

# WEIGHED AND FOUND WANTING

A critical analysis of *The Origin of Life - Five Questions Worth Asking* and  
*Was Life Created?*



This work is licensed under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License. Attribute to JB. To view a copy of this license, visit <http://creativecommons.org/licenses/by-nc-sa/3.0/>

## 1.1 Introduction

In 2010, The Watchtower Bible and Tract Society began printing and distributing two publications that address an alleged deficiency at the heart of the modern scientific enterprise, namely the field of biology. The two works, titled *Was Life Created?* and *The Origin of Life - Five Questions Worth Asking*, present various criticisms of the evidence supporting biological evolution and argue that the origin and diversity of life is better explained by a supernatural creator god, specifically the God of the Bible.

In many ways, the case presented will be familiar to those who have read earlier religiously motivated writings targeting the theory of evolution. Included are standard creationist tropes like the assertions that life is too complex and wonderful to be explained by natural processes, that the emergence of novel species is impossible, and that “true” religion and “actual” science are fully reconcilable.

However, there are some unique features of the material that should be noted. For example, the editors clearly avoid any politically charged language. Absent is the phrase ‘intelligent design’ and even terms like ‘creationist’ and ‘creationism’ are used very sparingly. Attempts by other religious groups to force creationism into the public school science curriculum are dismissed. So-called “fundamentalists” are ridiculed as much for their disregard of scientific evidence as for their “incorrect” interpretation of Scripture. Additionally, an effort was made to increase the transparency of the sources and quotations cited. Many of the scientific claims reference a bibliography, and several quotes from biologists feature an asterisk and the caveat that the person mentioned actually

accepts evolution.\* Lastly, both documents focus primarily on scientific and logical arguments. While the Bible, God, and religion are featured multiple times, they clearly play a secondary role in the presentation.

Many of the above mentioned editorial tendencies are ostensibly honorable. It may even be that the publishers are responding to complaints about their past writings dealing with the same subject. Despite these efforts and their motivation, the actual arguments presented fail to hit their target. The reasons for this are predictable. The logical appeals are confused and structural fallacies abound. The supposed “evidence against evolution” is manufactured from science that has been misunderstood, misapplied, or left conspicuously incomplete. As is often the case with people who are more accustomed to arguing about prophecy than phylogeny, the authors completely fail to grasp the purpose, method, and goals of science. The quotes, notwithstanding attempts at transparency, remain out of context and grossly misleading. The result is altogether unconvincing. This paper will address the specific claims made and evaluate the conclusions offered.

## 1.2 The Nature of Science

In order to grasp the considerable flaws in *Was Life Created?* and *The Origin of Life* (hereafter referred to as WLC and TOL respectively), one must have a basic understanding of the fundamental nature of science. Science involves observing empirical facts about reality and using

---

\*Readers are left to wonder how it is that a scientist can be intelligent and honest enough to utter the superficially creation-friendly quote while simultaneously working in the field of evolutionary biology.

them to formulate coherent theories to explain natural phenomena. New measurements and observations are continually being made, and therefore more facts made available. Hence, theories must be continuously revised, expanded, or superseded. This is not a weakness, rather it is the secret to the success of the scientific method. The fact that scientific knowledge is always open to newer and better evidence ensures that the theories produced are as close to truth as currently possible.

It must be noted that the sense in which the word ‘theory’ is used here differs greatly from the way it is often used in everyday speech. In colloquial terms, a theory is a guess, a conjecture, or maybe just a hunch. Many laypeople assume that science progresses from a hypothesis, to a theory, and finally to a law. This is a source of great misunderstanding which is exemplified when people state that “evolution is just (or simply) a theory”, implying that if scientists were actually confident in their findings they would call it the Law or Fact of Evolution.

In actuality, facts are the raw material on which science operates. Factual observations are important, but they are not the highest goal of science. Science seeks to understand why nature behaves in a certain manner. Understanding requires the application of an orderly process to gather and evaluate evidence. This process can be called the scientific method.

The scientific method usually proceeds in the following manner. A particular set of facts leads a scientist to pose a hypothesis. A hypothesis is a conditional statement in the format “if A happens, then B will follow.” Suggestions for potential experiments flow naturally from this structure. An experiment can be arranged such that A is brought about and the scientist can observe if B is the result. Hypotheses, however, do not

contain any explanations. At this stage, nothing can be said about whether A caused B, or what mechanism connects A and B. A hypothesis can be useful, but it does not impart understanding.

The same can be said for a law. A law is a simple description of some physical phenomena. For example, Newton’s law of universal gravitation describes the gravitational force generated between two objects. It does not explain what gravity is, or why it attracts things instead of, say, repelling them. Nonetheless, this law is useful for calculating the trajectories of many objects, including cannon balls and satellites. This is what a law really is, a generalized description that can be applied in normal circumstances. Although they are reliable tools for predicting natural phenomena, laws are not the “final word” on nature, and they are not accurate in all situations.

Once a hypothesis has been formulated and an experiment performed, the results of the experiment will either support the hypothesis or not. Assuming the observations were positive, a scientist may start to form a theory to explain the data. A good theory will provide a coherent explanation for the data that have been collected and will suggest new hypotheses to be tested. In this way, a theory constantly branches out to incorporate an ever increasing selection of experimental results, being shaped and trimmed depending on the success or failure of the experiments. Strong, well supported theories are the crown jewels of science. That does not mean they are static objects beyond the scope of future revision, but simply that they provide the best understanding of the world given current knowledge. There is no end to the scientific process. At no point will a scientist stop investigating and claim to possess “absolute truth”. There will always be some piece of data that is not un-

derstood yet, a question that has yet to be answered, a phenomenon that baffles. Science continues, rejoicing in the prospect of the unknown and constantly improving its theories.

### 1.3 Evaluating Explanations

With a hold on the basic nature of science as a continual process striving after ever-improving explanations, how should a person evaluate the quality of a scientific theory? Unlike other avenues of human interest, science has no place for arguments from authority, antiquity, or even “common sense”. For many thousands of years, humans believed that the sun circled around a stationary Earth. Respectable elders advocated this view, rooted in time immemorial, and the issue went uncontested. How could one argue the contrary, when it is intuitively clear the the Sun is moving and that the ground is not? The answer is that none of these justifications are considered scientific evidence. Old ideas, put forward by intelligent people, are discarded frequently and science consistently shows that nature is often subtle enough to mislead the crude faculty of common sense.

Clearly, different evaluative criteria are required to determine the merit of a theory. Four features must be assessed: explanatory scope, simplicity, plausibility and testability. Explanatory scope is how many facts or observations a theory can explain. The broader the scope, the more powerful and useful the theory. Simplicity involves how many independent concepts must be proposed as part of the theory. A simple theory has as few mechanisms and postulates as required to cover all the data. A single, elegant idea that unifies many seemingly disparate facts is better than a series of separate explanations

for each individual case. By reducing the number of theoretical components to a minimum, the opportunity for one of those elements to be incorrect is reduced. The principle is analogous to the fact that a computer is more likely to malfunction than a pen, due chiefly to the number of parts required to make a computer work. Plausibility describes how well a particular theory fits in with other pieces of scientific knowledge. For example, virtually every natural process observed conserves energy. That is, whatever energy is put in, exactly the same amount will come out, though possibly in different forms. If a new theory is proposed that violates conservation of energy, it should be subjected to extreme skepticism. A theory should sit comfortably alongside other scientific ideas, and not differ radically in its assumptions or character. The final criterion is testability. Scientific theories must be testable. If a theory proposes some phenomena that are, in principle, impossible to observe, there is very little tethering it to reality. Similarly, a theory must be able to be proven false. If any possible result can be explained away using a special exception, then in a real sense the theory has failed to explain anything at all. If untestable, unfalsifiable theories were allowed, it would be possible to construct an infinite number of them, and no explanations would ever be had.

### 1.4 The Limits of Science

In light of these criteria, supernatural explanations are ruled out of scientific investigation. This is not a prejudice against supernatural causes, but an inherent limitation of science. Why? Because supernatural causation, or claiming ‘God did it’ as a scientific conclusion, fails by nearly every measure of what constitutes a good

theory.

It is reasonable to propose that God has maximal explanatory scope, but the nature of the explanation is vague. When God causes an animal to exist, is it the same process as when he creates an angel, or a planet? How does this process work? While it is easy to answer any mystery by invoking an omnipotent power, and thereby yield a huge explanatory scope, upon scrutiny these explanations quickly fracture into many ill defined sub-explanations.

Simultaneously, these smaller explanations reduce the simplicity of supernatural causation. Additionally, even if a minimal Creator is the only thing being proposed, this is not the type of God the majority of people believe in. Most religions incorporate an active God who intervenes in history, reacts to human actions, and makes proclamations about morality and the afterlife. All of these extra details lead to a very complex theory.

What about plausibility? Supernatural beings are, by definition, not natural and do not obey natural laws. Hence, all current natural knowledge is useless for evaluating the actions of a non-natural actor. Because the supernatural is not constrained by the natural, it is impossible to determine plausibility. Does God creating life fit in with what supernatural beings are known to do? No one can say, because there is no background knowledge about the supernatural.

The final and most important element of science is testability. Scientific claims must be testable, but God is not testable. Individual claims about a god may be tested, but it is always possible to invent a special case that sidesteps the evidence. For example, studies have shown that intercessory prayer does not help hospitalized people heal faster. [19] However, believers can simply assert that God does

not heal people when they are part of a scientific study, thereby avoiding all objective empirical methods. Similar arguments can be used to avoid any piece of evidence. One can also continually move the divine back one step to maintain supernatural causation. Perhaps someone believes that Zeus causes lightning. A scientist could explain that lightning is actually static electricity resulting from the friction of particles of precipitation in a cloud. The believer can simply incorporate this information by claiming that static electricity is important, but that Zeus is the real “cause” of the lightning. It is impossible to scientifically validate or invalidate this theory because it is beyond the methods of science.

Science can only investigate natural events and causes, not because of an arbitrary bias against the divine, but because the tools of science cannot handle the supposed supernatural realm. For this reason, any claim that God is the best scientific explanation for some fact is a category error. A Creator may exist, and he may have designed life, but scientific methods cannot confirm or disconfirm this claim. Science can only play a role when religious people make statements about the natural world. These declarations can be tested and shown to be true or false. As always, a divine miracle may be invoked to get out of a sticky situation, but this move immediately ejects a claim from the scientific arena. This essay was not written to prove that it is impossible that God created life, but it will show that specific creationist claims are lacking scientific support.

## 1.5 The Scientific Community

Abstract principles about what science is, what it tries to accomplish, and how its results should

be viewed are crucial to understanding the role it plays in helping to understand reality. It is also important to be familiar with the way that science is actually performed in the real world. Too many people think of science either as some ethereal practice that could never be understood by the average person or as the mechanistic, uninspired cataloging of natural events. To be sure, gaining a competent understanding of a particular scientific field takes years of diligent work and the job can involve tedious and painstaking repetition, but the core feature of science is creativity. Scientific problems can be so complicated that only creative, intellectually resourceful people will make great breakthroughs.

Science is also not an individual pursuit. It is, by necessity, a community undertaking. No one person has enough time, funding, intelligence or interest to ‘go it alone’. A community is also required to verify ideas and balance out individual biases. This is accomplished through the process of peer review. If a scientist makes an exciting discovery or formulates a new theory, they submit a paper detailing their findings and have it anonymously reviewed by a selection of people in the same field. The reviewers probe the method and idea behind the paper and can recommend changes or clarification. This greatly improves the quality of the work and facilitates another key requirement in science: repeatability. If only one person can demonstrate a certain result, it is quite likely that some unnoticed factor is corrupting the experiment. By publicly announcing experimental findings, other scientists are able to repeat the experiment or use them as the basis for their own investigations.

Theories and techniques that are widely repeated and validated usually lead to a scientific consensus on a particular topic. A consensus does not guarantee that a theory is correct

(nothing can), but it does demonstrate that a particular theory has good supporting evidence and compelling arguments in its favor. Minority opinions always exist, and over time some of them will end up as majority opinions. When this transition occurs, it does not happen randomly. Minority views gain acceptance by being published in peer-reviewed journals, fitting the evidence better than the current perspective, and making daring predictions that are validated by experiment. For this reason, a scientific consensus is generally representative of the best understanding available in a certain field.

Science is a collective, empirical, evidence-driven tool for determining how nature works. It fully acknowledges that it is not infallible, and in fact embraces this fact to enable constant improvement. Scientific thinking is incredibly useful, both in practical matters and in general as a method of maintaining a reasonable picture of reality. It is this method that will be applied to analyze the many suspect claims made in WLC and TOL.

## 2.1 Look for Answers

*The Origin of Life* opens with a quick vignette describing a student who feels uncomfortable in science class because he has been taught by his parents that evolution is simply an unsupported “theory”. The scenario depicts the school teacher as claiming that evolution has “freed mankind from superstitious beliefs” and soliciting comments from class. Not only is this situation unlikely, but it immediately establishes the main talking point of the article: evolution has no basis in fact and a mere mention of the topic should elicit a negative reaction because it challenges previously held beliefs.

Laudably, the author recommends that each person should look at the evidence for themselves and determine whether evolution or creationism is supported by the scientific facts. Unfortunately, the writer immediately makes a misstep by stating that the purpose of the text is to examine the scientific claims surrounding the origin of life. This is a serious category error. The theory of evolution explains the diversity of life, not how the first cells formed. To criticize it on this basis is akin to complaining that a fork is not very good at combing hair and concluding that therefore forks must not be good for anything at all. That is not what a fork is for. Likewise, evolution is not concerned with explaining the origin of life. Biological evolution requires that some self-replicating genetic material already exists. From that basis it describes how variation and natural selection can lead to improvements in these molecules and eventually to many different types of life forms.

The topic that is actually being discussed is what scientists call abiogenesis, or life from non-life. Abiogenesis seeks to understand how the first biologically important molecules were synthesized and how these molecules came together to form a type of life. The conflation of abiogenesis and evolution is common but misleading. The pivot from one to the other is a rhetorical maneuver designed to take the normal academic jousting in a scientifically controversial field like abiogenesis and shift it to an established area like evolution. Abiogenesis is a relatively young and lightly funded field of research. No broad consensus exists, and much work remains for the future. Fortunately, this is exactly the type of situation in which science is most useful. If everything about nature was clear and obvious, painstaking research would never be required. Scientists, unlike their supernaturally-inclined critics, are

not afforded the luxury of sitting on the sidelines endlessly reiterating how difficult a particular problem is. They take the current state of knowledge and push ever forward. It should not be surprising that scientists currently lack a tidy account of a particular series of chemical reactions that could have taken place in a multitude of different environments billions of years ago. Neither should this fact lead anyone to conclude that some external agent is necessary to solve the problem.

## 2.2 The ‘God-of-the-gaps’

Religious attacks on this front represent a logical fallacy commonly known as the ‘god of-the-gaps’. If a certain phenomenon is not currently understood, God is used as an explanation. As soon as a naturalistic understanding is gained, God slips out of that gap and finds another. Because science will always have unanswered questions, this process can continue ad infinitum. The failure to have a natural explanation at any particular time does not show that an explanation is impossible to discover. It certainly does not support the claim that a supernatural force is required. The history of science demonstrates repeatedly that events and processes that were once thought to be beyond human comprehension, even in the realm of the gods, are able to be rationalized and even become simple enough to understand that they can be taught to young children.

The proponent of creationism may argue that science engages in a similar fallacy, a so called ‘naturalism-of-the-gaps’. However, anticipating that science will provide a natural explanation is not analogous to proposing a supernatural explanation. Science only deals with natural expla-

nations, so there will either be a natural explanation or no scientific explanation for any particular fact. Because it is impossible to know whether a certain phenomenon is unexplainable, the only reasonable choice is to wait for better evidence and withhold judgment on the issue.

To halt scientific inquiry because a problem seems too difficult to grapple with, or because an answer might challenge a metaphysical conviction, is to beg and plead for ignorance. In this behavior, the religious critic of science resembles a lazy schoolchild. This schoolchild, whenever he reaches a particularly difficult exercise, immediately relents and claims the problem is impossible to complete. The teacher urges him to keep trying and reminds him that all the previous problems had solutions and that they also seemed insurmountable at the time. Ignoring the teacher, the child continues to complain until another student completes the problem and demonstrates the solution. Even with this experience fresh in his mind, the boy immediately finds another problem beyond his skill and begins his protest anew. A cycle such as this would grow tiring quickly, and so it has within the scientific community in regards to promoters of the supernatural.

Those who support the intervention of a God or any other unnatural force in the origin of life are fighting an impossible war against the very nature of science. They may be correct in their dogmas, but science cannot be used as a supporting mechanism. Furthermore, it is not sufficient to offer a smattering of criticism against science and expect that this is enough to prove an opposing conclusion. In order to grant some plausibility to their claims, supernaturalists must show not only that all current natural explanations fail, but also that future explanation is highly improbable in principle. In addition, they must

demonstrate that nature is not in conflict with what they are proposing. To be clear, even if this was accomplished, it would not validate belief in a divine creator, but merely remove scientific objections to that specific belief.

## 2.3 Abiogenesis

The author of TOL begins *Question 1: How did life begin?* by briefly glossing some of the ideas that exist about how an early protocell could have formed. Eager to turn genuine scientific controversy into a gap for the supernatural, various quotes from people who advocate differing hypotheses regarding abiogenesis are presented. Alexandre Meinesz, who supports the view that essential biological molecules and perhaps even the original living systems were brought to earth via a meteoroid, is used to decry all research on terrestrial origins. It is also implied that scientists considered a hypothesis involving extraterrestrial material only because all of their prior work had failed. This is false. Meteoroids are considered as a source for important biological chemicals because it has been shown that these chemicals exist in certain space environments, and a considerable amount of this material has fallen to Earth over the history of the planet. [29] Even so, research in this area is in the minority.

Dr. Meinesz's quote regarding the lack of progress of any theory involving "nothing but a molecular soup" is both accurate and irrelevant. [60] Experiments conducted by Stanley Miller in the 1950s showed that amino acids could be created by combining simple chemicals and energy sources. While the particulars of his experiment were hotly debated, the main achievement was not in the details. The point was that something that was once thought impossible, the sponta-



neous synthesis of critical biological chemicals from basic precursors, was demonstrated to be within the realm of science.

The current state of the research on abiogenesis involves two general perspectives, ‘genes first’ and ‘metabolism first’. Basic life requires two things, a molecule to store genetic information, and a means to generate energy by metabolizing other compounds. The ‘genes first’ theory proposes that RNA emerged first as a molecule of heredity. Later, naturally selected collections of self-replicating RNA enclosed in a simple membrane, thereby creating a protocell. Processes for metabolism would be added later if they increased the replication rate of the protocell. On the other hand, the ‘metabolism first’ approach says that the initial environments for the origin of life were reactive minerals such as those found in deep sea vents. These networks of relatively simple metabolic processes were, in effect, a compositional genome that served as a list of the materials necessary to complete the reactions. More conventional genetic molecules like RNA may have been later appropriated originally to aid the reaction but were converted for use as a replicating instruction set.

A leading proponent of the ‘genes first’ model is Jack Szostak, a professor at Harvard Medical School and Nobel laureate. [50] His lab currently works on understanding the ways that RNA could eventually lead to a viable protocell. [69] The sectors of research include determining how replicating membranes could arise and how RNA can catalyze its own replication. [28] RNA aiding in the replication of itself should come as a surprise to the author of TOL and its readers. The article presses the idea that RNA is required to make proteins but that enzymes (a type of protein) are required for RNA to replicate. While it is true that there is no cur-

rent model for replication completely devoid of protein enzymes, the article completely ignores the great leaps in understanding related to RNA replication. [6] It has been demonstrated that a segment of RNA, called a ribozyme, can act as an enzyme. In fact, the modern ribosome is a ribozyme. This discovery was even awarded the 1989 Nobel Prize in Chemistry. [63] Previously, enzymes were the only known biological catalyst. The existence of an RNA catalyst itself made of RNA suggests that a direct mode of ribozyme-catalyzed RNA replication may exist. By excluding these findings, the article tries to ignore scientific advances that happened nearly 30 years ago, not to mention more recent research.

In addition to the discovery of ribozymes, the ‘genes first’ model has other evidence in its favor. Successful synthesis of RNA nucleotides in a plausible natural manner has been achieved and is indeed mentioned in a footnote of TOL. [38, 23] Future work in this area may lead to a robust model of nucleotide formation from prebiotic components. Once a sufficient number of nucleotides are present, a pathway must exist to polymerize them into longer chains like ribozymes. In this vein, it has been found that a clay called montmorillonite can facilitate this polymerization. [49] This clay can also catalyze the formation of cell membranes from fatty acids. These membranes, once they are formed, are stable and can join together to make larger ones. They also may be permeable to nucleotides, allowing these to concentrate inside the membrane. All a protocell requires is a membrane and replicating RNA structures. This protocell would be able to grow, copy itself, and evolve to become more complicated.

The opposing model of abiogenesis, the ‘metabolism first’ idea, attempts to avoid complicated RNA formation and polymerization and

instead focuses on energy production. A prominent advocate of this theory is Robert Shapiro of New York University. [74] He is also a vocal critic of ‘genes first’. In this capacity, TOL exploits his quotes to attempt to tear down ‘genes first’ while failing to explain the model he does support. In ‘metabolism first’, a particular mineral like iron disulfide catalyzes certain key biochemical reactions. This mineral is commonly found in deep sea vents. These vents also release gases that can be broken down by certain chemical processes to release energy. The metabolism of these gases produces organic compounds that could serve to further increase the efficiency of the original reaction. A possible clue to this ancient process is the presence of iron sulfide in several important enzymes used in cells today. From there, a cell membrane can be formed in a similar manner to that mentioned above. The introduction of RNA and genetic replication happens at a later stage after metabolizing units with a vesicle exist. This last step may end up including ideas from the competing ‘genes first’ hypothesis. Advocates of this model claim that the development of catalytic networks is a simpler and more robust starting point than genetic material. Ongoing research will surely throw light on this topic.

## 2.4 An Incomplete Story

Both of the two basic theoretical persuasions in abiogenesis research have many different sub elements and different possible explanations of how specific biological mechanisms came about. No conclusion has yet been reached on any of these topics. However, the prospects are good that scientific breakthroughs will lead to a much better understanding of the origin of life.

It is important to notice what these theories do

not say. Neither of these theories claims that the original protocells were nearly as complicated as even the simplest modern cells. The cells that are observed today have billions of years of evolutionary history that has crafted the complex interaction of their various systems. No theory involves RNA and proteins randomly coming together without plausible chemical pathways. The theories also do not claim that complex proteins just randomly appeared, making claims like that of Dr. Yockey irrelevant. The quoted probabilities of proteins randomly forming are also misleading. While a source is not provided, the math used to generate these stunningly small numbers is usually based on unsound assumptions. The calculations often assume that the random trials happen serially, as opposed to the massively parallel processes that would be present in a community of early cells. They also assume that only one specific amino acid sequence would meet the requirement for a particular biological function. This idea is false, because various different proteins can fill the same niche. These types of criticism come from an incomplete understanding of the physical principles involved.

The final drive of the argument seeks to undermine any future abiogenesis research. It questions whether even the successful creation of a protocell in the lab would demonstrate that the natural origin of life was a possible event. After all, if humans had to work hard to create a protocell, does that not just prove that intelligence is required to make life? The answer is no. It is akin to saying that crash tests of automobiles only evaluate the damage resulting from collisions that are caused on purpose but do not provide insight into the damage that may be caused by a real world accident. Abiogenesis researchers are not trying to create life by any means possi-

ble. There are people trying to create artificial life in this manner, and they have recently made considerable progress. [42] However, these scientists are not attempting to recreate any natural event. If they succeeded, it would grant a greater understanding of life, but not of how it actually arose. In contrast, those studying the natural origin of life only employ methods and environments that could plausibly be present when life arose. They are not “manufacturing” life, but are simulating the conditions they think led to its origin.

Accepting a particular theory of abiogenesis as plausible does not require a “leap of faith”. None of the scientists are requesting that anyone believe their particular model as finished truth. They are formulating theories, running experiments, and gradually increasing human understanding while being consciously aware that much remains to be explained. There is evidence suggesting certain conclusions, but the results are provisional. A person can choose to remain undecided until the theories are refined. A conclusion that cannot be logically drawn is that divine intervention is required. There is no detailed supernatural explanation anywhere to be found. TOL states that abiogenesis is fanciful, but what is more fanciful, a rigorous natural explanation based on chemical and biological evidence, or the unsupported claim that a God just willed complex life into existence out of nothing?

## 2.5 Simplicity

Question 2 of the TOL brochure asks *Is Any Form of Life Really Simple?* The broad narrative of this subsection is “Cells are complicated. Therefore, only God could have made them.” Abiogenesis and biological evolution are

once again conflated, with many differing chemical and biological processes sloppily grouped under the banner “evolution”.

For the first time since the introduction, the Bible is explicitly mentioned as a source for guidance in interpreting scientific evidence. The central argument is sharpened. TOL is not just advocating for any intelligent supernatural agent, but is specifically promoting Yahweh, Jehovah, the God of the ancient Hebrews. This fact is key. If the argument was only trying to demonstrate the action of some generic ‘creator’ the problem of recognizing design would be much more difficult. If you do not know anything about the mind of the creator, it is impossible to determine what they would design. A creator could be incompetent, evil, or lazy. There could be a committee of creators who designed life in a haphazard, compromised manner.

Helpfully, the brochure defines what sort of person this creator is. He\* is orderly, intelligent, “ingenious”, and exhibits “technical brilliance”. A Biblical analogy likens his making of the world to the human endeavor of building a house. It is implied that the designs of God can be likened to the engineering of man, just exponentially greater. It is possible, then, to evaluate biology and determine if its “designs” are good depending on how efficient and well devised they are by human standards. After all, the only way one can define “design” or identify it would be to apply human standards. If God only follows “godly” design rules, then it is pointless to try and find things designed in this fashion because we would have no way of distinguishing them from other objects.

After mentioning how many different types of cells there are in a human body, the article

---

\*Obviously, God is a ‘he’

defines the difference between prokaryotic and eukaryotic cells. Never missing an opportunity for a ‘god-of-the-gaps’ fallacy, the author points out that biologists do not currently have a complete explanation for how eukaryotes gained various structures including a differentiated nucleus. There are theories that involve prokaryotes ingesting other cells, eventually leading to a symbiotic relationship. [56] This process is not fully understood. As before, this is merely a current lack of knowledge, not evidence of divine causation. Bacteria behave in ways that are totally foreign to a common conception of an ‘organism’. They swap genes freely, their genomes being constantly remixed in new ways. A biological “alliance” between different bacteria is not nearly as strange as it may seem at first blush.

Following this brief diversion, the article gets back to making more factual errors. It claims that the original protocells resembled prokaryotes. This is true in some ways, except the fact that even the simplest modern prokaryotes have undergone billions of years of evolution and are therefore much more refined and complex than their ancient ancestors. By asking whether a cell similar to a modern prokaryote could “arise by chance”, TOL caricatures science in an attempt to shore up its argument. Evolution is an unguided process, but it does not claim that things like advanced cells spontaneously emerged without simpler precursors.

Exhaustingly, the author repeats the false claim that the theory of evolution should explain the origin of life. For reasons already covered, this is a category error. Evolution does explain how replicating systems can become more complicated by adapting to their environment, but it does not attempt to explain the origin of these systems.

## 2.6 Designed or Not?

The next few pages are spent explaining some basic concepts of cellular physiology including the cell membrane, protein synthesis, and respiration. The enthusiasm in these paragraphs would be refreshing if it was not in the service of bad science. There is no appreciation of the irony involved in attempting to ridicule the scientific method while citing facts that can only be known through that method.

Many details of the cell are highlighted as being efficient, clever, and “seemingly designed”. Of course, there is no effort made to present the explanation of complex biological systems offered by evolution. Correspondingly, no attempt is made to explain how proposing divine intervention actually provides any new scientific information. If one assumed that the cell was designed, how would that actually further science? Would that enable the manufacture of new antibiotics? Would scientists better understand how the parts of a cell work together? No. TOL advocates staring at the awesome machinery of life in a dumb stupor and implies that any further questioning is unnecessary. Real scientists continue to ask the big questions. This is the fundamental difference between pseudoscience like creationism and genuine inquiry into the natural world.

How does evolution explain complex cellular structures? The answer is actually quite simple, if unintuitive. The process of evolution requires that some sort of genetic material is present and this material is able to copy itself with some accuracy. Perfect accuracy, though, is not required. In fact, perfect copying would halt evolution in its tracks. The copying of genetic information must be fallible, mistakes must be occasionally made. These mistakes are the raw ma-

terial of evolution, an ore of possibility that is refined by natural selection. This is a clue that static ‘design’ is not present in a cell. If an automobile stops operating in the way it was designed, it has malfunctioned. In a living cell, the result is not so clear cut.

Most copying errors, or mutations, have little or no effect on an organism. Often, the mutations are harmful, even deadly. The tiny remaining fraction of mutations can be beneficial under the right circumstances. If a certain mutation helps an organism to reproduce more successfully in its current environment, this mutation will be passed on to descendants. That is the simplest form of evolution. Variation and natural selection take the current state of the genetic material, remix it slightly, and test to see if the result is favorable. Evolution cannot anticipate the future, and is limited to the materials on hand. However, this process can be extraordinarily “creative”.

## 2.7 An Analogy

How can this blind process produce seemingly elegant results? An analogy will clarify. Imagine that a hungry person walks out of their apartment in search of a restaurant. Not knowing how the city is laid out or where the nearest restaurant is, this person walks down the street. At each intersection, they randomly choose a direction. Eventually, the person walks right in front of a burger joint and satisfies their appetite. The next day, the person is hungry again, and knows one guaranteed route to a meal. The person sets out again to repeat the previous day’s route. Unfortunately, the person is so hungry that they forget which direction they turned at a particular intersection. So they make another random

choice. They may happen upon part of their previous route and complete the journey that way. They may also stumble upon the same burger joint by a different route. Sometimes, they will find a superior restaurant. Many times, the person will wander for a long time without finding any food, and will return to their home utterly dismayed.

This person repeats the above practice everyday. Each time they leave the apartment, they want to get food as fast as possible. They are able to time how long they have been walking, so they know the duration of their last successful route. However, their memory still fails occasionally, so they must sometimes randomly walk the streets. It is possible to visualize a map of the city streets and the vast multitude of routes that were taken by this hungry individual.

Some routes will lead nowhere, a fruitless search. Some will lead to the original restaurant, but will be slightly shorter than the original route. Over a long period of time, with the hungry human choosing the quicker path, it is easy to see how the route could become shorter and shorter until the optimal route is found. Most importantly, the person may find new restaurants that are more satisfying than the original. Given a certain walking radius and a very long period of time, the hungry person will eventually find the best restaurant that is closest to their house. If a restaurant closes down or moves across town, the person will be able to adapt and find a new place to eat. If nothing changes, the route will also remain unchanged, excepting the occasional memory failures.

Never does the person look at a map and “design” a route to the best eatery. However, after a sufficient amount of time, it would be impossible to distinguish between the final route created by trial and error and one chosen by consulting a

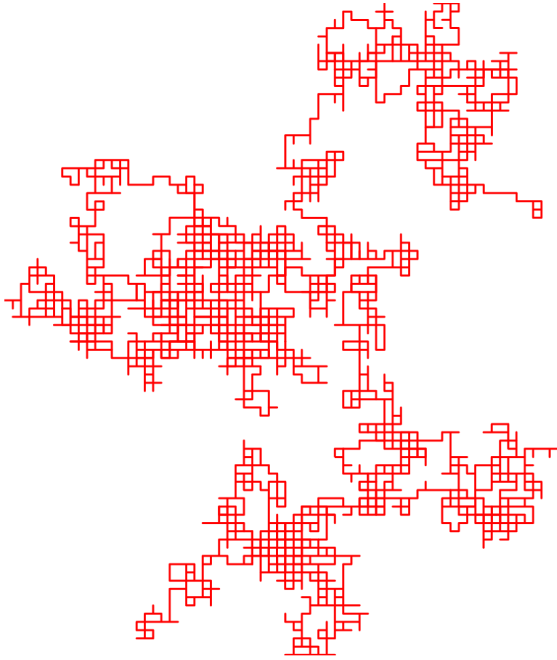


Figure 2.1: A series of random walks around town.

map. The only difference is that the “evolutionary” approach to locating a restaurant has a long history of pruning and error that led to the final state. In the example above, chance variation or mutations are represented by the memory errors and random turning at intersections. Natural selection is embodied in the hungry person who wants the fastest route to the restaurant. This is not to imply that an intelligent agent must choose among paths, the same thought experiment could include a robot that merely follows random paths and chooses the shortest. The length of the route and the quality of the restaurant can be likened to biological ‘fitness’. Routes that go nowhere are like deadly mutations while those of the same length are like neutral mutations. The closing or moving of restaurants rep-

resents a changing environment. Finding a path to a new restaurant is like a novel evolutionary solution.

This analogy is not perfect. In actual organisms, some genes are more important than others and exercise great control over key systems. Many features are governed by networks of genes, with each playing a subtle role. Cellular processes can be shaped by environmental factors. Creating new genetic information is very often not a simple point-by-point progression. Multiple mutations can build up in unused areas of the DNA, and then suddenly be triggered by another mutation. This can be likened to the way a bad poker hand can be radically improved by the addition of a single card. Also, evolution is something that happens to populations, not individuals. A specific mutation may occur in an individual, but adaptation and change occurs over time to a group of interbreeding organisms. Real biology is complicated and cannot be fully grasped with a short illustration. [3] However, the preceding thought experiment helps to show how, counterintuitive as it might be, random changes and selection pressures can create well arranged systems.

Vivid and pragmatic examples of evolution innovating and creating “well designed” biological structures can be found in the constantly changing worlds of viruses and bacteria. Viruses are relatively simple, they are just pieces of DNA or RNA with a protein coat. Viruses latch onto cells, inject their genetic code, and utilize the machinery of the cell to replicate themselves. Viruses are constantly mutating and thereby stumbling upon new ways to infect other cells. This is the reason that a new flu vaccine is required every season; the virus has changed so significantly that the old antibodies cannot recognize it. Similarly, the rapid evolution of HIV has

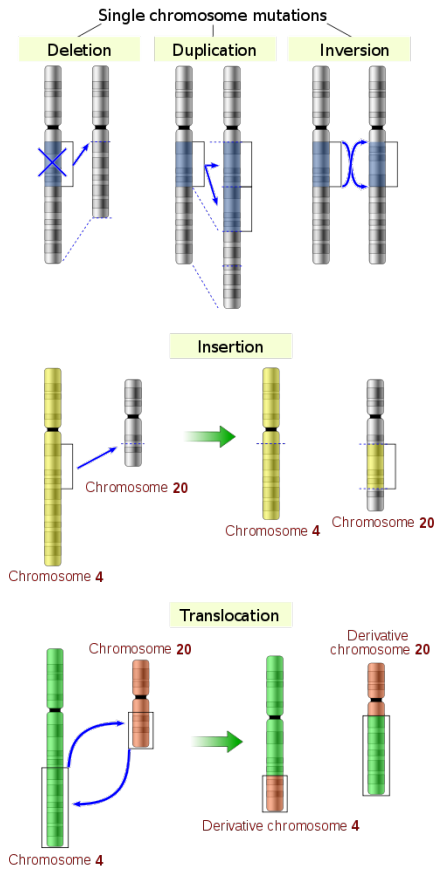


Figure 2.2: Different types of chromosomal mutation.

made developing a vaccine very difficult. Bacteria also constantly react to their environment. Due to the excessive and improper use of antibiotics, many strains of bacteria are highly resistant to treatment. Disregarding human concerns, viruses and bacteria have been in an arms race with the defenses of other cells for billions of years. This competition explains why even “simple” prokaryotic bacteria are so well adapted to their biological niche. While humans and other animals may not appreciate it, these infectious

biological systems are very well “designed” by evolution to evade immune systems and multiply themselves. If good “design” requires divine action, does this mean that God is engineering a new flu virus every year to sicken as many people as possible and thwart our medical technology? Is he likewise carefully tuning all the individual parts of the Methicillin-resistant *Staphylococcus aureus* (MRSA) bacterium so that they are “brilliantly designed” for infecting hospital patients? Did he “engineer” these deadly organisms in the first place?

## 2.8 Different Perspectives

Some object that these examples are merely ‘microevolution’ and are hardly comparable to the ‘macroevolution’ that leads to new species. However, this is a false distinction. [26] Mutation and natural selection only work at one scale, the scale of the genome. To a strand of DNA, the only difference between gaining resistance to a drug and developing some other novel trait is a pattern of nucleotides. Humans are able to view the resulting changes on difference scales, micro and macro, but the distinction is arbitrary. Just as someone is able to walk across a room, using the same method they could walk down the street or even across town. The scale of the observation is different, but the salient action, putting one foot in front of the other, is identical. There is no magical point where walking ceases to become effective for movement. There is similarly no mysterious barrier that mutation and natural selection cannot pass. Whether evolution is shaping a novel virus or a new species, the process is exactly the same.

Though not obvious, it can be understood how a slow, undirected process can create complex

and well adapted biological structures. “Creativity” comes from the random mutations. These changes are selected based upon their ability to confer a reproductive advantage to the genome of which they are a part. Over long periods of time, this natural process “feels” out the figurative ‘landscape’ of survival, snaking around and discovering new genetic patterns that lead to increased survival rates. Complex biology does not just pop into existence by chance, but slowly builds through generations of natural selection. The various parts of a cell work well together because they have developed side by side over billions of years. No scientist claims that these systems appeared out of nowhere “by accident”. There is a demonstrable natural process creating these biological synergies. [17]

At the end of this section, TOL returns to the refuted refrain “evolution does not explain the origin of life.” As stated previously, the two subjects are separate and rely on different collections of evidence. The author appears to become suddenly aware of this criticism, and instead portrays abiogenesis as a weak foundation for evolutionary biology. This argument can be compared to declaring that the “theory” of cheese-making is unsound because the farmer cannot explain how a cow produces milk or that an athlete needs to know the history of basketball in order to play it correctly. Even if someone decided to believe that God created the original cell, this would not invalidate any part of evolutionary theory. The constant confusion of two separate topics is logically fallacious and intellectually bankrupt.

## 2.9 Detecting Intention

Question 3 of TOL is *Where Did the Instructions Come From?* This subsection focuses on

the structure of DNA and the information represented by it. Like the previous question, the author spends many paragraphs describing basic biology, in this case the nature of DNA. The descriptions are acceptable, but the conclusions drawn are unsound. A familiar pattern repeats itself: DNA is complex, therefore God made it.

There is a flaw in reasoning here, a subtle false analogy. To clarify, it is useful to propose two categories of objects, those that were designed and those that were not. Humans know of many things that are designed, like cars, computers, and coffee machines. There are also things that do not seem to be designed, like rocks, ponds, and dirt. How is this distinction made? Well, everyone knows that humans make cars, computers, and other devices. Everyone has seen a factory and has probably designed an object themselves at some point. What about rocks and ponds? There are places on earth where great quantities of lava spew out onto the earth and cool to form new rock. A long day of rainfall can make a small depression into a pond. Both of these processes are mechanical and do not seem to involve any design or intention. If a person sees a Coca-Cola can tossed on the side of the road, they can immediately determine that it is a human-made artifact and not a natural occurrence. This is because that person knows that Coke cans are made by people. Understanding the origin or manufacture of an object allows one to judge if it was designed or not.

There are other rules of thumb that help to determine if something was created with intention. Human-made objects tend to include geometric shapes, involve materials that do not exist naturally, and usually serve a comprehensible purpose. An automobile has many precision engineered surfaces, it is made of synthetic alloys and plastics, and it seems to work well for



transportation. Background information about how ‘designed’ objects are made in contrast to ‘natural’ objects is key to making a distinction between them.

What happens when a person comes upon an object with an unknown source and ambiguous qualities? For example, some people would argue that a Jackson Pollock painting exhibits very few signs of design or intent. However, it is known that these works were created by a human. What about a snowflake? Snowflakes, and many other crystal structures, possess complex, intricate patterns that look as if they were designed. In reality, these patterns are merely emergent behavior from simple physical rules about certain materials. All large celestial bodies, like the moon, sun and Jupiter, appear at first observation to be perfect spheres. This aspect led some ancient peoples to conclude that they were made in this perfect form by the gods. In modern times, it is understood that gravity is the cause of this geometrically pleasing effect.

Clearly, a thorough investigation must be made to determine if an object is designed or not. Simple rules of thumb fail when the origin of something is not well understood and the subjective ‘design’ qualities are easily misinterpreted. Many creationists will argue, in the manner of TOL, that certain biological systems look like things made by humans. These objects may look “well engineered”, “efficient”, and “ordered”. In order to identify these qualities, a contrast must be identified with things that are not designed but are produced by natural processes. This includes stars, mountains, nebulae, and sunsets. Humans may perceive them as having great beauty, but no more divine intervention is required than is needed for a pot of water to boil on a stove or for a ball to fall to the surface of the earth. Of course, creationists believe that

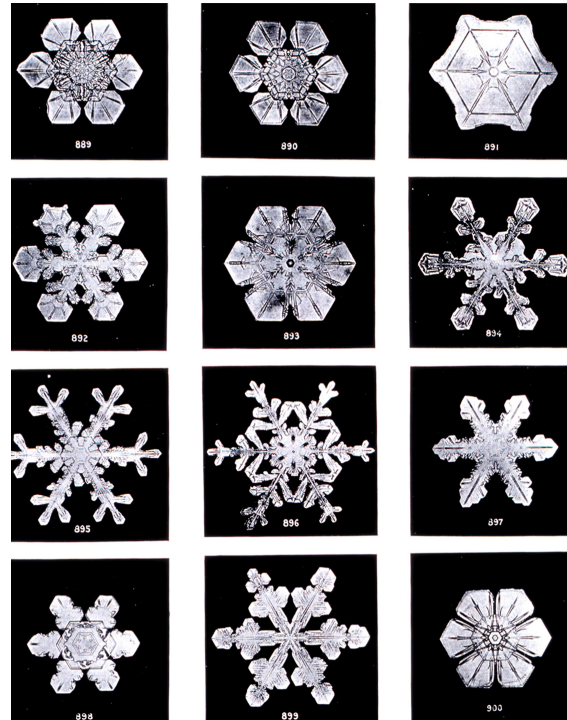


Figure 2.3: Intricate patterns from simple rules.

God designed all of these natural things also, and thus they have demolished the distinction between design and non-design upon which their analogy rested. If God can be invoked to explain both things that appear designed and those that do not, then it is impossible to determine if any natural object is designed.

Determined design proponents may attempt to side step this problem, and continue comparing the characteristics of human design to that found in biology. However, this proposed similarity is only superficial. Living systems do not look much like human-designed machines. Living things reproduce, grow, and metabolize food from the environment. Machines cannot (yet) reproduce themselves, they usually remain in their

initial configurations throughout their existence, and the energy used to operate them is supplied for them from an external source. Someone may attribute these differences to the fact that God is a superior engineer, and thus his designs are so far beyond those of mere humans that they should be expected to have more advanced qualities. However, by stating that divine designs are so much more sophisticated than those of humans, the attempted analogy between the two is considerably weakened.

## 2.10 Function, Not Purpose

Further differences include the fact that things designed by humans usually have some clear purpose. Tools enable easier work, art creates aesthetic pleasure, and airplanes enable faster transportation. Attributing purpose, though, can only come logically after knowing that an object is designed. For example, hammers are known to have been designed by humans to drive nails. Unless nails were designed, hammers are purposeless. Intentional design creates purpose. A hammer may be used to shatter windows or bruise thumbs, but these uses are merely coincidental with the actual purpose. Therefore, it is not logically sound to conclude that just because an object *can* do something, that its ‘purpose’ is to do that thing and therefore that this ‘purpose’ comes from design. Reasoning in this manner is exactly backwards.

For instance, imagine watching seagulls eat discarded food from a restaurant parking lot. One might say, incorrectly, that the ‘purpose’ of seagulls is to clean up the parking lot. In reality, the birds are merely taking advantage of a resource. On the other hand, if an employee of the restaurant is seen picking up the same waste,

it is appropriate to attribute purpose. This inference can only be made with the knowledge of how businesses operate. It is a known fact that people are employed by businesses for various purposes, including grounds keeping. Businesses “design” their selection of employees and assign each a particular purpose. Without knowledge of how or why a business would hire someone to clean their grounds, it would be impossible to interpret these actions. A human or a bird picking up food from a parking lot are doing the exact same thing. Attributing purpose to the human, but not the bird, is based entirely on background information. One could not simply observe the action alone, in a contextual vacuum, and conclude that the presence of the bird or the human was purposeful.

In relation to biology, the same principle applies. Biological systems are certainly capable of doing a specific task in an organism. Many of these systems are efficient and elegant. However, interpreting this as a sign of purpose, and hence design, is circular reasoning. If one is trying to argue that biology is designed, the fact that a living system is very good at achieving some task is irrelevant, because attributing purpose assumes the very intentional design whose demonstration is attempted.

## 2.11 DNA

Finally, the topic of DNA can be broached. TOL explains how effective DNA is at storing information in a compact format and the various steps involved in transcribing this information into proteins. It also falsely implies that scientists think that this molecule just appeared “by chance”. The precise origin of DNA is currently unknown, but a plausible pathway of de-

velopment exists. It is thought that the original protocells utilized only RNA to store genetic information. RNA is chemically and structurally very similar to DNA. The differences between the two allow DNA to maintain longer, more stable strands of nucleotides. While early cells could exist with only RNA, there would be survival advantages to evolving DNA as a storage medium. The fact that both are intimately related in the transcription process, and that the protein-building ribosome contains important RNA sequences is likely a record of the ancient derivation of the DNA / RNA relationship from a simpler RNA-only configuration.

The chemistry of the molecular structures involved in DNA transcription is highly functional, but not by “chance”. These molecules were honed over billions of years to a state of high efficiency, just as modern viruses and bacteria are very proficient at defeating the constantly adapting immune systems of other organisms. Furthermore, the separate parts of these biological mechanisms have a natural chemical affinity for each other. The reason that Watson and Crick were able to determine the structure of DNA was that the principles of chemical bonding between the atoms were known and could be used to rule out certain patterns. So, biological systems differ in another way from most human machines. No screw, bolt, or shaft will naturally collect other parts. This is in contrast to the microscopic building blocks of biology, which are attracted by electrostatic forces and governed by chemistry.

DNA replication is another efficient, though imperfect process. While DNA is copied with very high accuracy, the fact that errors occasionally occur is critical. A human cell contains about 3 billion base pairs. Statistically, DNA replication makes one error for every 2 billion

nucleotides, which results in an average of five errors, or mutations, per cell. [25] With trillions of cells that are constantly replicating their DNA, errors are always popping up. Most are inconsequential, but some mutations introduce new genetic information for natural selection to operate on. Certain mutations may cause single point changes, or shift the ‘reading frame’ and lead to entirely new proteins. [33] Without replication mistakes, life would be unable to adapt and evolution would not occur.

## 2.12 Not Quite Perfect

What about the information represented by the structure of DNA? While DNA is a very dense form of raw information storage, the functional portions of these “instructions” are not efficiently arranged in the genome. Even TOL mentions that only a tiny portion of the genome actually codes for proteins. The rest consists of the unfortunately named ‘junk DNA’. While the term ‘junk’ seems belittling, it just refers to the fact that these long stretches of DNA are not transcribed. That does not mean that they are entirely devoid of function. Some of the code serves a regulatory purpose or is important for the structure of chromosomes. Even so, large parts of the genome are apparently without function. This conclusion is based on many points of evidence including the presence of redundant pseudogenes, the insertion of endogenous retroviruses (ERVs), and the comparative size of genomes from different organisms.

Redundant pseudogenes are copies of another gene that are reinserted into the DNA. The original gene still exists and fulfills its function, but a copy is placed somewhere else. These extra copies serve little, if any, function. Most do not

effect the organism in any way. They may be left untranscribed or even untranslated. Additionally, these redundant genes are rapidly altered by random mutations, which is expected due to the fact that a mutation in the pseudogene has no effect and hence cannot be selected for or against by natural selection. One would hardly expect a perfect designer to write the cellular instructions with various pointless copies of genes that are already present in the code. Evolution, on the other hand, predicts that random errors will leave some cruft and a history of failed genetic “experiments” in the genome.

Endogenous retrovirus are parts of a virus genome that are inserted into the genetic code of the infected host. About 1% of the human genome is made up of various retroviruses that have been collected by humans and their ancestor species over evolutionary time. [76] This genetic information, being a random foreign intrusion, is without function and therefore collects mutations just like redundant pseudogenes. Again, if the genome was carefully designed by God, why would he allow hundreds of viruses to inject their own code randomly throughout his work?

A final clue that the genome is a not a perfectly optimized set of instructions is the wide variation in genome size among different organisms. A creationist may propose some unknown function for all the old virus and pseudogene remnants littered throughout the humane genome, but then a conundrum must be addressed: why do many species, including the onion *Allium cepa*, have several times more non-coding DNA than humans? [18] Do onions require all this extra code to serve some as yet undiscovered need? Are onions so much more complex than humans that God granted them a super-sized helping of this seemingly useless

DNA? Evolution predicts these facts as the result of the unguided process of genetic duplication and mutation. An advocate of creation must explain why a “brilliant” divine engineer would leave all this extra genetic material around cluttering up the genome.

## 2.13 The Future is Now

After an analysis of the structure of DNA and various cellular processes involving it, anyone would be impressed. Those who are most impressed become biologists. TOL argues that these scientists, who devoted their careers to studying the mechanics of life, are too blind or ignorant to reach the “obvious” conclusion that all of biology must have been designed by God. The author tries to get as much rhetorical mileage as possible out of the things that scientists have yet to discover. The ‘god-of-the-gaps’ resurfaces multiple times. The danger of this approach becomes apparent in the face of advancing scientific knowledge.

A marvelous example of this danger results from the claim that “Scientists cannot create DNA with all its replication and transcription machinery; nor can they fully understand it.” Such an assertion sets itself up to be toppled by future progress. To strengthen this foolish declaration, the great physicist Richard Feynman is quoted as saying, “What I cannot create, I do not understand.” Editors no doubt finalized the text of TOL sometime in 2009, oblivious to the work of researcher Craig Venter. Early in 2010, Venter and his team announced the successful artificial synthesis of a complete cellular genome. [42] This artificially generated genome was inserted into an empty cell and “booted up”, just as functional as a natural cell.

Venter's team took a further step that is interesting from the perspective of this specific debate over biological 'design'. These scientists, cognizant of the fact that the genome they synthesized may be indistinguishable from a natural organism, embedded messages in the non-coding sections of the DNA. They developed an easily decipherable code that could represent the alphabet, numbers, and punctuation. Using this code, they inserted their own names, a website URL, and various quotes into the genome. [51] In a coincidence overflowing with irony, one of the quotes included in this artificial genome is that exact same Richard Feynman statement mentioned above. Here, the publishers of TOL are caught out by scientific progress in the most embarrassing manner possible. Not only was the achievement that they declared beyond human ability actually accomplished, but the same quote they used to make their point was physically incorporated in the *very event* that proved them wrong. Poetic justice of this magnitude is rare.

This scientific milestone prompts a further question. If mere humans had enough foresight to embed an unambiguous code into the genome they synthesized, why did God not do the same? What prevented the omnipotent creator of the universe from incorporating, say, the entire text of the Bible into the noncoding portions of the human genome? If this was not possible, perhaps room could have been made in the bloated genome of the noble onion for a few chapters of the Gospels.

## 2.14 Always Quoting

The concluding paragraphs of this subsection of TOL are devoted to misrepresenting a famous

scientist and irrelevantly quoting a well known philosopher. A decades-old book authored by Francis Crick detailing directed panspermia, the idea that genetic material was launched to Earth by intelligent extraterrestrials, is used to erect a weak criticism of any theory about the natural origin of DNA. Crick's ideas on this subject were never widely accepted among scientists, and even Crick himself later withdrew his criticisms of origin of life research in light of progress in the field. [67] Another poorly aimed rhetorical dart is the anecdotal change of heart by former atheist philosopher Anthony Flew. Flew being a philosopher and not a biologist, his personal views regarding the origin of DNA have little weight in a largely technical scientific discussion.

Similarly, the dubious claim that no human method of information storage can parallel DNA is inconsequential. [70] Even if true, the attempted point rings hollow. Humans are incapable of creating hurricanes or planets, but this does not imply that divine power is needed to make these objects.

In a crescendo of intellectually shallow pleading, the author of TOL attempts to impose unfounded incredulity onto his readers. He constructs a misguided factory analogy that collapses under the same logical analysis presented earlier in this essay. A cell is not like a factory because it is known that factories are built by humans to achieve some purpose. Projecting purpose onto biology when design has yet to be demonstrated is fallacious. Furthermore, declaring that the origin and development of life is beyond science displays gross unfamiliarity with the pertinent literature and complete ignorance of the progress made in the fields of evolutionary biology, abiogenesis, and chemistry.

Every reflective person must agree that life is beautiful and amazing. No group feels this

awe more deeply than the scientists who devote their collective efforts to researching biology. It is telling that these experts reject the vacuous claims of religiously-motivated amateur critics. To quote TOL, “Really, the evidence speaks for itself.”

## 2.15 The Family Tree

A fourth “question worth asking” is *Has All Life Descended From a Common Ancestor?* This is indeed a very important question. The fossil and genetic evidence for common descent are so strong and well established that any attempt to refute the concept arouses skepticism. Never failing to satisfy the worst expectations, TOL systematically misrepresents the evidence, ignores the conclusive findings of modern genetics, and misquotes scientists at every turn.

The author immediately begins with some Biblical “insights” into the origin of species. These are less insights than they are reiterations of the ancient myths of a prescientific Middle Eastern society. The core assertion is that life forms are restricted to variation within the ill-defined category ‘kind’, and that the fossils and genetic evidence do not indicate evolutionary relationships among different organisms.

The ‘tree of life’ is a simple mental model for understanding the process of speciation. Current species, the most exterior branches, are related by way of many common ancestors, the forks, back to a common trunk. As with all simple models, there are various subtleties and complexities that are not captured by this quick, publicly accessible description. Biology, like every area of knowledge, requires a sufficiently deep understanding of many interrelated concepts in order to grasp the full picture. Unfortu-

nately, TOL is not a work of scientific subtlety or sophistication but instead presents shoddy, misleading summaries of emerging research.

Problems arise as soon as TOL attempts to characterize recent advancements in evolutionary biology. Apparently unfamiliar with the concept of a constantly improving body of scientific understanding, the author frames the introduction of new evidence as necessitating the elimination of all previous knowledge. It is true that Darwin’s original theory failed to explain certain data from later decades. That is why it was revised and expanded. Today, mainstream biology is being modified and improved to include new discoveries enabled by computational genetic analysis. These changes, however, do not alter Darwin’s fundamental conclusion: all life is related. Refinements to the grand picture serve only to strengthen, not weaken, that conclusion. [73]

The nescient author points out that scientists have genetically analyzed many organisms to determine how they are related. Unsurprisingly, he puts forward the blatant falsehood that these analyses have failed to show common descent. Instead, the data show a more intricate and multi-leveled “tree of life” that still points unambiguously to common descent.

Confusion breaks out as soon as TOL starts quoting Malcolm S. Gordon and an infamous *New Scientist* issue titled “Darwin Was Wrong”. Dr. Gordon is correct when explaining that the tree of life (phylogeny) may have various “roots” and not a single starting point. Ancient single-celled organisms swapped genetic information through a process called horizontal gene transfer. Evolved features and mechanisms could be traded back and forth leading to radically new types of life. This chaotic environment is not amenable to a simple tree. Instead, a modified

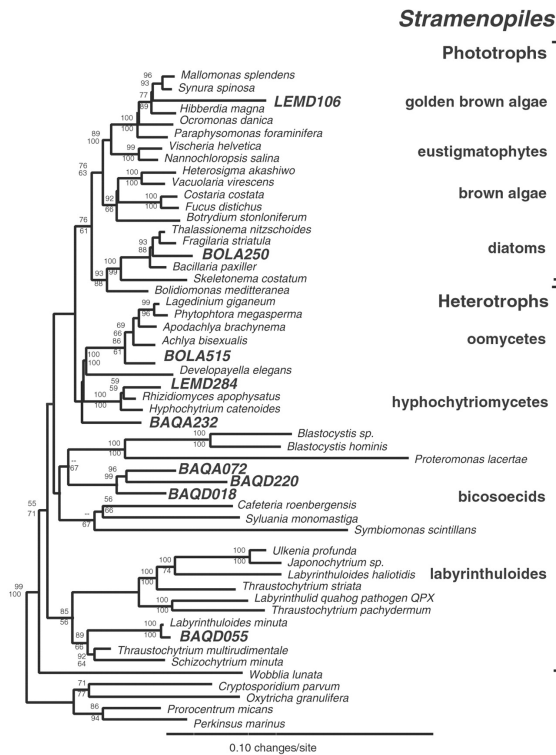


Figure 2.4: An example of a phylogenetic tree.

tree would feature branches splitting off, curling and recombining in strange ways.

This phenomenon was unknown to Darwin, so his simpler conception of phylogeny needs refinement. This is to be expected, being that he lived 150 years ago. Modern biology owes its foundations to Darwin, but in a way, evolution is not really “Darwin’s theory” anymore. His key insights remain, but they have been radically improved and supplemented. Science is not a dogmatic collection of immutable statements made by unassailable saints. It does not matter that Darwin was incorrect about many things, as science is not tied to any individual.

Dr. Gordon’s other comments should be

placed in context by noting that the title of the published work in which his statements appear is *The Concept of Monophyly: A Speculative Essay*. This publication is a speculative work addressing emerging concepts in the complicated world of biological classification called cladistics. Comments involving the reality of categories like kingdom or phylum are intimately related to inquiries into the ancient history of single-celled organisms. This work does not challenge the fact that modern species are related by common ancestors.

The deceptive use of the *New Scientist* issue proclaiming “Darwin Was Wrong” falls along the same lines. While the publishers of TOL try to avoid charges of dishonest quote mining with a footnote, they are still guilty. It is true that advanced computational tools are opening up new possibilities for analyzing the genomes of organisms. The results of this work are leading scientists to revise old models, adding detail and nuance. All of this research only further solidifies the theory of evolution.

The editors of *New Scientist*, while perhaps too quick to publish sensational cover statements, were fully aware that their work would be misappropriated by creationists in exactly the fashion that TOL does. It is best to quote directly from the magazine itself:

“None of this should give succour to creationists, whose blinkered universe is doubtless already buzzing with the news that ‘*New Scientist* has announced Darwin was wrong’. Expect to find excerpts ripped out of context and presented as evidence that biologists are deserting the theory of evolution *en masse*. They are not.” [15]

Recent findings may necessitate reconsidera-

tion of the early stages of life's diversification. A simple tree may no longer be sufficient to capture the complicated interactions of ancient life forms. The topic is controversial. [77, 13] This fact has little impact on the evolutionary relationships that exist between modern multicellular organisms. The idea of a 'universal common ancestor', which means that all life can be traced back to a *single* organism, is different from the more general 'common descent', which is the fact that all species are related by common ancestors.

## 2.16 History in the Rocks

Satisfied with clumsy quotations regarding common ancestry, TOL moves on to construct a similarly ridiculous case against the fossil record. It starts by quoting David M. Raup who explains that the fossil record is incomplete and shows that species are relatively stable much of the time. This is true, unremarkable, and has been known and acknowledged for many decades. The author of TOL has no idea what the fossil record actually is, or what should be expected from it. This ignorance is due not only to a lack of understanding about the process of evolution but the mechanisms and limitations of fossilization itself.

Creationists imagine that if animal species are related by evolutionary mechanisms, that a fossilized example of each intermediate step should be found. This is incorrect on a few accounts. Fossilization is a rare process, as most organisms are not preserved in the proper manner to create a fossil. Some environments are not conducive to fossilization. Some organisms do not have hard tissues that can be fossilized. Finally, finding a particular fossil is quite difficult.

More importantly, the process of evolution is

not the linear, ever advancing, steady process that some people assume. Evolution is not "trying" to get anywhere in particular. Organisms cannot be arranged in a straight ladder structure with "better" creatures on top and "primitive" ones below. Evolution is more accurately pictured as a bush, with many arms spreading in all directions. Only a few branches actually increase in complexity and introduce new structures or features.

The environment is frequently the force behind the derivation of new species, so the rate of environmental change is very important to the stability of a species. Many species remain fairly unchanged over long periods of time, a state called stasis, because the environment is stable. In contrast, rapid speciation may occur under certain circumstances when abrupt environmental change or other pressures are present. The speed and limited geographical extent of this process makes it unlikely that all intermediates will be preserved.

An example of relatively speedy biological diversification is the oft-mischaracterized 'Cambrian explosion'. While "fast" by geological standards, the Cambrian explosion took place over at least five million years. This period of evolution was relatively rapid, though not miraculous in nature. There is evidence of complex life in the Precambrian period and there are transitional fossils within the Cambrian. [30, 10, 78] It is unclear exactly why TOL thinks the Cambrian explosion is a problem for evolution or an asset to their own position. It is possible that the editors consider the emergence of certain major body plans as an example of the 'creative days' of God, but this is unfounded. Virtually none of the animal groups that existed during the Cambrian period resemble any modern species. There were no mammals, birds, or insects. Interestingly, no



land plants evolved until much later, in contradiction with the book of Genesis. It is clear that the “vegetation” actually came after some “creatures” like trilobites already existed for millions of years.\* The implied Biblical interpretation of the Cambrian explosion is actually hurt by any detailed examination of the character and nature of biological history.

Is evolution incapable of explaining the diversification recorded in the Cambrian strata? TOL suggests, by quoting a suspect interview of Stuart Newman, that Cambrian history “. . . is causing some evolutionary researchers to question the traditional version of Darwin’s theory.” [68] Of course, no biologist accepts “traditional” evolutionary theory as described 150 years ago. Darwin lacked much of the fossil evidence that exists now, and had no knowledge of genetics, much less the sophisticated genetic tools of the 21<sup>st</sup> century. New evidence necessitates improved theories. Emerging research suggests that other genetic phenomena that would have been unimaginable to Darwin are important for shaping species. When Dr. Newman refers to the “Darwinian mechanism”, he is referring specifically to natural selection. Other mechanisms like gene flow, genetic drift, and recombination can also lead to biological change. No biologist would be surprised to hear the evolution is not restricted only to natural selection.

Even considering that evolution has an uneven tempo, with very slow change punctuated with periods of blooming biological diversity, there should still be many examples of transitional fossils with intermediate characteristics. Contrary to TOL, there are many transitional forms that have been discovered. Notable transitions include land mammals-to-whales, fish-to-

tetrapods, reptiles-to-birds and apes-to-humans. [12, 41, 24, 35, 64, 43, 66, 20, 22] Even the particular example of the evolution of bats has been illuminated in recent years. [37] These collections are not complete, as every possible intermediate has not been unearthed. However, the fossil evidence is more than adequate to demonstrate that life has changed considerably over time.

In the face of such evidence, the author of TOL must try to obscure the scientific conclusion. The first objection is that “. . . the comparative size of the creatures placed in the reptile-to-mammal sequence is sometimes misrepresented in textbooks.” No reference is provided to an actual example of this in a real textbook. Even if there was, it would be a nonissue. Ignoring the fact that figures presented in a text are likely sized to allow readers to compare features and not to show the creatures to scale, organisms can vary greatly in size while having very similar genetic makeup. As an example, even most creationists will admit that all dog breeds have a common ancestor. Yet, the difference in size between a Chihuahua and a Great Dane is considerable. The genes that regulate size can differ among closely related species even if other features are nearly identical.

The second, more “serious” supposed challenge to the fossil record is the fact that this record is incomplete. Species that are related can be separated by millions of years. Is this a problem? Not when it is understood that the series of related species that make up a phylogeny (a nested tree of biological relationship) are not claimed to be direct ancestors. As mentioned previously, the history of evolution resembles a bushy, branching structure. Many of the organisms found in the fossil record may be evolutionary dead ends or evolutionary “cousins”, not direct “links” between two points on a tree.

---

\*Genesis 1:11-21

However, by comparing fossils, scientists can see the development of certain biological structures through time.

## 2.17 One Clear Solution

TOL asserts that biologists are merely imposing an evolutionary tree of common ancestry on a fossil record that admits of no obvious interpretation. The author likens developing a phylogenetic tree to inferring the plot of a movie from a mere handful of frames. Again, TOL thrusts a scientist inappropriately into an argument he is not making. Richard Morris is quoted as saying, “They had been trying to interpret fossil evidence in terms of accepted evolutionary theory.” Dr. Morris is referring historically to the introduction of the concept of punctuated equilibrium, or relatively rapid evolution, by paleontologists Niles Eldredge and Stephen Jay Gould. Before this idea was introduced, scientists were limited to trying to understand fossils only as representatives of gradualistic change. As Morris explains in the same chapter quoted by TOL, scientists must first try to use current theories to understand new evidence. If this was not done, new data would be incomprehensible. However, when anomalous evidence cannot be explained by a current theory, the theory is revised. This is exactly what happened in the 1970s in relation to punctuated equilibria. It is now understood that species can remain stable for long periods of time and can also change relatively quickly. Revision and improvement based on new evidence is how science works. This change no more impacts the fact of common ancestry than Einstein’s formulation of general relativity affects the fact that Earth has gravity. Both are examples of new theories offering better explanations of the data

than the old ones. Dr. Morris summarizes his statements:

“You shouldn’t imagine that Eldredge’s findings cast any doubt on the idea of natural selection. He had only observed that certain species had remained static for long periods of time. They had certainly evolved from earlier forms, and natural selection was the only thing that could have caused them to do so.” [61]

What about the fossils that do show changes? Are biologists just arranging them in an arbitrary order that they deem convenient? To understand why the evolutionary phylogenetic tree best explains the fossils that have been discovered, one has to know how that tree is constructed. Before it was possible to map the genome of an organism, the only way to differentiate species was by their physical characteristics, what scientists call morphology. For example, the differences and similarities between a cat and a fish can be reduced to a list of physical characteristics. One is a mammal, and one is not. One has lungs, the other has gills. However, they are both vertebrates. Using morphology, organisms can be categorized by species, genus, family, and so on. This system, with its familiar two-part Latin naming convention is still used today.

Originally, this taxonomy was not seen as representing anything other than a convenient way to categorize different creatures. The inventor, Carl Linnaeus, was a Christian creationist who lived a century before Darwin. He was in no way trying to promote common descent, which he had no conception of, or suggest that different species were related in any profound way.

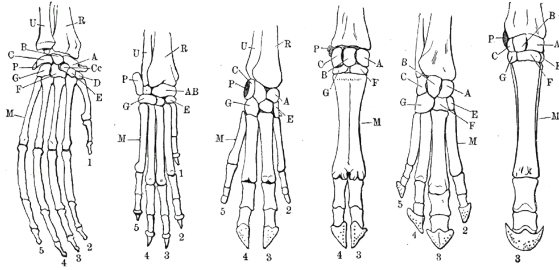


Figure 2.5: Homologous structures in mammals.

Beyond classifying organisms by their physical features, it is also possible to arrange them according to their developmental processes. One can compare the way a larva becomes an insect or the way a embryo grows into a mammal. By observing the manner in which different parts are formed, similarities emerge. The developmental process is fundamental and difficult to alter, so if evolution is correct, creatures that share common ancestry should share developmental pathways.

Utilizing the morphological and developmental characteristics of different organisms, a fairly detailed nested hierarchy can be created. One might object that picking certain characteristics by which to develop a hierarchy is arbitrary. This would be correct in some cases. For instance, airplanes could be split into propeller and jet propelled categories. Among each of these groups, further divisions could be made according to the number of engines, passenger capacity, or some other feature. Though it may be useful for remembering different types of airplanes, any random selection of features could be used to create totally different hierarchies. Because airplanes do not reproduce to make other airplanes, these nested trees would be arbitrary.

If all living things were created separately and did not have a common descent, the phylogenetic

trees created by biologists should be endlessly variable, just like the airplane tree. One biologist could group animals by whether they moved primarily by walking, swimming or flying. Another could differentiate according to warm or cold-bloodedness. However, each of these arbitrary hierarchies would fail to fit with other data. Bats and birds both have wings, and therefore could be grouped together. Unfortunately, their skeletal features differ greatly, along with the fact that one is a mammal and the other is not. All arbitrary methods of generating phylogenetic trees run into the same problem when it comes to incorporating multiple types of data.

By contrast, if organisms are biologically related by a branching tree of common descent, many different types of features should cluster together. Traits that developed early in evolutionary history should be found among the following branches, and nowhere else. A nested hierarchy constructed by assuming that organisms are related by common ancestors best fits all the data. A tree created according to morphology will match very closely with one developed according to development. Each independently generated phylogeny validates the structure of the other. In fact, it can be shown mathematically that a phylogeny developed according to genealogical relationship is superior to one that uses arbitrary characteristics. [39, 44]

If creation is true, there is no reason that this should be the case. A nested hierarchy based on common descent should be just as variable as one created according to any other criteria. While common descent can explain why certain life forms share morphological or developmental characteristics, creationism cannot. Why do no birds have fur? Why are there no fish with mammary glands? Why do no nonvascular plants have flowers? Why do all fish develop differently

than all squid? If life was created by a divine engineer, one would expect specific traits to be less strictly segregated. In reality, these characteristics are distributed on the tree exactly as would be predicted by common descent.

## 2.18 It's in the Genes

Modern genetic evidence further reinforces this tree of common ancestry. Instead of looking at the physical features of an organism, scientists can now analyze the genome also. Genetic structures show a similar distribution of descent with modification. Many creatures share the same molecular machinery to archive basic biological tasks. An example of a ubiquitous biological element is the protein *cytochrome c*. *Cytochrome c* is vital for generating energy within the cell, and all living things have it. Interestingly, this protein can be structured in vastly different ways and still fulfill its role. The version of *cytochrome c* present in humans differs in nearly half of its coding from the version in a yeast. However, the human protein code can be transferred into a yeast that has had its own version deleted, with no loss in function. [40]

Because there are a huge number of *cytochrome c* variants that are equally useful, different species can have very different versions. If organisms were created distinctly, there should be no overarching pattern in the distribution of different formulations of *cytochrome c*. Again, the variations do not fall randomly among species, but show the same common descent pattern previously evidenced by morphology and development. It is important to reiterate that related species do not have similar variants of this protein for any functional reason, because even radically different versions are

operationally equivalent.

A good example of genetically related *cytochrome c* variation is seen in apes. The human and chimpanzee protein differs only slightly from that of other mammals. The chance of this happening without a hereditary relationship is almost zero. Without fail, species that are more closely related by common descent have more similar versions of *cytochrome c*.

More evidence is found by revisiting endogenous retroviruses (ERVs). These are portions of various virus genomes that have been randomly inserted into a host genome. They were mentioned earlier when discussing non-coding DNA. Common descent would predict that related species would share portions of retrovirus code inherited from a common ancestor. This is exactly what is found in nature. Humans and chimpanzees share a minimum of seven common insertions, which would be almost impossible if they did not share a common ancestor. [21] Similar genetic relationships can be found for other animals. [46] A phylogeny based on retroviruses again reinforces the same tree determined from other facts. Without admitting common ancestry, how can creationists explain these genetic patterns?

Various independent threads of evidence refute TOL's intimation that scientists are merely interpreting the evidence in a biased manner to achieve the result they want. The distribution of physical traits, genetic code, and developmental processes all point to a tree of common descent for multicellular organisms. While it is unreasonable to expect to find each transitional form, multiple sources of data all corroborate the same story of the history of life. Aside from divine deception, creationists are without explanation for these clear pointers to the shared ancestry of all living things.

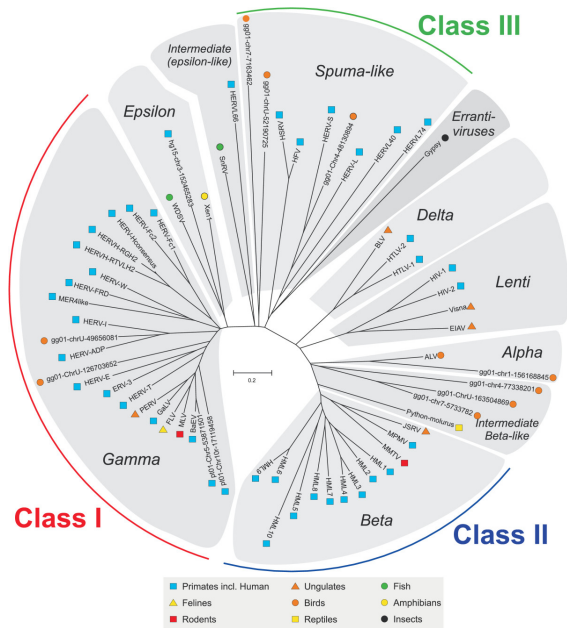


Figure 2.6: A phylogeny created according to ERVs.

## 2.19 The Naked Ape

Attempting to apply the faulty conclusions of its previous line of “questioning”, TOL attacks the evidence for the origin of humans from other apes. The first target is a strawman description of the fossil evidence for the ancestor species of modern humans. While acknowledging the sheer number of specimens, it is claimed that there is no consensus among anthropologists about the specific line of descent that led to humans. This is strictly true, just as it is for any species. Constructing the exact line of succession is virtually impossible, but using the methods mentioned above, a tree structure still emerges. The reason scientists disagree about which species led to another, and which ones coexisted or went extinct, is due to the gradual nature of specia-

tion in complex animals. If, as evolution claims, species change relatively gradually, it should be difficult to tease apart the differences between related species. But that does not mean that differences cannot be found.

Picture a line of color that transitions smoothly from red to orange. If the eye follows the line slowly from one end to the other, there is no specific point when red becomes orange. If a certain point is chosen, what makes another point just a fraction of an inch to the left or right not the true demarcation? By following this logic, it would be possible to argue that a point immediately to one side was just as good as the previous one, and soon the eye would end up at the red or orange end. However, it would be foolish to argue that the whole line is the same color or that the transition does not exist. One end is definitely red, the other definitely orange, and the points in between are a mix of the two.

The same predicament is met when investigating the remains of ancient human predecessors. The process of evolutionary change was slow, and therefore the science of determining strict categories is difficult and painstaking. Experts debate the various features of bones, and try to reconstruct the “family” tree. The techniques used to make these distinctions are complex and beyond this essay, but can be found in any college-level anthropology textbook. [8] While there are definitely informed disagreements among scientists, the picture of human origins as a whole is fairly clear. Modern humans were preceded by various *Australopithecus* and *Homo* species, which each possessed a mosaic of human-like and ape-like features. It is certainly true that intact skulls and skeletons are rarer than individual fragments, but more than enough physical evidence exists to determine that there were many transitional species

that eventually led to *Homo sapiens*. In addition to these specimens, there are many features of human and modern ape genomes that indicate common descent, as explained earlier.

Next, TOL details the discovery of the fossil called Ida in 2009. It is accurate when it describes the media hype surrounding this specimen. Ida was accompanied by a television documentary and website that were unveiled simultaneously with the scientific article. Ida was claimed by newspapers to be “the missing link” in human evolution. Satisfied with pointing out the apparent folly of scientists, TOL fails to mention that the rest of the scientific community was skeptical when Ida was announced. [9] The people who initially discovered and studied the fossil were criticized for not allowing the broader scientific establishment to examine their claims before Ida was highly publicized. When other scientists were able to do their own work, it was determined that though Ida was a beautiful and valuable find, the original claims were overstated. [36] The scientific community was not “fooled” by Ida. Only popular newspapers were misled by the over-hyped unveiling. These same news sources also published the contrary research when it was published. [62] Finally, the term ‘missing link’, loved by sensational headline writers, is scientifically vacuous. As explained previously, direct evolutionary relationships are impossible to establish. There is no magical fossil that would “prove” human evolution. That history has already been firmly established.

TOL next questions the scientific basis for museum and textbook depictions of ancestral species related to *Homo sapiens*. This complaint is accurate but irrelevant. The reconstruction of the specific facial features of long extinct species is influenced by artistic considerations. The same goes for the pigmentation of dinosaur

skin and the multicolored pictures of the cosmos taken by the Hubble space telescope. No one yet knows what color dinosaurs were, and Hubble photos are printed in false color to show detail. This is done for public consumption to make scientific findings more approachable. The same goes for fleshed out depictions of the faceless remains of human ancestors. Fortunately, the evidential basis for human evolution is not founded on what the mugshot of a *Homo erectus* may have looked like. The various cranial features of these species are evidence in themselves, and cosmetic facial characteristics are inconsequential.

The last argument TOL poses in this section focuses on the brain size of the ancient predecessor species of modern humans. It is claimed that biologists use brain size to determine the temporal relationship of the species that led up to humans, but that this is invalid because there is no relationship between brain size and intelligence. The logical disconnect in this statement is fairly obvious. Even if brain size had no relation to intelligence, it would still be possible to determine the approximate ages of various fossil specimens. Earlier species had smaller brains, and modern humans have larger brains. Ignoring the issue of intelligence, this gap in sizes must be filled by intermediate examples. These examples exist and show a correlation between the age of the fossils and brain size. [58] How size is related to mental ability is a much more complicated topic, which is the origin of the quotes listed in TOL. It has been determined that factors such as brain structure may play an important role in determining how intelligent a creature is, and that size should not be used as a singular guide to ability. [53] Notwithstanding, this has no effect on whether size is related to relative age. On this point, the editors have completely failed even to make a co-

herent argument from misappropriated quotes.

Creationists unceasingly attack all evidence for the evolution of humans from other species because it deeply impacts their theology and perception of people as separate from the rest of creation. They must ignore the fossil and other anthropological evidence and hopelessly search for “holes” in which insert religious explanations. When talking about Neanderthals, TOL tries to claim that they were merely a “race” of humans. Once again, they have misinterpreted the author they are quoting, Milford Wolpoff. Wolpoff is using the term ‘race’ to mean subspecies, not in the way that people use the word in common speech to refer to ethnic variation. [83] Some scientists do argue that Neanderthals should be classified as a subset of the genus *Homo*, and evidence shows that they interbred with humans at some point. [48] However, humans and Neanderthals differ greatly in morphology, and even a layman would be hard-pressed to confuse the fossils. In this instance, TOL continues its pattern of misrepresentation of sources and poor research.

## 2.20 The Good Book

The final question in the brochure asks *Is it Reasonable to Believe the Bible?* Here, the real goal of TOL is seen in stark relief. Throughout the previous 30-odd pages, the editors have attempted to argue largely along “scientific” and “logical” lines, only occasionally featuring overt religious statements. This technique is now abandoned for direct and unashamed Bible promotion. It would be understandable if a reader of TOL is confused by the transition. Since when did the Bible become important in cutting edge scientific research? Why should the reader care

at all what the Bible says about anything? TOL is assuming that the target audience is already sympathetic to their position and is merely supplying the “obvious” conclusion: if evolution is false, the Bible must be correct! This unsupported leap in logic is incomprehensible unless the reader already believes that the Bible is the word of God. In that case, the author is foolishly assuming the very thing he has yet to prove.

As this essay is focused on evaluating the evidence for scientific claims, the portions of TOL dealing with arguments for Biblical accuracy or the tertiary value of its contents are irrelevant. It is simple enough to list many Biblical passages that are in conflict with scientific fact\*, but as these could be dismissed with slippery arguments about metaphorical interpretation or miraculous events, further space will not be devoted to them here.

To conclude the critique of TOL, it is necessary to address a few of its final statements. The author makes the incredibly condescending statement that the Watchtower’s brand of Biblical interpretation “leaves ample room for scientific inquiry”. It is not the place of a scientifically ignorant religious organization to dictate arbitrary boundaries for science. Similar declarations made hundreds of years ago by religious authorities regarding astronomy and medicine were ignored and the ensuing progress in these fields revolutionized human civilization. Groups that have granted scripture precedence over science are, in time, marginalized by society but continue to declare the accuracy of divine revelation. The Watchtower is already far down this path, and its noisy protests against science are evidence of this retrograde trajectory.

To end on a positive note, it is refreshing to

---

\*Genesis 31:11-13, Joshua 10:12, Leviticus 11:13-19

see that TOL rejects the idea that evolution can be used as a legitimate basis for racism or genocide. The brochure also recommends that people seek out evidence and foster curiosity about nature. These recommendations are praiseworthy, however, actually following them will probably lead to the opposite result from that advocated by TOL. When the scientific evidence has been investigated thoroughly, and not just by way of Watchtower publications, an unbiased reader will conclude that evolution is an elegant and powerful explanation of the awesome biological diversity on Earth.

### 3.1 Was Life Created?

The second creationist brochure distributed by the Watchtower Society is *Was Life Created?* (WLC) It covers some of the same arguments and material in TOL, but incorporates a wider perspective on what they see as evidence for design. As before, there is a large amount of uninformed criticism of evolution. In addition, the author presents a few other arguments related to the ecosystem of planet Earth, the highly adapted nature of many creatures, and some emotional appeals. The brochure, like its companion, emphasizes the importance of evidence but confuses the reader by blending specific, Bible-based ideas with more generic design arguments.

Instead of focusing on biology, the initial subsection of WLC focuses on the physical features of Earth that allow life to exist. Factors such as the location of the planet in the solar system, the atmosphere, the magnetosphere, the water and nitrogen cycle, and the length of the day are all pointed to as proof that Earth must have been designed. However, this reasoning is flawed.

The argument implies that the particular biological features of humans and other life forms were somehow determined before the solar system existed, and that the planet was tailored to fit the creatures that were to live on it. This line of thought is backwards. It is not logically sound to reason from the perspective of a human on Earth and conclude that the planet had to be “designed” in a certain way for this result to obtain. This is because the existence of the person doing the thinking requires that Earth is a planet capable of supporting life in the first place. The fact of existence acts as a sort of ‘screen’ that keeps one from evaluating the probability of a specific set of original starting conditions on the planet.

This is called the observational selection effect. An example from the philosophical literature will clarify the concept. [75] Imagine that a person is fishing in a lake with a net. After a period of time, he discovers that all of the fish that have been caught in the net are 10 inches or more in length. He concludes that it is probable that all the fish in the lake are at least 10 inches long. However, upon further investigation, he discovers that the holes in the net are 10 inches wide, meaning that no matter how much fishing is done, there will never be a 4 inch fish in the net. With this information, he realizes it is impossible to determine what fraction of the fish in the lake are larger than 10 inches. Maybe only a small percentage are that large, or maybe they all are. The features of the net preclude any judgment in this regard.

Humans on Earth are faced with a similar situation. The only way a person would be able to observe that the Earth is able to support life is if it *was* able to support life. Any sentient creature that exists will observe that its home planet is capable of supporting life, whatever particular



set of physical circumstances this includes. Existence is like the holes in the net. Just as no small fish will be caught by a net with big holes, it is impossible, by definition, for life to evolve on an uninhabitable planet.

With this in mind, the ability of Earth to support life should not be surprising. Without a magnetic field, large multicellular organisms would be unable to survive the radiation exposure. Without an atmosphere, not only would humans be bombarded by space debris but they would not be able to breathe! It is not miraculous that the Earth is a livable ecosphere. If it was not, there would not be anyone around to realize it.

The same goes for the water and nitrogen cycles. Both processes are physical phenomena that result directly from chemistry. These features allow life to exist, but do not appear to be designed for life. In contrast, some aspects of the planet are harmful to life. Over the four billion year history of Earth, the climate and environment have changed radically, including vast stretches of time during which complicated organisms could not survive. [82] In fact, large portions of the planet, like deserts and arctic regions, are currently hostile to most life forms, including humans. On multiple occasions, catastrophic events including meteor impacts and rapid climate change have wiped out much of the global ecosystem. Additionally, the same molten core that generates the protective magnetosphere also causes plate tectonics, which is responsible for volcanoes, earthquakes, and tsunamis that can kill hundreds or thousands of people. The Earth is without doubt the most hospitable planet yet discovered, but it is not some supernaturally-ordained paradise for humans.

To put it in mathematical perspective, there

are billions of galaxies in the universe, and billions of stars in each galaxy. Many stars have planets, a fact scientists were only able to confirm recently. Statistically speaking, some of these planets will resemble Earth in their ability to support life. The search for these types of planets is a very active field of research. [5] The Earth happens to be one of possibly millions of planets in the galaxy that are habitable.

### 3.2 Life Finds a Way

The other factor that explains why such a vast quantity of living things thrive on Earth is that evolution is extremely effective at adapting populations to the environment and filling out different survival niches. Life can adapt to even the most extreme conditions like high acidity, high temperature, high radiation, and so on. It fits itself to conditions, conditions need not be tailored for it. The sun does not exist so that humans can see. Human eyes evolved to see the wavelengths that the sun shines in.

Life also changes the environment. The only reason there is such a huge amount of oxygen in the atmosphere is because photosynthetic bacteria made it. Once there was sufficient oxygen, things that breathe oxygen could evolve. Life constantly changes in response to the biosphere and stays in a dynamic equilibrium. Nothing is stable over the long term. That is why 99.9% of all species that have ever existed have gone extinct. [65] This could be seen as incompetent design, but it is actually the result of natural selection killing things that do not change. This rich biological history of constant failure and occasional success is recorded in the rocks and in the DNA of every living thing.

The next subsection of WLC highlights the

topic of biomimetics. It asserts that because human engineers are learning things from the anatomy of animals, a master designer must have created the animals in the first place. The idea is intuitively appealing, but falters when investigated.

The first problem is the implicit assumption that the features of evolved creatures should be poorly adapted or random amalgams of cells. Of course, evolution predicts that organisms will be very well adapted to their environment. Over billions of years, one should expect the methods and mechanisms of life to be finely honed for survival, producing what could be called ‘apparent design’. It would be very strange indeed if whales were bad at swimming and birds at flying. However, evolution is a blind, natural process that cannot foresee the future, cannot change the past, and usually finds the easiest path to a solution. Hence, there should be evidence of unplanned changes and a history of adaptation.

This evidence is found in abundance in the natural world. To start, evolution cannot see the future. It must make do with existing structures, existing DNA, and whatever mutations come along. It is not possible for a mindless process to “plan” for future changes. A great example is the mammalian inner ear. The tiny bones that form this structure and allow hearing did not just pop into existence and become useful. They developed over a long period from the jaw bones present in reptilian ancestors. [47] There is extensive fossil evidence for this transition. [7] This shows that parts of the anatomy can be modified and used for entirely new purposes and that intermediate forms of a particular organ or system do not necessarily have the same function as its precursors. Evolution is resourceful with the limited tools and raw materials that it has. [31]

As a result of this tendency to use existing features to new ends, there also exists a developmental record of particular structures that reveals their evolutionary history. For instance, mammals, which give birth to live young, evolved from reptiles, which lay eggs and require an egg tooth or a caruncle to open the shell when hatching. Revealing the evolutionary connection, during the development of marsupial mammals like the koala or bandicoot, the developing animal becomes encapsulated in a translucent eggshell that is reabsorbed before birth. These creatures also retain a vestigial caruncle even though there is no shell to escape from. [79] Remnants of the previous reproductive process is clear evidence that these animals shared common ancestors with reptiles.

Evolution takes the “path of least resistance” when modifying biological structures. This leads to “designs” that can be puzzlingly round-about if one tries to understand them as being planned by an intelligent designer. Take the recurrent laryngeal nerve. Instead of running directly to its destination, as in fish, the mammalian version splits in two, with one part plunging down to the base of the neck, around other structures, and then back up the neck. In animals with long necks, like a giraffe, the superfluous length of the nerve can amount to many feet. [11] A similarly circuitous anomaly is seen in the vas deferens, the seminal ducts which connect the testes to the penis. In human males, instead of taking the obvious route between the two intimately situated organs, the duct runs up and over the ureter and then back down to its termination point. (Williams plan and purpose) No supernatural, or even mediocre designer would craft these needlessly lengthy plumbing arrangements if he was “brilliant” and “orderly”. Evolution, however, with no idea where certain structures

may end up, simply makes the easiest incremental change possible. A solution arrived at by a long chain of short, easy steps is often more complicated than that which could have been made by one larger, deliberate step. [59]

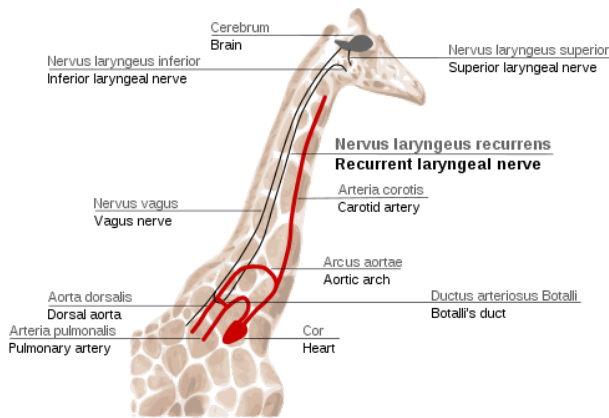


Figure 3.7: Circuitous path of the laryngeal nerve.

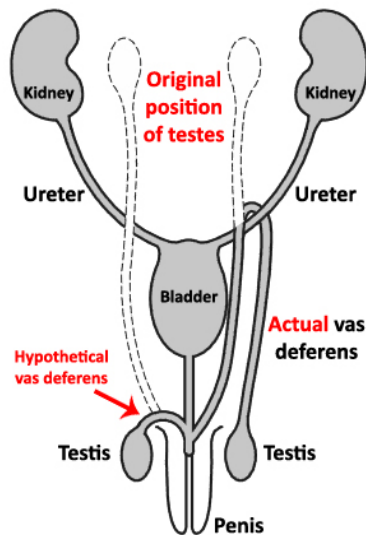


Figure 3.8: Redundant length of vas deferens.

The purpose of these examples is show that nature is not made up of perfectly designed organisms. For every elegant, highly adapted organ or system, there is another that is compromised by the limits of evolutionary change. Blind, incremental change can produce finely honed mechanisms, like hydrodynamic fish and efficient wings, but it simultaneously leads to vestigial structures and processes. It also results in the vast numbers of animals and entire species that die or go extinct.

To return to the original thread of the argument, it is true that engineers attempt to mimic biological mechanisms in order to improve their own designs. A fact that WLC forgets to mention is that engineers are also directly utilizing the process behind natural “design”. In fields that require the optimization of many interrelated factors, engineers are now using genetic or evolutionary algorithms to computationally search out the best design. Such algorithms take the features of some system, like an airplane or a rocket engine, and assign them to virtual genes and chromosomes. [57, 45] These genes are then randomly changed and recombined. The results are then evaluated according to the design specifications. The best examples are automatically selected and then “bred” together with more random mutation and recombination. Over thousands of generations, the optimal design is found. Trying out all of these different permutations, or trying to engineer them from the top down would be impossibly difficult and time consuming for any human designer, but evolution and selection provide a tidy solution. According to the style of argument favored by WLC, the fact that engineers are aping an unintelligent natural process to improve their machines should prove that natural processes must have created complex biology.

### 3.3 Just Facts, Please

The following subsection is titled *Evolution: myths and facts*. Contrary to this informative sounding headline, the pages include no clarifying facts but merely misrepresented science. It starts with the tired claim that microevolution, which the Watchtower accepts as change within the undefined category ‘kind’, is fundamentally different from macroevolution, which they imagine to be something like the transition between apes and humans.

As pointed out on previous pages, this is a false distinction based on a faulty understanding of what evolution actually claims. All evolutionary changes are relatively minor. So-called microevolution and macroevolution are the same process viewed on different time scales. Macroevolution is not the claim that one type of organism suddenly gave rise to an entirely different organism. There was never a point in history when a reptile magically gave birth to a mammal. The transition between these two points was gradual, not instantaneous. Accepting the reality of small evolutionary changes alone but not the accumulation of these changes is like accepting that a plane can fly from New York to Pennsylvania, but not from Maine to California. At the base level of the genome, there is no qualitative difference between the genetic changes that take place on the micro or macro timescale. Large accumulations of evolutionary change take millions of years to form, which is why biologists rely on genetic and fossil evidence to reconstruct that history. The smaller constituent changes, like that from one species to another, can be seen in the lab.

Speciation can happen when two populations are split, either literally by geography or by certain reproductive behavior, and the separate

groups slowly evolve apart until they no longer interbreed. Both species are quite similar, but they are still different species. After billions of years of population divergence and evolution, the tips of the evolutionary tree are radically different. It is crucial to remember that species do not just “turn into” other species. They split, and the descendent populations then share a common ancestor. Mice and dogs share a common ancestor. That does not mean that there was a half-mouse, half-dog transitional species in the past. These creatures are related by a multi-leveled hierarchy, not a direct line. Observed instances of speciation are plentiful. [55, 72, 27, 32]

### 3.4 A Curious Case

In an attempt to discredit the vast number of examples of speciation and the evidence of common ancestry among all organisms, WLC quotes a single source multiple times: the writings of Wolf-Ekkehard Lönnig. The objectivity of this source is highly questionable, as Lönnig is a long time member of Jehovah’s Witnesses and a creationist. [4] The book he authored that is referenced in WLC also fails to inspire confidence, not being from a prestigious university press but produced by an obscure Indian pay-to-print publishing service. [71] Lönnig’s opinions are not shared by his colleagues at the Max Planck Gesellschaft or the scientific community. In fact, when he posted several creationist essays to his professional website, his employer pulled the pages down out of embarrassment. [1, 52] The repercussions of this incident are surely what necessitates the disclaimer printed in WLC which explains that Lönnig’s opinions are his own and are not to be associated with the MPG.

There are some half-truths in Lönnig’s writ-

ings. Species do have certain limits. It is physically impossible to breed a 40 foot tall human because the skeleton is unable to bear the weight. Some biological machinery does remain intact over millions of years. Deeply embedded genetic and developmental pathways rarely change because they are so integral to the survival of the organism. Most importantly, natural selection is not the only mechanism for evolutionary change. Other processes like genetic drift and recombination play an important role.

What about Lönning specific claims regarding mutation breeding? He characterizes the field as overly ambitious, with nothing to show for itself and no modern Western practitioners. While mutation breeding proved not to be as effective as first hoped, it is absolutely false to say that no beneficial plant varieties were obtained with the method. There exists many crucial plant species that were improved with respect to hardiness or nutritional value. [80, 2] The decline in popularity of the field is due to the rise of more sophisticated and scientifically “exciting” genetic engineering techniques in advanced countries, not some gross failure. [81] Further, the scope of this research is so limited that it provides no evidence against the possibility of speciation in a larger context.

In making its argument against mutation breeding, WLC stumbles by admitting that more traditional forms of breeding are effective at producing superior plant varieties. Selective artificial breeding is a human-directed version of natural selection. Plants randomly mix their genes during reproduction, and by choosing the plants with the most desirable features, humans can radically change these species. Examples of the effects of domestication and artificial selection include dogs, cows, corn, sunflowers, and bananas. While these organisms are still usually

classified as the same species, they are qualitatively very different. [34] This demonstrates that selective pressures can change living things in drastic ways.

### 3.5 How New is ‘New’?

These changes, though, will not make some organism magically become “an entirely new one”. This is WLC’s repeated error in understanding how evolution works. Biologists do not expect a corn plant to start making seeds that become potato plants, no matter how much selection takes place. These species have a shared ancestor, several “levels” away on the tree of life, that split into two or more separate populations millions of years ago. In the same way, a cat will not turn into a dog by selecting dog-like features in generation after generation of cats, nor would a biologist expect it to. They share a distant common ancestor, so they are related, but one cannot transmute into the other.

By repeatedly saying that evolution is not making “entirely new” species from previous species, WLC is attacking a strawman concept that no scientist would ever expound. In reality, one population splits into separate groups, and these organisms evolve independently according to differing environments and other effects. Initially, the differences will seem quite small. So small, that if the populations were brought back together into the same genetic pool, the differences would quickly be washed away by gene flow. However, after a sufficiently lengthy isolation period, they would truly be different species, and would not interbreed. They remain closely related to the common ancestor. Only long ages of repeated branching and diversification ultimately lead to the amount of diversity seen to-

day.

WLC attempts to build off of Lönning's dubious case against speciation with a sloppy description of Darwin's famous finches. The author of WLC is so unfamiliar with the ground upon which he treads that facts taken for granted in the scientific community are seen by him as surprising or scandalous. The fact that different populations can interbreed and induce enough gene flow to remove any large distinctions is not new knowledge. Creationists are stuck thinking that organisms exist in strict, inflexible categories. But biology is not a rigid arrangement of elements, it is constantly in flux. For this reason, the fact that two species may merge through the flow of genes seems strange to them, but not to actual scientists.

The Galapagos finches are still finches. This is to be expected. Over a short period of time, one would not expect very large changes. The fact that WLC expects a finch to become something "new", perhaps a mouse or fish, just underlines how deep its lack of scientific understanding is. By remaining stupefied that a bird has not morphed into a "new" creature, creationists miss the importance of the finches. They demonstrate how natural selection works and how species are related by common ancestors. [16]

WLC also fails to grasp what George C. Williams and Jeffrey Schwartz mean when they say that natural selection does not "create anything new". This is true. The point biologists are trying to make is that natural selection only chooses among individuals that already exist. The new information comes from genetic changes. Natural selection is just a pruning mechanism. It does not cause genetic change. Genetic change happens, and then natural selection can operate. The distinction is apparently too subtle for the Watchtower writing staff to

discern. While scientifically incompetent, they feel comfortable enough to smear the National Academy of Sciences by accusing it of biased presentation of evidence. This is nearly comical and certainly ironic given the blatant misappropriation of sources and facts that occurs in their own publications.

The final topic in this subsection is merely a regurgitation of failed arguments and distortions about the fossil record that were featured in TOL. Content to gloss over the wealth of fossils that paleontology has discovered and categorized, WLC just keeps reiterating twisted descriptions of concepts like evolutionary stasis. It then tries to "catch" Richard Lewontin admitting that the only reason he accepts the evidence for evolution is because he is godless, or something. In reality, Lewontin is just explaining the fact that science looks for natural explanations, and that because of their vagueness and inability to be tested, supernatural explanations are beyond the purview of science. [54] The philosophical necessity for this arrangement was covered earlier in this essay.

### 3.6 Tin Foil Hats

To conclude, WLC implies that evolutionary biology is some sort of vast conspiracy by agnostic or atheistic scientists to mislead the population for some unstated purpose. Rodney Stark, a sociology professor at the Christian affiliated Baylor University, is quoted as saying that at research universities "... the religious people must keep their mouths shut." This entire idea is ridiculous given the fact that many scientists are religious, including the famous biologists Francisco Ayala and Ken Miller. [14] What WLC tries to obscure is that the overwhelming major-

ity of biologists, believers and unbelievers alike, accept evolution.

### 3.7 Myths Misused

To rest its argument, WLC sets out trying to reconcile the Biblical creation myth with scientific knowledge about the origin of the universe, Earth, and life. Quite aware that the Genesis account sounds entirely implausible and illogical to modern ears, the author immediately starts dispensing weak apologetic arguments. To explain how there can be a day and night before the sun existed, he speculates wildly that the light from the preexisting sun was “somehow” blocked, “possibly by thick clouds”. There is no evidence presented for this scenario. If literalism is the rule, the Bible clearly states that God made the sun and moon after day and night were established and even after vegetation had been created. Note that terrestrial plants are created before animals, in conflict with known biological history. The Bible also says that stars were created after the Earth, contrary to cosmology. Strained, implausible harmonizations are all WLC is left with to satisfy skeptical modern readers of Genesis. Of course, the ancient Hebrews were writing mythical poetic literature that was not meant to be interpreted literally by people living 3,000 years later in a world of mathematical physics, computers, and space travel.

WLC is also quick to tamp down any idea that the progressive appearance of more complicated life forms over billions of years lends credence to evolution, even though this evidence strongly supports the theory. It admits that the Bible provides no definition for the unscientific category ‘kind’, and offers none of its own. The author then incorrectly states that the fossil record

supports special creation events.

WLC further asserts that scientists reject the Biblical creation account because of external philosophical reasons. This is inane. Scientists reject the Biblical creation myth for the same reasons they reject native American creation stories, the Babylonian *Enûma Eliš*, the Norse Prose Edda, and ancient Greek notions of primordial Chaos. None of these myths, however beautiful or interesting, are scientific in nature. They contain no testable empirical content, and favor mystical and metaphorical explanations of the universe. None of these stories make scientific predictions, despite credulous claims that the Bible writers knew that the universe had a beginning and that life appeared progressively. These “advanced”, “scientifically accurate” notions are vague and typical of ancient literature. The prevalence of magical and unscientific events in the Bible provides sufficient evidence to conclude that the writers had the same premodern and scientifically illiterate worldview as every other contemporary culture.

### 3.8 Does it *Feel* Like Data?

The ultimate page of WLC wraps up the brochure with a series of emotional appeals. In a transparent argument from consequence, the author insists that accepting the scientific evidence for evolution leads one inevitably to accepting the following notions: life is pointless, God does not exist, and the future of humanity is unavoidably bleak and terrible. On the other hand, rejecting science leads to a wonderful immortal existence full of “loving purpose” and obeying God. No actual evidence is presented for these extravagant claims, but the author is careful to clarify that “. . . such a belief is not based on mere wish-

ful thinking.” A reader should be excused for getting the opposite impression.

## 4.1 Conclusion

To conclude this essay, it is helpful to review the general tactics and motivations for TOL and WLC. Both works are philosophically naive, with no understanding of what science is, how it is done, or what types of questions it can answer. More egregiously, the authors and editors, whether out of malice or incompetence, misrepresent nearly all of their sources. Nuanced concepts are bludgeoned with unadulterated scientific ignorance. Cogent argument is abandoned, with neighboring sentences occasionally lacking any discernible logical relationship. While paying lip service to “investigating the evidence” and “looking at both sides”, the documents fail to present any cogent description of the idea they are arguing against. In the eyes of creationists, evolution is a random collection of impossible events and scientifically disproven speculations. It is interesting to wonder what exactly they imagine tens of thousands of trained biologists are doing all day in their labs if evolution is so obviously false that a 32 page brochure can conclusively debunk it.

The goal of these Watchtower documents is to present a caricature of science, while covertly inserting as many unsubstantiated ideas as possible into the conversation. The authors make no attempt to conceal their Biblical biases, but they also fail to connect broad design-centered arguments to any particular theology. Even if a reader was convinced by their basic case, why should one accept the Biblical God? The Watchtower assumes that the audience is going to grant them the existence of the supernatural, the truth

of Christianity more broadly, and literal methods of Biblical interpretation including complete inerrancy. None of these concepts are supported by evidence in the text, but they are necessary to reach the supposedly “obvious” conclusion presented by the Watchtower. The authors of TOL and WLC insult readers’ intelligence and take them to be uninformed, minimally skeptical rubes.

The superficial goal of these brochures is noble. It *is* important to ask about the origins of life, humanity, and the universe itself. The scientific pursuit of these most ultimate questions is one of the greatest adventures ever embarked upon by humans. It is vitally important to understand what is known about reality and how it is known. Religion, myth, and literature may have a place in many peoples’ lives, but not in the rigorous scientific investigation of nature. Everyone should look at the evidence, unencumbered by ancient biases or preconceived notions. The world is surely a wondrous, awesome place in which to live. Understanding the scientific picture of how it came to be that way does not endanger this fact.



# Bibliography

- [1] Abbott. Axeing of website article sparks row at max planck. *Nature*, 422:460, April 2003.
- [2] International Atomic Energy Agency. Plant breeding and genetics, August 2010. <http://www-naweb.iaea.org/nafa/pbg/index.html>.
- [3] Bard. A systems biology view of evolutionary genetics. *BioEssays*, 32(7):559–563, July 2010.
- [4] Watchtower Bible and Tract Society. Why we believe in a creator. *The Watchtower*, pages 21–23, September 2006.
- [5] Borucki. Kepler space mission: Detection of earth-size planets in the habitable zone of solar-like stars. In *Aerospace Conference IEEE*, pages 1–2, 2010.
- [6] Szostak Budin. Expanding roles for diverse physical phenomena during the origin of life. *Annual Review of Biophysics*, 39:245–263, 2010.
- [7] Robert Carroll. *Vertebrate Paleontology and Evolution*. W. H. Freeman and Co., 1988.
- [8] Cela-Conde and Ayala. *Human Evolution*. Oxford University Press, 2007.
- [9] NGM Blog Central. Darwinius and the real missing link, August 2010. [http://blogs.ngm.com/blog\\_central/2009/05/darwinius-and-the-real-missing-link.html](http://blogs.ngm.com/blog_central/2009/05/darwinius-and-the-real-missing-link.html).
- [10] Simon Conway Morris. *Crucible of Creation*. Oxford University Press, 1998.
- [11] Richard Dawkins. *The Greatest Show on Earth: The Evidence for Evolution*. Free Press, 2009.
- [12] Domning. The earliest known fully quadrupedal sirenian. *Nature*, 413:625–627, 2001.
- [13] W. Ford Doolittle. Uprooting the tree of life. *Scientific American*, pages 90–95, February 2000.
- [14] Ecklund and Scheitle. Religion among academic scientists: Distinctions, disciplines, and demographics. *Social Problems*, 54(2):289–307, May 2007.
- [15] Editorial. Darwin was wrong. *New Scientist*, page 5, January 2009.
- [16] Abzhanov et al. The calmodulin pathway and evolution of elongated beak morphology in darwin’s finches. *Nature*, 442:563–567, 2006.
- [17] Barrick et al. Genome evolution and adaptation in a long-term experiment with es-

- cherichia coli. *Nature*, 461:1243–1247, October 2009.
- [18] Bennett et al. Allium cepa l. cultivars from four continents compared by flow cytometry show nuclear dna constancy. *Annals of Botany*, 85:351–357, 2000.
- [19] Benson et al. Study of the therapeutic effects of intercessory prayer (step) in cardiac bypass patients: A multicenter randomized trial of uncertainty and certainty of receiving intercessory prayer. *American Heart Journal*, 151(4):934–942, April 2006.
- [20] Berger et al. Australopithecus sediba: A new species of homo-like australopith from south africa. *Science*, 328(5975):195–204, 2010.
- [21] Bonner et al. Cloned endogenous retroviral sequences from human dna. *Proceedings of the National Academy of Sciences*, 79(15):4709–4713, August 1982.
- [22] Brown et al. A new small-bodied hominin from the late pleistocene of flores. *Nature*, 431:1055–1061, 2004.
- [23] Choudhary et al. A stereoelectronic effect in prebiotic nucleotide synthesis. *ACS Chemical Biology*, 5(7):655–657, 2010.
- [24] Daeschler et al. A devonian tetrapod-like fish and the evolution of the tetrapod body plan. *Nature*, 440:757–763, 2006.
- [25] Enger et al. *Concepts in Biology*. The McGraw-Hill Companies, 2002.
- [26] Gompel et al. Chance caught on the wing: cis-regulatory evolution and the origin of pigment patterns in drosophila. *Nature*, 433:481–487, 2004.
- [27] Herrel et al. Rapid large-scale evolutionary divergence in morphology and performance associated with exploitation of a different dietary resource. *Proceedings of the National Academy of Sciences*, 105(12):4792–4795, 2008.
- [28] Johnston et al. Rna-catalyzed rna polymerization: Accurate and general rna-templated primer extension. *Science*, 292:1319–1325, May 2001.
- [29] Kvenvolden et al. Nonprotein amino acids in the murchison meteorite. *Proceedings of the National Academy of Sciences*, 68(2):486–490, February 1971.
- [30] Martin et al. Age of neoproterozoic bilaterian body and trace fossils, white sea, russia: Implications for metazoan evolution. *Science*, 288:841–845, 2000.
- [31] Matsuoka et al. Neural crest origins of the neck and shoulder. *Nature*, 436:347–355, 2005.
- [32] McKinnon et al. Evidence for ecology’s role in speciation. *Nature*, 429:294–298, 2004.
- [33] Okamura et al. Frequent appearance of novel protein-coding sequences by frameshift translation. *Genomics*, 88(6):690–697, December 2006.
- [34] Roberts et al. Human induced rotation and reorganization of the brain of domestic dogs. *PLoS ONE*, 5(7), July 2010.
- [35] Schubin et al. The pectoral fin of tiktaalik roseae and the origin of the tetrapod limb. *Nature*, 440:764–771, 2006.

- [36] Seiffert et al. Convergent evolution of anthropoid-like adaptations in eocene adapiform primates. *Nature*, 461:1118–1121, August 2009.
- [37] Simmons et al. Primitive early eocene bat from wyoming and the evolution of flight and echolocation. *Nature*, 451:818–821, February 2008.
- [38] Sutherland et al. Synthesis of activated pyrimidine ribonucleotides in prebiotically plausible conditions. *Nature*, 459:239–242, March 2009.
- [39] Swafford et al. *Molecular Systematics*. Sinauer Associates, 1996.
- [40] Tanaka et al. Amino acid replacement studies of human cytochrome c by a complementation system using *cyc1* deficient yeast. *The Journal of Biochemistry*, 104:477–480, 1988.
- [41] Thewissen et al. Whales originated from aquatic artiodactyls in the eocene epoch of india. *Nature*, 450:1190–1194, 2007.
- [42] Venter et al. Creation of a bacterial cell controlled by a chemically synthesized genome. *Science*, 329(5987):52–56, July 2010.
- [43] Xu et al. A basal troodontid from the early cretaceous of china. *Nature*, 415:780–784, 2002.
- [44] Faith and Cranston. Could a cladogram this short have arisen by chance alone?: on permutation tests for cladistic structure. *Cladistics*, 7(1), 1991.
- [45] Farnell and Williams. Genetic algorithm for ion thruster grid design. In *Pulsed Power Conference IEEE International*, pages 670–673, 2007.
- [46] Douglas Futuyma. *Evolutionary Biology*. Sinauer Associates, 1998.
- [47] Scott Gilbert. *Developmental Biology*. Sinauer Associates, 1997.
- [48] Hamblin and Di Rienzo. Detection of the signature of natural selection in humans: Evidence from the duffy blood group locus. *The American Journal of Human Genetics*, 66(5):1669–1679, May 2000.
- [49] Huang and Ferris. One-step, regioselective synthesis of up to 50-mers of rna oligomers by montmorillonite catalysis. *Journal of the American Chemical Society*, 128:8914–8919, 2006.
- [50] Howard Hughes Medical Institute. Szostak lab, August 2010. <http://genetics.mgh.harvard.edu/szostakweb/index.html>.
- [51] J. Craig Venter Institute. First self-replicating synthetic bacterial cell, August 2010. <http://www.jcvi.org/cms/press/press-releases/full-text/article/first-self-replicating-synthetic-bacterial-cell-constructed-by-j-craig-venter-institute-researcher/>.
- [52] Kutschera. Designer scientific literature. *Nature*, 423:116, May 2003.
- [53] Roger Lewin. *Human Evolution: An Illustrated Introduction*. Blackwell, 2005.
- [54] Lewontin. Billions and billions of demons. *The New York Review*, page 31, January 1997.

- [55] Macnair and Christie. Reproductive isolation as a pleiotropic effect of copper tolerance in *mimulus guttatus*. *Heredity*, 50:295–302, 1983.
- [56] Lynn Margulis and Rene Foster. *Symbiosis as a Source of Evolutionary Innovation: Speciation and Morphogenesis*. MIT Press, 1991.
- [57] Andre C. Marta. Parametric study of a genetic algorithm using a aircraft design optimization problem.
- [58] McHenry. Tempo and mode in human evolution. *Proceedings of the National Academy of Sciences*, 91:6780–6786, 1994.
- [59] Mehta and Wainwright. Raptorial jaws in the throat help moray eels swallow large prey. *Nature*, 449:79–82, 2007.
- [60] Alexandre Meinesz. *How Life Began: Evolution's Three Geneses*. University of Chicago Press, 2008.
- [61] Richard Morris. *The Evolutionists*. Macmillan, 2002.
- [62] CBS News. Controversial “ida” fossil no missing link, August 2010. <http://www.cbsnews.com/stories/2009/10/22/tech/main5408922.shtml>.
- [63] Nobelprize.org. The nobel prize in chemistry 1989, August 2010. [http://nobelprize.org/nobel\\_prizes/chemistry/laureates/1989/press.html](http://nobelprize.org/nobel_prizes/chemistry/laureates/1989/press.html).
- [64] Norell and Clarke. Fossil that fills a critical gap in avian evolution. *Nature*, 409:181–184, 2001.
- [65] American Museum of Natural History. Extinction, August 2010. <http://www.amnh.org/exhibitions/dinosaurs/extinction/mass.php>.
- [66] National Museum of Natural History. Human fossils, August 2010. <http://humanorigins.si.edu/evidence/human-fossils>.
- [67] Orgel and Crick. Anticipating the rna world. some past speculations on the origin of life: where are they today? *FASEB Journal*, 7(1):238–239, 1993.
- [68] Massimo Pigliucci. Is there fundamental scientific disagreement about the theory of evolution?, August 2010. <http://rationallyspeaking.blogspot.com/2008/07/is-there-fundamental-scientific.html>.
- [69] Exploring Origins Project. Exploring life's origins, August 2010. <http://exploringorigins.org/index.html>.
- [70] Stanford Report. Reading the fine print takes on a whole new meaning, August 2010. <http://news.stanford.edu/news/2009/january28/small-012809.html>.
- [71] Transworld Research. Transworld research network, August 2010. <http://www.trnres.com/services.htm>.
- [72] Rice and Salt. The evolution of reproductive isolation as a correlated character under sympatric conditions: experimental evidence. *Evolution*, 44:1140–1152, 1990.

- [73] Rose and Oakley. The new biology: beyond the modern synthesis. *Biology Direct*, 2(1), November 2007.
- [74] Shapiro. A simpler origin for life. *Scientific American*, pages 24–31, June 2007.
- [75] Sober. Absence of evidence and evidence of absence: Evidential transitivity in connection with fossils, fishing, fine-tuning, and firing squads. *Philosophical Studies*, 143(1):63–90, March 2009.
- [76] Sverdlov. Retroviruses and primate evolution. *Bioessays*, 22(2):161–171, February 2000.
- [77] Theobald. A formal test of the theory of universal common ancestry. *Nature*, 465:219–222, May 2010.
- [78] The New York Times. Translating stories of life forms etched in stone, August 2010. [http://www.nytimes.com/2010/07/27/science/27creatures.html?\\_r=3&ref=science](http://www.nytimes.com/2010/07/27/science/27creatures.html?_r=3&ref=science).
- [79] Tyndale-Biscoe and Renfree. *Reproductive Physiology of Marsupials*. Cambridge University Press, 1987.
- [80] Colorado State University. History of plant breeding, August 2010. <http://cls.casa.colostate.edu/transgeniccrops/history.html>.
- [81] A. M. van Harten. *Mutation Breeding*. Cambridge University Press, 1998.
- [82] Wallace and Hobbs. *Atmospheric Science*. Elsevier, 2006.
- [83] Wolpoff. How neanderthals inform human variation. *American Journal of Physical Anthropology*, 139(1):91–102, May 2009.