puzzle stretching back to the beginning of time. I suddenly realized I had known it all for a long time but had never allowed the pieces to come together all the way.

I didn't tell anyone at first. It's scary to undergo a complete paradigm shift. Over time, though, things became easier.

One of the things I've explained before is how fundamentalism often defines its doctrines in terms of their position on science. This redefinition is intended to bolster faith in the doctrines, but when the pseudoscience is exposed, it often takes those doctrines down with it. It has been difficult to reevaluate my religious beliefs outside of the backdrop of creationism, but the process has been very rewarding overall.

I was recently asked what I would go back and tell my teenage self about creationism, given the opportunity. All I can think of is to encourage my former self to study and understand the scientific method. That's what made all the difference for me.

How do you reach creationists? Well, it can be difficult. There are a few things to keep in mind, though.

Be patient. I do not think I would have ever made the switch if not for all the people who painstakingly pointed out my errors over and over, and forced me to look at the evidence for myself. It might seem futile, but you *can* make a difference.

Know your enemy. And your enemy is not the person you're talking to. Your enemy is the fundamentalist worldview telling the person how they are allowed to think. Understand how it works; understand where the beliefs and rhetoric are coming from. Ask questions. The more questions you ask, the more your opponent will be forced to investigate things for themselves. And that's where the real progress is made. Read creationist literature and try to see where the arguments are coming from.

Know your role. You're the teacher. Understand the evidence and the arguments. Know your facts. Pseudoscience flourishes because real science does not. It's a popular trope in fundamentalism that True Religion automatically displaces false religions, so the Christian doesn't even need to study other worldviews as long as he's secure in the Truth. That might not be a very good argument in a religious context, but it's absolutely true of science. Real science displaces pseudoscience: tell a man about science and he might trust your authority, but teach a man how science works and he won't need your authority at all. Do your best to instill confidence in the scientific process apart from the question of origins.

---

that has left a trail of stars and hot gas hundreds of thousands of lightyears long as it forces its way through the center of its galaxy cluster. And of course there are numerous supernova remnants with nebulae much larger than could form in only 6,000 years.

Stick to the facts. Activists like Dawkins make the mistake of accepting fundamentalism's claims of validly representing the Bible in particular and religion in general. But fundamentalism's claims are simply false. As I stated before, creationism botches literary and biblical criticism just as badly as it botches science. Don't ever make the mistake of attacking a creationist's faith; if you do so, you're simply reinforcing their misconception that evolution is synonymous with atheism. Read the explanations given by theistic evolutionists. Ask questions like, "How do you know your interpretation of the Bible is correct? How do you know that Genesis should be treated as chronological narrative? How would the original audience have understood it? Why wasn't your interpretation a majority view throughout Christian history?" Be prepared to explain the history of creationism.

Be generous. Creationists will often employ *ad hominem* attacks, confuse correlation with causation, and use numerous other gross fallacies. Recognize how these approaches come out of the worldview. Assume your opponent is sincere. Understand how difficult it is for a creationist to question deeply held views that he thinks have essential religious importance.

Keep learning. The evidence continues to accumulate every single day. The strength of science is not that we know everything, but that we know how much we have left to learn.

Acknowledgments.

I want to thank everyone who has followed this series, as well as everyone who has been involved in the ongoing discussions. I've seen a lot of great questions and good ideas. I also want to thank the handful of creationists who have consistently provided excellent examples of the very misconceptions this series was intended to outline.

My family also deserves credit. Even though they don't share my conclusions, they were the ones who initially instilled my desire to find out the truth, and that's what is most important.

I should acknowledge Dr. Lisa Blankinship, one of the biology professors at my alma mater, for helping me nail down some of the critical concepts concerning reproduction and the principles of evolutionary progress, as well as Dr. Joel Duff of the University of Akron for help with understanding genetics and DNA.

Finally, I need to thank Dr. Young, both for hosting this series and for his Eagle-Eyed Editing™. His extensive editing tips, fact-checking, and proofreading really helped me make this series clear and concise; I couldn't have asked for a more thorough and helpful editor.