

## Twenty Questions about Science and Religion

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05 February 2014

### Introduction

Today there is a widespread perception of a “war” between science and religion. On one hand, writers of secular and scientific backgrounds, notably a group known as the “New Atheists,” have recently become significantly more outspoken. They criticize religion as fundamentally irrational and harmful, and blame religion for much of what ails the world today. On the other hand, writers of certain religious backgrounds (mostly not LDS) perceive the rise of modern science as a mortal threat to their fundamental religious beliefs. They emphasize flaws and gaps in scientific theories, and promote their material to local and state school boards.

Yet both science and religion have much to gain from respectful interaction. Both are part of a fundamental quest for truth, as exemplified by the scripture, “Seek and ye shall find [Matt. 7:7]. Both espouse the “idea of progress,” which Robert Nisbet defined as the notion that “mankind has advanced in the past, is now advancing, and may be expected to continue advancing in the future” [Nisbet1980, pg. 4-5] (note the similarity to the LDS Ninth Article of Faith). Finally, both scientists and religious believers can stand in awe at the majesty of the universe, which is now known to be much vaster, more intricate and more magnificent than ever before realized in human history [Bailey2014].

Nonetheless, while science and religion have much in common, there are still many specific issues that must be addressed. To that end, this paper attempts to briefly address some of the questions that arise. This analysis is presented in an LDS context, although many of the issues and discussion apply to a general Judeo-Christian audience. As always, these comments are the author’s own; others may have different perspectives.

#### 1. Does modern science refute religion? Does science have all the answers?

As mentioned above, one of the central assertions of the New Atheists and other critics of religion is that modern science refutes religion. They often argue that all precepts, including the existence of God, must be tested scientifically and rejected if not confirmed. But this view, known variously as “scientific materialism” or “scientism,” has long been rejected by philosophers of religion: God is not a scientific hypothesis.

Part of the difficulty here is to properly define what science is. Perhaps the most succinct definition is given by the National Academy of Science [NAS2008, pg. 10]: *The use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process.* The Academy elaborates as follows:

In science, explanations must be based on naturally occurring phenomena. Natural causes are, in principle, reproducible and therefore can be checked independently by others. If explanations are based on purported forces that are outside of nature, scientists have no way of either confirming or disproving those explanations.

It is thus clear that science, properly defined, cannot conflict with religion: science can say nothing one way or the other about the existence or nature of a supreme being. It is also worth pointing out that scientism is itself a belief system that is not testable by the methods of empirical science. Thus if one rejects religion because it is not empirically testable, then one would also have to reject scientism as well. There is no free lunch.

## 2. Does modern science repudiate miracles?

It is widely believed that modern science stands at odds with miracles as recorded, say, in the Bible. This stems from the traditional notion, taught for decades if not centuries, that miracles are contraventions of natural law. Eighteenth century philosopher David Hume, for example, defined a miracle as “a transgression of a law of nature” [Hume1748, pg. 128]. Contemporary creationist Kevin Anderson declared that “a miracle is an event not explainable to natural processes” [Anderson2009]. If one presumes this view, then indeed miracles lie utterly outside the world of scientific laws.

But in the LDS tradition, this basic premise is rejected. Parley P. Pratt declared:

Among the popular errors of modern times, an opinion prevails that miracles are events which transpire contrary to the laws of nature, that they are effects without a cause. If such is the fact, then, there never has been a miracle, and there never will be one. The laws of nature are the laws of truth. Truth is unchangeable, and independent in its own sphere. A law of nature never has been broken. And it is an absolute impossibility that such law ever should be broken. [Pratt1855, pg. 102]

Brigham Young was even more explicit:

Yet I will say with regard to miracles, there is no such thing save to the ignorant -- that is, there never was a result wrought out by God or by any of His creatures without there being a cause for it. There may be results, the causes of which we do not see or understand, and what we call miracles are no more than this -- they are the results or effects of causes hidden from our understandings. [JD, pg. 140-p.141 (11 Jul 1869)]

James E. Talmage added the following:

Miracles are commonly regarded as occurrences in opposition to the laws of nature. Such a conception is plainly erroneous, for the laws of nature are inviolable. However, as human understanding of these laws is at best but imperfect, events strictly in accordance with natural law may appear contrary thereto. The entire constitution of nature is founded on system and order. [Talmage1899, pg. 220]:

It is true that many of the miracles recorded in the Bible may have more prosaic explanations. For example, two scientists recently concluded, based on computer simulations, that a “wind setdown” effect may have been the cause of the drying up of the sea where the and Israelites crossed [McAlpine2010]. Also, modern medicine can now treat conditions that required miraculous cures in the Bible, such as healing diseases like leprosy (by antibiotics), and restoring vision to certain blind persons (by corrective lenses and/or surgery). But in any event, miracles need not be transgressions of natural law.

### 3. How old is the Earth? How old are the geologic ages?

One challenge in assessing the age of the Earth is the fact that virtually all rocks that were originally on the face of the earth when it first formed have subsequently been subducted into the Earth's mantle. The oldest mineral ever found on earth, a zircon specimen found in the Jack Hills region of Western Australia, has been measured to be 4.4 billion years old, so the Earth is at least this old [Wilde2001]. Scientists have noted that many meteorites, which were formed at the same time as the Earth, are roughly 4.56 billion years old, so this figure is generally taken to be the age of the Earth.

Geologists have observed layers of rock throughout the world, each with a unique set of fossils and a sequence of dates extending back from the present to the formation of the Earth, as mentioned above. Each of these epochs has been dated, typically to many millions of years ago, in numerous studies. For example, the Cambrian explosion, when many skeletal organisms arose, has been dated as occurring over a period of roughly 50 million years, starting 541 million years ago. Similarly, the Cretaceous-Tertiary meteorite impact, which evidently killed off the last of the dinosaurs, occurred 66 million years ago. A listing of the currently understood geologic time scale can be found in any recent geology text, or in the Wikipedia article on the topic [Geologic2013].

### 4. How reliable are these geologic dates?

The figures mentioned above are based on *radiometric dating*, which is based on radioactive decay of certain nuclear isotopes. Radioactive decay is a very basic physical phenomenon, well understood as a consequence of quantum mechanics. Quantum mechanics is, in turn, one of two cornerstones of modern physics (the other is general relativity), having been precisely confirmed in thousands of very exacting experiments.

Some question whether scientists can be certain that rates of radioactive decay have been constant over geologic time, but, in addition to the deduction from quantum mechanics that they are constant, empirical studies have confirmed this hypothesis in several ways. For instance, when astronomers view a supernova exploding in a distant galaxy, they see the process of radioactivity and the action of the laws of quantum mechanics in exquisite detail, indistinguishable from experiments in Earth-based laboratories. Yet these supernovas are typically many millions of light-years away, so that the explosion we see in a telescope today actually occurred many millions of years ago. In other words, a telescope is a "time machine" of sorts, permitting one to see the laws of physics in operation long ago.

For these reasons, scientists have considerable confidence in radiometric dating, when used in accordance with procedures that have been developed and refined over several decades. During the 1950s and 1960s, when these schemes were first being developed, one could assert "reasonable doubt" on these dates, but the same cannot be said today. For technical details on how these dates are measured and calculated, and why scientists consider them to be so reliable, see [Bailey2013a; Bailey2013b; Dalrymple2004].

5. Since there are potential difficulties with radiocarbon dating, doesn't this draw into question scientists' dating of geologic eras?

Radiocarbon dating, also known as carbon-14 dating, is a particular form of radiometric dating. It is based on the fact that when a plant or animal organism dies, it stops ingesting carbon-14, and the amount of carbon-14 gradually decreases, with a half-life of approximately 5730 years. Because of this relatively short half-life, radiocarbon is useful for dating artifacts of a relatively recent vintage, as far back as roughly 50,000 years before the present.

Radiocarbon dating, like any empirical procedure, is indeed subject to certain errors and anomalies. For example, in 1969 scientists found that previous published measurements needed to be corrected, due to a factor now well understood. Recently the radiocarbon scale was accurately calibrated based on analyses of sediment layers [Reimer2009].

But in any event, potential difficulties with radiocarbon dating have no bearing on one way or the other on the age of the Earth or the ages of any of the major geologic eras. This is because radiocarbon measurements are limited to specimens no older than 50,000 years in age. Other radiometric techniques must be used beyond this point.

6. How can we reconcile geologic dates with scripture?

Much has been written attempting to reconcile geologic dates with scripture. Some, mostly of conservative Protestant backgrounds, have insisted that the Earth was created in six 24-hour days (see, for example, [Ham2013]). Others, including Elder Bruce R. McConkie for instance, have taught that the physical creation lasted 6,000 years, based on each day of creation being a day "according to Kolob" [McConkie1958, pg. 130, 184] (although McConkie later wrote that each day was "an age, an eon, a division of eternity" [McConkie1982]).

Still other LDS authorities have opted for a more expansive time frame, and more in keeping with modern science. In 1844, W. W. Phelps wrote that eternity has been going on in this system for 2,555,000,000 years, a figure evidently derived by reckoning each day of the 6,000 years to be a day according to Kolob ( $6,000 \times 365 \times 1,000 = 2,555,000,000$ ) [TS, vol. 5, pg. 758 (1 Jan 1844)]. Brigham Young took a more open-ended position on the issue:

As for the Bible account of the creation we may say that the Lord gave it to Moses, or rather Moses obtained the history and traditions of the fathers, and from these picked out what he considered necessary, and that account has been handed down from age to age, and we have got it, no matter whether it is correct or not, and whether the Lord found the earth empty and void, whether he made it out of nothing or out of the rude elements; or whether he made it in six days or in as many millions of years, is and will remain a matter of speculation in the minds of men unless he give revelation on the subject. [JD, vol. 14, pg. 116 (14 May 1871)]

In the April 2000 LDS general conference, Elder Russell M. Nelson was similarly noncommittal: "In Genesis and Moses, those periods are called days. But in the book of Abraham, each period is referred to as a time. Whether termed a day, a time, or an age, each phase was a period between two identifiable events – a division of eternity." [Nelson2000].

In short, from all evidence the LDS Church does not officially state the age of the Earth, nor by what specific means it was created. For example, the article “Age of the Earth” in the *Encyclopedia of Mormonism*, which was produced with careful consultation with senior LDS authorities, starts with the noncommittal statement, “The scriptures do not say how old the earth is, and the Church has taken no official stand on this question. ... Nor does the Church consider it to be a central issue for salvation.” [Petersen1992].

#### 7. Isn't evolution just a “theory”?

Merriam-Webster's Dictionary lists several definitions for the word “theory,” including (a) “a plausible or scientifically acceptable general principle or body of principles offered to explain phenomena, e.g., the wave theory of light” and (b) “a hypothesis assumed for the sake of argument or investigation; an unproved assumption.” In most scientific discourse, scientists use definition (a), while in popular public discourse, definition (b) is more widely assumed. This distinction is the root of the widespread misunderstanding of the phrase “theory of evolution.”

Evolution is not termed a “theory” because it is a sketchy conjecture that has never been seriously tested. To the contrary, evolution has passed more than a full century of rigorous empirical tests. It is termed a “theory” in the same sense that one refers to “atomic theory” or “theory of relativity” or “theory of equations,” namely because it is a general principle with substantial explanatory power and falsifiability that has withstood rigorous scrutiny.

On the other hand, most scientists are content with the double meaning of “theory,” as a form of self-imposed humility and resistance against taking any theory as unchangeable truth. The tentative nature of scientific theories was impressed on scientists most vividly in the early 20th century, when Newton's classical laws of motion and gravitation, which had dominated scientific research for more than three centuries, were displaced by Einstein's relativity (for objects traveling at very high speeds) and by quantum mechanics (for very small objects, such as atoms and subatomic particles). Thus even well-established theories such as evolution may need to be modified, as more and more experimental evidence is accumulated.

#### 8. Does the Second Law of Thermodynamics contradict the theory of evolution?

Some creationists have argued that the Second Law of Thermodynamics refutes the theory of evolution. This law states that the level of disorder (made suitably precise) of an isolated system that is not in equilibrium will tend to increase over time. At a fundamental level, this is really a statement about probability. For example, if billiard balls are placed on a billiard table in the triangle frame, and then scattered by a cue, it is overwhelmingly more likely that when they all stop moving they will be in a rather “random” configuration, rather than, say, all in one corner.

However, there is a severe fallacy in applying this principle to evolution. A key condition of the Second Law is that the system being described is a “closed system,” in particular one that has no influx or outflow of ordered energy. However, the Earth's biosphere is definitely not a “closed system.” To the contrary, every day the Earth receives a prodigious amount of highly ordered energy from the Sun, an amount that is roughly 10,000 times the total daily energy consumption of the entire present-day human civilization. Indeed, biology can be seen as a process that

extracts ordered energy from the environment to create order and complexity in living things. So the Second Law really isn't really a problem for biological evolution.

#### 9. Aren't there gaps in the fossil record that disprove evolution?

Those who question evolution as a means for the physical creation often cite gaps in the fossil record. Creationist Henry Morris, for instance, asserts that there are "systematic gaps" in the fossil record, and "There is no evidence that there have ever been transitional forms between these basic kinds." [Morris1985, pg. 78-79].

It is undeniably true that gaps exist in the fossil record, but such gaps are natural and predictable. Almost all biological organisms that have ever lived were either eaten by predators or otherwise destroyed soon after death, leaving no trace. Most that persisted in some form (e.g., as skeletons) were later destroyed by chemical effects, or were part of a geological layer that subsequently disappeared into the Earth's molten mantle. Almost all fossils that have survived these and numerous other perils lie far beneath the Earth's surface and will never be seen by humans. Thus the fossil record will never be "complete" – all we can expect is to capture glimpses of the Earth's flora and fauna over its multi-billion-year history.

Also, in discussing this issue, one first must carefully define terms. By "gap," does one mean a "gap" that had been identified in Darwin's time, or one that was identified say in the 1950s, or one that exists now? And if a transitional fossil is found within a given gap, does that mean that two more gaps have suddenly appeared and must be filled (one on each side)?

In any event, it is simply not true that no transitional fossils have been found. At least one if not more transitional fossils have been found for virtually all gaps thought to exist in Darwin's day, and even most of the "gaps" known 50 years ago have been filled with the discovery of transitional fossils [Prothero2007].

For example, scientists once despaired ever finding transitional fossils linking the hypothesized link between ancient land mammals and marine mammals (e.g., orcas, whales and dolphins). But within the last two or three decades, at least 30 intermediate fossil species have been found, with exactly the expected combination of terrestrial and aquatic features [Zimmer2001, pg. 138]. As another example, in 2004 researchers discovered the "Tiktaalik" fossil in a remote area of Ellesmere Island, above the Arctic Circle in Canada. It spans the transition between ancient fish and the earliest four-legged creatures [Prothero2007, pg. 228-229].

In summary, while it is undeniably true that gaps exist in the fossil record, so many transitional fossils have been found in recent years that it is not clear that the "gap issue" has any force against evolutionary theory. For additional discussion, see [Bailey2013c].

#### 10. What does DNA evidence say about evolution?

In the past few years, modern genome sequencing and computer technology have placed an enormous volume of DNA data only a mouse-click away from researchers worldwide. The first complete human genome sequence was completed in 2000, after a ten-year effort that cost over

\$500 million. But now genomes can be sequenced at a cost of \$1,000 [Vance2014]. Thus it is inevitable that genome sequencing will become a standard part of modern medicine. But this same sequencing technology has enabled biologists to study the genomes of thousands of other biological species, including many common (and not-so-common) plants and animals, thus permitting evolution to be studied at the most basic level.

One example of DNA-type data is the table below, which compares the 146-unit amino acid sequences of beta globin (a component of hemoglobin) among various species of animals. Amino acids are coded directly by triplets of DNA letters, and thus the study of amino acid sequences is very close to the study of DNA sequences themselves. In the table below, note that human beta globin is identical to that of chimpanzees, differs in only one location from that of gorillas, yet is increasingly distinct from that in red foxes, polar bears, horses, rats, chicken and salmon. Anyone with an Internet connection can generate similar data using online tools and databases [Evolution2009]:

Percent Agreement between Beta Hemoglobin of Various Species

	Human	Chimp	Gorilla	Red Fox	Dog	Polar Bear	Horse	Rat	Chicken	Salmon
Human	100.	100.	99.3	91.1	89.7	89.7	83.6	81.5	69.2	49.7
Chimp	100.	100.	99.3	91.1	89.7	89.7	83.6	81.5	69.2	49.7
Gorilla	99.3	99.3	100.	91.8	90.4	90.4	82.9	80.8	68.5	49.0
Red Fox	91.1	91.1	91.8	100.	98.6	95.2	80.8	80.1	72.6	49.7
Dog	89.7	89.7	90.4	98.6	100.	94.5	80.1	79.5	71.2	49.0
Polar Bear	89.7	89.7	90.4	95.2	94.5	100.	80.8	82.9	71.9	48.3
Horse	83.6	83.6	82.9	80.8	80.1	80.8	100.	76.0	67.8	46.3
Rat	81.5	81.5	80.8	80.1	79.5	82.9	76.0	100.	65.8	49.7
Chicken	69.2	69.2	68.5	72.6	71.2	71.9	67.8	65.8	100.	54.4
Salmon	49.7	49.7	49.0	49.7	49.0	48.3	46.3	49.7	54.4	100.

The picture is the same if we consider the pattern of mutations between closely related species. For example, the gene that, when mutated, results in cystic fibrosis in humans is nearly identical to the corresponding gene in chimpanzees, but is progressively less similar to the corresponding gene in orangutans, baboons, marmosets, lemurs, mice, chicken and puffer fish [NAS2008, pg. 30]. As yet another example, Cytochrome C, which is essential for cell respiration, differs only in one location out of 104 between humans and rhesus monkeys. Comparing humans and horses, there are 12 differences; comparing rhesus monkeys with horses, there are 11 differences. Evidently the single difference between humans and rhesus monkeys occurred after our hominid ancestors split from the lineage that led to present-day monkeys [Ayala2007, pg. 128-129].

Another interesting example is the “GULO” gene, which is an essential part of the biochemical machinery that makes Vitamin C in animals. Humans lack a functioning copy of this gene – our copy is mutated. Scurvy, that scourge of British sailors and Mormon pioneers crossing the plains, occurs in humans when they do not get enough Vitamin C. But although the human GULO gene is mutated and useless, humans and chimpanzees have very similar copies of it

(98% identical). Evidently a common ancestor of humans and chimps adopted a diet rich in fruits and vegetables, and thus a chance mutation that disabled Vitamin C production was not deleterious and was passed on to posterity [Fairbanks2007, pg. 53-55].

One additional item of evidence for evolution comes from examining “transposons” or “jumping genes.” These are sections of DNA that have been randomly copied from one part of an organism’s genome to another. Most of the time, these inserted genes do no damage, because they “land” in relatively unimportant sections of DNA. But they do provide an excellent means to classify species into their phylogenetic (“family tree”) relationship. This is because it is exceedingly unlikely that the same random insertion of an entire gene would occur at the same spot in the genomes of two or more different organisms or species, unless, of course, each inherited this curious feature from a common ancestor. It is also exceedingly unlikely that a group of species with “random” assortments of transposons could be organized into a family tree. Here is an example of how transposon data can be used to determine the phylogenetic relationships of various primates. The columns labeled ABCDE denote five blocks of transposons, and x and o respectively denote that the block is present or absent. It is clear from this data that our closest primate relatives are chimpanzees and bonobos [Rogers2011, pg. 89].

		Transposon blocks				
Species		A	B	C	D	E
/-----	Human	o	x	x	x	x
/-----	Bonobo	x	x	x	x	x
/\-----	Chimp	x	x	x	x	x
/-----	Gorilla	o	o	x	x	x
----- -----	Orangutan	o	o	o	x	x
\-----	Gibbon	o	o	o	o	o

#### 11. Doesn't probability refute evolution?

Probability arguments are often employed in criticisms of biological evolution. Writers argue that certain features of biology are so improbable that they could never have been produced by a purely natural, “random” process. They often equate the hypothesis of evolution to the absurd suggestion that monkeys randomly typing at a typewriter could compose a selection from the works of Shakespeare, or that an explosion in an aerospace equipment yard could produce a working 747 airliner.

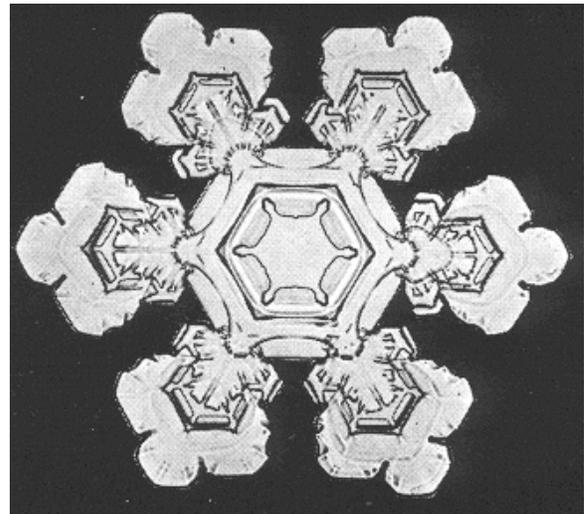
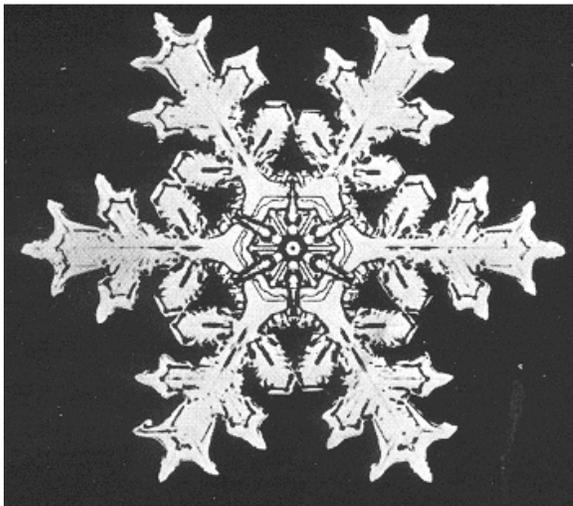
One such argument goes like this: the human alpha-globin molecule, a component of hemoglobin that performs a key oxygen transfer function, is a protein chain based on a sequence of 141 amino acids. There are 20 different amino acids common in living systems, so the number of potential chains of length 141 is  $20^{141}$ , which is roughly  $10^{183}$  (i.e., a one followed by 183 zeroes). These writers argue that this figure is so enormous that even after billions of years of random molecular trials, no human alpha-globin protein molecule would ever appear [Foster1991, pg. 79-83; Lennox2009, pg. 163-173].

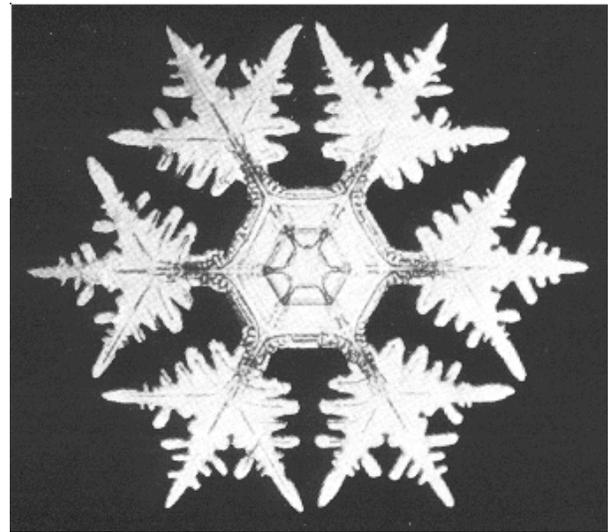
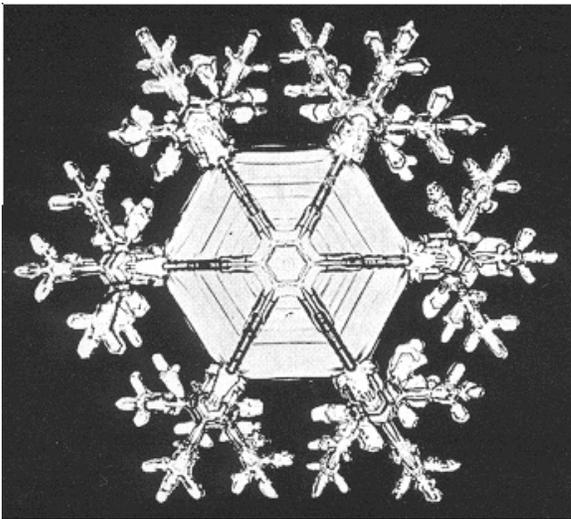
One difficulty in this particular argument is that it ignores the fact that a large class of alpha-globin molecules can perform the essential oxygen transfer function. Indeed, most of the 141

amino acids in alpha-globin can be changed without altering the key oxygen transfer function, as can be seen by noting the great variety in alpha-globin molecules across the animal kingdom (see the previous item). When one revises the calculation above, based on only 25 locations essential for the oxygen transport function (which is a generous over-estimate), one obtains  $10^{33}$  fundamentally different chains, a huge figure but vastly smaller than  $10^{183}$  [Bailey2000].

But even after this revision, the calculation still suffers from the fatal fallacy of presuming that a structure such as human alpha-globin arose by a single all-at-once random trial event (which, after all, is the creationist theory, not the scientific theory, of its origin). Instead, available evidence from many published studies on the topic suggests that alpha-globin and other proteins arose as the end product of a long sequence of intermediate steps, each of which was biologically useful in an earlier context [Hardison2001]. Thus any simple probability calculation (whether it is arguing for or against some aspect of evolution) that does not take into account the step-by-step process by which the structure came to be is not meaningful and can easily mislead [Bailey2000; Musgrave1998].

Some of the potential difficulties with probability arguments can be illustrated by considering snowflakes. Bentley and Humphrey's book *Snow Crystals* includes over 2000 high-resolution black-and-white photos of real snowflakes, each with intricate yet highly regular patterns that are almost perfectly six-way symmetric [Bentley1962]. Four of Bentley's photos are shown below. By employing a reckoning based on six-way symmetry, one can calculate the chances that one of these structures can form "at random" as roughly one part in  $10^{2500}$ . This probability figure is even more extreme than those mentioned above. So is this proof that each individual snowflake has been designed by a supernatural intelligent entity? Obviously not.





The fallacy here, once again, is presuming an all-at-once random assembly of molecules. Instead, snowflakes, like biological organisms, are formed as the product of a long series of steps acting under well-known physical laws, and the outcomes of such processes very sensitively depend on the starting conditions and numerous environmental parameters.

In short, a process as complicated as the evolution of life on Earth, over many millions of years, involving millions of species and many more biomolecular structures, cannot be reduced to simple probability calculations. The theory evolution may indeed have weaknesses, and may eventually need to be revised, but this will require more sophisticated arguments and better empirical evidence than provided by probability-based arguments [Bailey2000].

12. Does “irreducible complexity” pose a serious challenge to evolutionary theory?

Intelligent design scholar Michael Behe has argued that certain biological systems, including bacterial flagella, blood clotting machinery, and the vertebrate immune system, are “irreducibly complex” – they consist of multiple subsystems, the removal of any one of which would render the system nonfunctional. He argues that such systems must have been designed by an intelligent entity, because none of the components could have evolved in the absence of the others [Behe1996, pg. 39-139]. Behe illustrates irreducible complexity with a mousetrap, which consists of a platform, spring, hammer, hold-down bar and catch. If any of these parts is removed, the mousetrap cannot function to catch mice. Thus it must have been designed.

But as with probability-based arguments, there are significant difficulties with such reasoning. Scientists note that the components of “irreducibly complex” systems can arise by natural evolution, since they may arise separately, each useful in different context, and then later be combined into a larger system. With regards to Behe’s example of the bacterial flagella, researchers recently found that its DNA sequence is almost identical to that of a “needle” that certain bacteria use to insert toxins [Jones2008]. Biologist Kenneth Miller has shown in addition that several components of the flagellum have other functions [Miller2003].

Another example frequently mentioned by both creationist and intelligent design writers is the human eye. They insist that a high-resolution light gathering system, such as the retina, would be useless without a lens, and vice versa. Yet even Charles Darwin proposed a multi-step scenario of how eyes might have developed, beginning with a photosensitive cell, progressing to an optic nerve surrounding pigment cells, and finally concluding with muscles that could contract around the lens. What's more, within the animal kingdom one can find a wide range of eye designs, including numerous instances that are significantly better than human eyes. Octopuses and other mollusks, for example, have optic nerves that emerge from the back of the retina, thus avoiding the blind spot that afflicts human vision. Similarly, hawks have a visual acuity rating of 20/5, significantly better than the 20/20 vision of humans. Owl eyes are 50 to 100 times more sensitive to light at nighttime than are human eyes [Isaak2007, pg. 65, 94-95].

In a similar way, scientists have found that most of the proteins involved in the blood clotting system are genetically similar and most likely are the result of gene duplication [Fairbanks, 2007, pg. 150-156]. Thus while Behe's notion of "irreducible complexity" is intriguing, it is not clear that any solid examples have yet been identified that pose a serious challenge to evolution. And in a larger sense, it is not clear that highly technical issues such as "irreducible complexity" have a proper place in discussions of science and religion.

### 13. Can evolution generate truly novel biological features?

One central issue in the debate over evolution is the question of novelty – can evolution produce truly novel features? The consensus of biologists is that it can. Here are some examples:

- a. *1974 E. coli experiment.* In a 1974 paper Barry Hall and Daniel Hartl identified a gene in the bacterium *E. coli* that is responsible for metabolizing lactose, using a complicated three-part process. They removed this gene, and then permitted the bacteria to multiply in a stressed environment containing lactose. Within 24 hours the bacteria had evolved a capability to utilize lactose, by means of a similar but distinct three-part biochemical pathway, involving two mutated genes [Hall1974].
- b. *1994 E. coli result.* Biologist Richard Lenski and his colleagues have been conducting a long-running experiment on bacterial evolution that began in 1988. Starting with 12 flasks of *E. coli* bacteria, identical except for some neutral markers, they have followed the course of these bacteria for 45,000 generations. As the generations continued, each of the 12 lines grew progressively better at processing glucose. Examining the results after 20,000 generations, the experimenters found that two of the 12 lines had independently "discovered" virtually the same improved scheme for glucose metabolism. Later in the experiment, shortly after generation 33,000, the average population of one of the lines shot up by a factor of six above the others. The investigators found that this line had developed the ability to utilize citrate by means of a remarkable combination of two distinct mutations [Lenski1994].
- c. *Japanese nylon-eating bacteria.* In 1994, Japanese biologists discovered a bacterial species that thrives in nylon waste. It turns out that these bacteria had undergone a

“frame shift” mutation, where an extra base pair had been inserted into the bacteria’s DNA that by remarkable chance endowed the bacteria with the facility to metabolize nylon [Negoro1994].

- d. *The Milano mutation.* Scientists recently discovered that certain persons in an Italian community, all descended from a single individual several generations back, possess a genetic mutation that increases good cholesterol and provides an effective antioxidant, thus resulting in measurably improved cardiovascular health [Kotz2002].
- e. *Antibiotic-resistant diseases.* Perhaps the best-known examples of evolution in action are, sadly, the recent evolution of new strains of tuberculosis that are resistant to all known anti-TB drugs. By analyzing DNA sequences, researchers have identified at least six different families of tuberculosis, at least one of which appears to be evolving on an unexpected and potentially very dangerous path [Lehrman2013]. Another example is drug-resistant strains of HIV. Researchers are devising strategies, such as keeping “second-line” treatments in reserve for patients who do not respond to “first-line” treatments [Coghlan2010].

Some additional examples are given in [Bailey2013d].

#### 14. Is there evidence that species (including humans) have been individually designed?

Writers in the creationism and intelligent design community have argued that each individual “kind” has been separately created and/or designed in detail by an intelligent being. They cite intricate, well-adapted features of biological organisms, including humans, as evidence of this designer, which is usually identified as the Judeo-Christian God [Behe1996]. But others caution that it is not wise to base one’s religious faith on this type of argument.

To begin with, the design hypothesis by itself fails to explain the pain, violence and suffering that is often seen in the natural world, together with the numerous known examples in the biological world that do not appear to be designed in detail by an intelligent, benevolent God. And it does not seem right to suggest that God meticulously “designed” individual species by the millions, only to see virtually all of them ultimately fall into extinction.

For example, as mentioned above, Vitamin C (ascorbic acid) is required for a wide range of essential metabolic reactions, and scurvy results when humans don’t get enough. Yet while almost all mammals generate their own Vitamin C, and although humans have the same overall biochemical machinery, it doesn’t work because mutations have inactivated a key step [Fairbanks2007]. Thirty percent of the roughly 1000 human genes associated with the sense of smell are inoperable due to accumulated mutations [Shubin2008, pg. 146]. Finally, in the eyes of humans and other mammals, the optic nerves emerge from the front of the retina, and then travel to the back, resulting in a blind spot. By contrast, the eyes of cephalopods (including the octopus, squid, cuttlefish and nautilus) are designed more logically with nerve connections on the back of the retina [Fairbanks2012, pg. 34-37].

Did God meticulously “design” humans with these specific deficiencies and vulnerabilities, or did he, at a higher level, create the world and a system of laws that are conducive to the formation of living creatures, including us? And is it not our religious duty to utilize the scientific method to understand these problems, and, where possible, to counter their effects and mitigate the suffering that results from them [Ayala2007]?

#### 15. Did God employ evolution for the physical creation?

Some are reluctant to accept the notion that God employed evolution indirectly as the means for the creation, preferring instead a direct, “hands-on” creation (see, for example, [Ham2009]). One traditional objection has been the issue of time frame required for an indirect creation via evolution. But as we have seen above, there is no fundamental theological reason that the days of creation could not be much longer eras, and, quite frankly, the evidence for a multi-billion-year creation is very strong.

Along this line, it is interesting to note that the Bible itself often uses similar indirect, figurative language to refer to God’s creation. For example, Psalm 139:13-16 declares that God formed me “in my mother's womb. I will praise thee, for I am fearfully and wonderfully made (*asah*)... My substance [bone frame] was not hidden from thee, when I was being made (*asah*) in secret.” Isaiah 44:24 describes God as the one who “formed (*yatsar*) thee from the womb,” and Isaiah 49:5 says, “And now, saith the Lord that formed (*yatsar*) me from the womb to be his servant.” Similarly, Isaiah 44:2 declares, “Thus saith the Lord that made (*asah*) thee and formed (*yatsar*) thee from the womb.” Clearly no one, certainly not the ancient Hebrews, thought that God literally, hands-on, created babies bone-by-bone in their mother’s womb. Yet the Hebrew words *asah* and *yatsar* used in these passages are the same words that are used in Genesis to describe God’s creation of the sun, stars, plants, animals and humans [Moritz2013].

#### 16. What have religious leaders said about evolution?

Most large Judeo-Christian denominations have made their peace with science in general. Some, particularly in the evangelical Protestant community, are opposed to evolution, but larger denominations generally accept the principle, without going into detail on particular aspects of this or any other major theory. For example, Pope John Paul II declared:

Today, ... some new findings lead us toward the recognition of evolution as more than an hypothesis. In fact it is remarkable that this theory has had progressively greater influence on the spirit of researchers, following a series of discoveries in different scholarly disciplines. [Pope1996]

In 1909, the LDS First Presidency released a statement entitled “The Origin of Man.” It included the following passage [BYU1992]: “It is held by some that Adam was not the first man upon this earth, and that the original human being was a development from lower orders of the animal creation. These, however, are the theories of men.” However, a few months later, in 1910, an editorial by the First Presidency in the *Improvement Era* addressed the question, “In just what manner did the mortal bodies of Adam and Eve come into existence on this earth?” The editorial responded, after citing some basic creation scriptures:

Whether the mortal bodies of man evolved in natural processes to present perfection, through the direction and power of God; whether the first parents of our generations, Adam and Eve, were transplanted from another sphere, with immortal tabernacles, which became corrupted through sin and the partaking of natural foods, in the process of time; whether they were born here in mortality, as other mortals have been, are questions not fully answered in the revealed word of God. [BYU1992]

In 1925, the First Presidency released a statement “Mormon View of Evolution” [BYU1992]. This statement was essentially a shortened and edited version of the 1909 statement, although it did not include the text, mentioned above, on whether humans developed from earlier species.

In 1930, Elders Joseph Fielding Smith, Brigham H. Roberts and James E. Talmage were debating the issue of whether there were “pre-Adamites” or other creatures before the fall of Adam. Elder Smith argued against the possibility of pre-Adamites, or, in a larger sense, of any evolution, a view that he later expanded in his book *Man: His Origin and Destiny* [Smith1952]. Elder Roberts countered that we should pay attention to findings of scientific research, a view that he elaborated on in his 1931 manuscript *The Truth, the Way, the Life*:

On the other hand, to limit and insist upon the whole of life and death to this side of Adam's advent to the earth, some six or eight thousand years ago, as proposed by some, is to fly in the face of the facts so indisputably brought to light by the researcher of science in modern times. [Roberts1931, pg. 364]

Elder Talmage's view is indicated by the following, from a 1931 talk published by the Church:

According to the conception of geologists the earth passed through ages of preparation, to us unmeasured and immeasurable, during which countless generations of plants and animals existed in great variety and profusion and gave in part the very substance of their bodies to help form certain strata which are still existent as such. ...

Geologists say that these very simple forms of plant and animal bodies were succeeded by others more complicated; and in the indestructible record of the rocks they read the story of advancing life from the simple to the more complex, from the single-celled protozoan to the highest animals, from the marine algae to the advanced types of flowering plant – to the apple-tree, the rose, and the oak.

What a fascinating story is inscribed upon the stony pages of the earth's crust! [Talmage1931]

After several manuscripts were circulated, the First Presidency subsequently concluded that additional debate would be fruitless, and sent a letter to all Church leaders that concluded:

Upon the fundamental doctrines of the Church we are all agreed. Our mission is to bear the message of the restored gospel to the people of the world. Leave Geology, Biology, Archaeology and Anthropology, no one of which has to do with the salvation of the souls of mankind, to scientific research, while we magnify our calling in the realm of the Church. [BYU1992]

In 1958, Elder Bruce R. McConkie published the first edition of his book *Mormon Doctrine*. Among the entries was an article on evolution that concluded, “There is no harmony between the truths of revealed religion and the theories of organic evolution.” [McConkie1958, pg. 256].

President McKay asked a committee consisting of Elders Mark E. Petersen and Marion G. Romney to review the book. They reported numerous areas of concern, including the treatment of “evolution and evolutionists” [Prince2005, pg. 50], although the article on evolution remained in the second edition.

According to several accounts, President McKay personally accepted evolution [Prince2005, pg. 46], although he never openly taught this view. He did, however, briefly mention the “millions of years of the earth’s existence” in talks to BYU students [McKay1956], and he mentioned “evolution’s beautiful theory of creation” both in a 1952 BYU talk [McKay1952] and later, using nearly the same language, in a 1968 general conference talk [McKay1968].

In 1991, as part of the compilation of the *Encyclopedia of Mormonism*, the editors referred the question of evolution to President Gordon B. Hinckley. He forwarded to them a copy of the 1931 First Presidency letter mentioned above, together with a draft of a short article. The text of the resulting article, which is almost word-for-word what President Hinckley provided, includes the passage, mentioned above, “Leave Geology, Biology, Archaeology and Anthropology, no one of which has to do with the salvation of the souls of mankind, to scientific research, while we magnify our calling in the realm of the Church.” [Evenson1992].

Finally, in 1992, the BYU Board of Trustees and the First Presidency approved what is known as the BYU Packet on “Evolution and the Origin of Man.” It includes the 1909 statement, the 1910 editorial, the 1925 statement and the 1992 *Encyclopedia of Mormonism* article [BYU1992]. As far as the present author is aware, the BYU Packet is the latest word on the LDS Church’s “official” view of evolution.

#### 17. What is the evidence for the big bang cosmology?

“Big bang cosmology” is a name given to the big bang, which scientists now date at 13.81 billion years ago, and the evolution of the universe since the big bang. In 1924, American astronomer Edwin Hubble measured the distance to nearby spiral nebulae and showed that these systems were actually other galaxies, not merely objects within the Milky Way. In 1927, Georges Lemaitre, a Belgian Roman Catholic priest, argued that the recession of these nebulae was due to the expansion of the fabric of universe, in consequence of Einstein’s general theory of relativity. In 1929, Hubble confirmed this hypothesis, by showing that the distances to these galaxies were roughly proportional to their outward velocities, as measured by their red shift (this fact is now known as Hubble’s Law). This inferred that the entire universe is expanding, not only away from us but also away from every other position in space, much like dots on the surface of an expanding balloon all appear to be moving away from each other. Thus that there must have been a time when the universe was very much more dense than it is today.

The big bang cosmology received substantial confirmation from an important discovery in 1964. Two radio astronomers used a large antenna at Bell Laboratories in New Jersey to make some measurements of radio waves. After fruitlessly trying to eliminate background noise, they finally realized that this noise was emanating from the sky. Physicists at nearby Princeton University quickly recognized that this noise must be the primordial echo of the universe itself

from 300,000 years after the big bang, since the spectrum of the noise fit a “black body” radiation curve that had been predicted earlier by theoreticians [Guth1997, pg. 57-83].

At about the same time, theoretical calculations by researchers concluded that the big bang would have produced a universe that is roughly 75% hydrogen, 25% helium, with traces of other elements. Measurements verified these figures in impressive detail [Guth1997, pg. 101-103].

More recent astronomical measurements continue to confirm the big bang theory. For example, in 1993 measurements of the cosmic microwave background using the Cosmic Microwave Background Explorer (COBE) satellite were found to perfectly fit a black body radiation curve with a characteristic temperature of 2.725 K, plus or minus 0.01 K. Data obtained from the Wilkinson Microwave Anisotropy Probe (WMAP) spacecraft, which was in operation from 2001 through 2010, showed even more spectacular agreement – plus or minus 0.001 K. These measurements have also found that this radiation is equal in all directions to within one part in 100,000. Interestingly, in the early 1990s fluctuations were found lower than this level, at just the amount predicted by theory to account for the “lumpiness” of the present universe [Tegmark2014, Ch. 5].

Given such impressive agreement with theory in multiple tests, the big bang cosmology is now widely accepted. However, some questions remain. One of these regards the “inflation” scenario, namely the theory that the universe underwent a spectacular expansion, by some 30 orders of magnitude, during the first tiny fraction of second after the big bang. This explains many curious features of our present universe, such as why different parts of the universe, from our vantage point, appear to have the same characteristics, even though they could not have had any “communication” between them since the big bang. However, more recent studies are starting to raise serious questions about the inflation scenario, so we may well see it significantly revised in the coming years. For additional details on these controversies, see [Gefter2012].

#### 18. What are the “cosmic coincidences”?

Some of the most remarkable findings of modern physics and cosmology are the “cosmic coincidences,” namely indications that our particular universe and its laws seem remarkably fine-tuned for the rise of intelligent life. For example, if gravitation had been very slightly stronger in the early universe, the expansion would have stopped and even reversed long ago, ending the universe in a big crunch long before any intelligent creatures would have arisen. On the other hand, if gravitation had been very slightly weaker, stars and galaxies might not have formed until matter was too dispersed, leaving the universe a cold and lifeless place.

A few of these cosmic coincidences that have been noted in previous years now have reasonable explanations, but numerous other coincidences remain inexplicable, and, if anything, recent developments in physics and astronomy have compounded these mysteries. They have even led some leading scientists to propose the controversial “anthropic principle”: the reason we see these cosmic coincidences is that if the universe weren’t constructed in a very special way, we would not be around to discuss the issue [Barrow1986]. Other writers see the hand of God in these coincidences.

Here are just a few of the coincidences that have been noted in the scientific literature:

- a. *Carbon resonance and the strong force.* As mentioned above, approximately 74% of the mass in the universe is hydrogen, another 24% is helium, and all other elements comprise less than 1%. The currently understood laws of physics, coupled with the big bang cosmology, are dramatically successful in explaining these abundances. The synthesis of heavier elements, beginning with carbon, remained a mystery until 1951, when astronomer Fred Hoyle hypothesized and then discovered a nuclear “resonance” that is just energetic enough to permit carbon to form. The energy at which this resonance occurs depends sensitively on the interplay between the strong nuclear force and the weak nuclear force. If the strong force were slightly stronger or slightly weaker (by just 1% in either direction), there would be no carbon or any heavier elements anywhere in the universe, and thus no carbon-based life forms like us [Davies2007, pg. 133-138].
- b. *The electromagnetic-gravitational strength ratio.* In 1974, Brandon Carter noted an interesting relationship between the ratio of the strengths of the electromagnetic and gravitational fields, which is roughly  $10^{40}$ , and the properties of stars. If gravity were slightly stronger (so that the ratio is lower), all stars would be radiative rather than convective, and planets might not form. But if gravity were somewhat weaker (so that the ratio was higher), then all stars would be convective and supernovas might not happen. Since all elements from carbon on up are synthesized in supernova explosions, we might not be here to discuss the issue [Davies2007, pg. 144].
- c. *The proton-to-electron mass ratio.* The ratio of the mass of the proton to that of the electron is approximately 1836.15, according to latest measurements. The ratio of the mass of the neutron to the mass of the proton is approximately 1.0013784. In other words, the neutron's mass is slightly more than the combined mass of a proton, an electron and a neutrino. As a result, free neutrons (neutrons that are not tied up in the nucleus of an atom) spontaneously decay with a half-life of about 10 minutes. If the neutron were very slightly less massive, then it could not decay without energy input. If its mass were lower by 1%, then isolated protons would decay instead of neutrons, and very few atoms heavier than lithium could form [Davies2007, pg. 145].
- d. *The cosmological constant.* Perhaps the most startling “cosmic coincidence” is the fine-tuning of the cosmological constant. This paradox derives from the fact that when one calculates, based on known principles of quantum mechanics, the “vacuum energy density” of the universe, focusing on the electromagnetic force, one obtains the incredible result that empty space “weighs”  $10^{93}$  grams per cc (the actual average mass density of the universe is  $10^{-28}$  grams per cc) [Susskind2005, pg. 70-78]. Physicists, who have fretted over this paradox for decades, have noted that calculations such as the above involve only the electromagnetic force, and so perhaps when the contributions of the other known forces are included, all terms will cancel out to exactly zero, as a consequence of some unknown fundamental principle of physics.

These hopes were shattered with the 1998 discovery that the expansion of the universe is accelerating, which implies that the cosmological constant must be slightly positive. But this

means that physicists are left to explain the startling fact that the positive and negative contributions to the cosmological constant cancel to 120-digit accuracy, yet fail to cancel beginning at the 121-st digit. Curiously, this observation is in accord with a prediction made by physicist Steven Weinberg in 1987, who argued from basic principles that the cosmological constant must be zero to within one part in roughly  $10^{120}$ , or else the universe either would have dispersed too fast for stars and galaxies to have formed, or else would have recollapsed upon itself long ago [Susskind2005, pg. 80-82].

Other examples are presented in [Bailey2013e].

#### 19. Is the fine-tuning of the universe evidence for God?

From the previous item, we see that numerous features of our universe seem fine-tuned, often amazingly so, for the existence of intelligent life. While some physicists still hold out for a “natural” explanation, other physicists are coming to grips with the notion that our universe is profoundly “unnatural,” with no good explanation other than the anthropic principle – the universe is in this extremely improbable state, because if it weren’t, we wouldn’t be here to discuss the fact [Wolchover2013].

Some writers argue that these coincidences constitute proof that our universe was designed by a supreme being. But others recommend caution. Long experience has taught us that claims that one can “prove” God via arguments based on apparent design or other inexplicable phenomena in the natural world are likely to disappoint in the long run – this is the “God of the gaps” approach, which has left a legacy of disappointment as science advances. Furthermore, invoking a Creator or Designer every time unexplained phenomena arise is a “thinking stopper,” burying the grand questions of science and religion in the mind of God. This may be a satisfactory theological approach, but it is not a productive scientific approach. Let’s be careful here.

#### 20. Is science the best approach to religious faith?

This is an exciting time to be alive. As we have seen just from the survey above, the world of science and technology is surging ahead with remarkable discoveries on many fronts: DNA sequencing, biomedical technology, the discovery of numerous planets orbiting other stars in the “habitable zone,” molecular computing, the multiverse, artificial intelligence and many others. And, as we have seen from the review above, numerous intriguing questions have emerged at the interface of science and religion.

But some caution is in order. For example, while discussions of evolution and cosmology may be engaging and intriguing, it is not clear that they relate in any substantive way with what most religious people experience. Was Mother Theresa inspired by the cosmic coincidences to devote her life to India’s poor? Did Johann Sebastian Bach have the “God of the big bang” in mind when he composed over 1000 pieces of sacred music? Are millions of persons, of LDS and other religious traditions, inspired by developments at the forefront of high-energy physics when they devote their lives to religious service? Probably not. As Holmes Rolston observed, “The religion that is married to science today will be a widow tomorrow. ... Religion that has too thoroughly accommodated to any science will soon be obsolete.” [Rolston2006, pg. ix].

So while all of this may be interesting, in the end religious faith is not proven (or disproven) by science. One is still more likely to find God on his/her knees and in the soup kitchen than in the scientific laboratory.

## References

- [Anderson2009] Kevin Anderson, “The Wonderful Unscientific Teachings of Christianity,” 26 Feb 2009, available at <http://www.answersingenesis.org/articles/2009/02/26/wonderful-unscientific-teachings-of-christianity> (viewed 18 Dec 2013).
- [Ayala2007] Francisco J. Ayala, *Darwin’s Gift to Science and Religion*, Joseph Henry Press, Washington, DC, 2007.
- [Bailey2000] David H. Bailey, “Evolution and Probability,” *Report of the National Center for Science Education*, vol. 20 (2000), no. 4. See also updated version available at <http://www.sciencemeetsreligion.org/evolution/probability.php> (viewed 18 Dec 2013).
- [Bailey2013a] David H. Bailey, “How does radiometric dating work?,” 18 Dec 2013, available at <http://www.sciencemeetsreligion.org/evolution/radiometric-dating.php> (viewed 18 Dec 2013).
- [Bailey2013b] David H. Bailey, “How reliable are geologic dates?,” 18 Dec 2013, available at <http://www.sciencemeetsreligion.org/evolution/reliability.php> (viewed 18 Dec 2013).
- [Bailey2013c] David H. Bailey, “Do gaps in the fossil record present serious difficulties for the theory of evolution?,” 18 Dec 2013, available at <http://www.sciencemeetsreligion.org/evolution/fossils.php> (viewed 18 Dec 2013).
- [Bailey2013d] David H. Bailey, “Can evolution generate truly novel biological features?,” 18 Dec 2013, available at <http://www.sciencemeetsreligion.org/evolution/novelty.php> (viewed 18 Dec 2013).
- [Bailey2013e] David H. Bailey, “What are the cosmic coincidences, and what do they mean?,” 18 Dec 2013, available at <http://www.sciencemeetsreligion.org/physics/cosmic.php> (viewed 18 Dec 2013).
- [Bailey2014] David H. Bailey, “Science vs. religion: Can this marriage be saved?,” Proceedings of the Interpreter Symposium on Science and Mormonism, Provo, UT, 8 Jan 2014.
- [Barrow1986] John D. Barrow and Frank J. Tipler, *The Anthropic Cosmological Principle*, Oxford University Press, New York, 1986.
- [Behe1996] Michael J. Behe, *Darwin’s Black Box: The Biochemical Challenge to Evolution*, Simon and Schuster, New York, 1996.
- [Bentley1962] W. A. Bentley and W. J. Humphreys, *Snow Crystals*, Dover Publications, New York, 1962.
- [BYU1992] “Evolution and the Origin of Man,” BYU Packet, June 1992, available at <http://biology.byu.edu/DepartmentInfo/EvolutionandtheOriginofMan.aspx> (viewed 18 Dec 2013).
- [Coghlan2010] Andy Coghlan, “Drug-Resistant HIV Set to Surge,” *New Scientist*, 15 Jan 2010, available at <http://www.newscientist.com/article/dn18394-drugresistant-hiv-set-to-surge.html> (viewed 18 Dec 2013).
- [Dalrymple2004] G. Brent Dalrymple, *Ancient Earth, Ancient Skies: The Age of Earth and its Cosmic Surroundings*, Stanford University Press, Stanford, CA, 2004.

[Davies2007] Paul Davies, *Cosmic Jackpot: Why Our Universe is Just Right for Life*, Houghton-Mifflin Co., New York, 2007.

[Evenson1992] William Evenson, "Evolution," from Daniel Ludlow, ed., *Encyclopedia of Mormonism*, Macmillan, NY, 1992.

[Evolution2009] Evolution and the Nature of Science Institutes, "Investigating Evolutionary Questions Using Online Molecular Databases," not dated, available at <http://www.indiana.edu/~ensiweb/lessons/p.stdnt.pdf> (viewed 18 Dec 2013).

[Fairbanks2007] Daniel J. Fairbanks, *Relics of Eden: The Powerful Evidence of Evolution in Human DNA*, Prometheus Books, New York, 2007.

[Foster1991] David Foster, *The Philosophical Scientists*, Marboro Books, New York, 1991.

[Gefter2012] Amanda Gefter, "What kind of bang was the big bang?," *New Scientist*, 2 Jul 2012, available at <http://www.newscientist.com/article/mg21428710.100-what-kind-of-bang-was-the-big-bang.html> (viewed 18 Dec 2013).

[Geologic2013] [no author] "Geologic Time Scale," Wikipedia article, not dated but viewed 18 Dec 2013, available at [http://en.wikipedia.org/wiki/Geologic\\_time\\_scale](http://en.wikipedia.org/wiki/Geologic_time_scale) (viewed 18 Dec 2013).

[Guth1997] Alan H. Guth, *The Inflationary Universe*, Helix Books, New York, 1997.

[Hall1974] Barry G. Hall and Daniel L. Hartl, "Regulation of Newly Evolved Enzymes," *Genetics*, vol. 76 (1974), pg. 391-400.

[Ham2013] Ken Ham, *Six Days: The Age of the Earth and the Decline of the Church*, Master Books, Green Forest, AR, 2013.

[Hardison2001] Ross C. Hardison, "Organization, evolution and regulation of the globin genes," in Martin H. Steinberg, Bernard G. Forget, Douglas R. Higgs and Ronald L. Nagel, *Disorders of Hemoglobin: Genetics, Pathophysiology, Clinical Management*, Cambridge University Press, Cambridge, UK, 2001, available at [http://www.bx.psu.edu/~ross/pubs/OrgEvolGlbGenes\\_DisordersHb\\_wFigs.pdf](http://www.bx.psu.edu/~ross/pubs/OrgEvolGlbGenes_DisordersHb_wFigs.pdf) (viewed 18 Dec 2013).

[Hume1758] David Hume, *An Inquiry Concerning Human Understanding*, originally published 1748, reprinted by Liberal Arts Press, New York, 1955.

[Isaak2007] Mark Isaak, *The Counter-Creationism Handbook*, University of California Press, Berkeley, CA, 2007.

[JD] *Journal of Discourses*, 26 vol., Liverpool Publishers, 1854-1886.

[Jones2008] Dan Jones, "Uncovering the Evolution of Bacterial Flagellum," *New Scientist*, 16 Feb 2008, pg. 40-43.

[Kotz2002] Dan Kotz, "The Milano Mutation: A Rare Protein Mutation Offers New Hope for Heart Disease Patients," available at <http://www.eurekaalert.org/features/doe/2002-05/dbnl-tmm061302.php> (viewed 18 Dec 2013).

[Lennox2009] John C. Lennox, *God's Undertaker: Has Science Buried God?*, Lion Hudson, Oxford, UK, 2009.

[Lenski1994] R. E. Lenski and M. Travisano, "Dynamics of Adaptation and Diversification: A 10,000-Generation Experiment with Bacterial Populations," *Proceedings of the National Academy of Sciences*, vol. 91 (1994), pg. 6808-6814.

[Lehrman2013] Sally Lehrman, "New Genetic Insights Show How Tuberculosis May Be Evolving to Become More Dangerous," *Scientific American*, 2 Jul 2013, available at <http://www.scientificamerican.com/article.cfm?id=new-genetic-insights-show-how-tuberculosis-may-be-evolving-become-more-dangerous> (viewed 18 Dec 2013).

[McAlpine2010] Kate McAlpine, "How wind may have parted the sea for Moses," *New Scientist*, 22 Sep 2010, available at <http://www.newscientist.com/article/dn19489-how-wind-may-have-parted-the-sea-for-moses.html> (viewed 18 Dec 2013).

[McConkie1958] Bruce R. McConkie, *Mormon Doctrine*, Deseret Book, 1958, second edition 1966.

[McConkie1982] Bruce R. McConkie, "Christ and the Creation," *Ensign*, June 1982.

[McKay1952] David O. McKay, "A Message for LDS College Youth," *BYU Speeches of the Year*, 10 Oct 1952, pg. 6-7.

[McKay1956] David O. McKay, "Gospel Ideals – Life's Surest Anchor," *BYU Speeches of the Year*, 30 Oct 1956.

[McKay1968] David O. McKay, *LDS Conference Report*, Apr 1968, pg. 92.

[Miller2003] Kenneth R. Miller, "Answering the Biochemical Argument from Design," in Neil Manson, ed., *God and Design*, Routledge, New York, 2003, pg. 292-307, available at <http://www.millerandlevine.com/km/evol/design1/article.html> (viewed 18 Dec 2013).

[Morris1985] Henry M. Morris, *Scientific Creationism*, Creation-Life Publishers, El Cajon, CA, 1985, reprinted 2000.

[Moritz2013] Joshua M. Moritz, "God's Creation Through Evolution and the Language of Scripture," *Theology and Science*, vol. 11 (2013), pg. 1-7.

[NAS2008] National Academy of Sciences, Institute of Medicine, *Science, Evolution, and Creationism*, National Academies Press, Washington, DC, 2008.

[Musgrave1998] Ian Musgrave, "Lies, Damned Lies, Statistics, and Probability of Abiogenesis Calculations," *TalkOrigins Archive*, 21 Dec 1998, available at <http://www.talkorigins.org/faqs/abioprob/abioprob.html> (viewed 18 Dec 2013).

[Negoro1994] S. Negoro, K. Kato, K. Fujiyama and H. Okada, "The Nylon Oligomer Biodegradation System of Flavobacterium and Pseudomonas," *Biodegradation*, vol. 5 (1994), pg. 185-194.

[Nelson2000] Russell M. Nelson, "The Creation," *LDS Conference Report*, April 2000.

- [Petersen1992] Morris Petersen, "Age of the Earth," in Daniel H. Ludlow, ed., *The Encyclopedia of Mormonism*, Macmillan, New York, 1992, available at <http://eom.byu.edu> (viewed 18 Dec 2013).
- [Pope1996] Pope John Paul II, "Message to the Pontifical Academy of Sciences: On Evolution," 22 Oct 1996, available at <https://www.ewtn.com/library/PAPALDOC/JP961022.HTM> (viewed 12 Feb 2014).
- [Pratt1855] Parley P. Pratt, *Key to the Science of Theology*, reprinted by Deseret Book, Salt Lake City, UT, 1965.
- [Prince2005] Gregory A. Prince and William Robert Wright, *David O. McKay: The Rise of Modern Mormonism*, University of Utah Press, Salt Lake City, UT, 2005.
- [Prothero2007] Donald R. Prothero, *Evolution: What the Fossils Say and Why It Matters*, Columbia University Press, New York, 2007.
- [Reimer2009] P. J. Reimer and 27 other authors, "Intcal09 and Marine09 radiocarbon age calibration curves, 0-50,000 years cal BP," *Radiocarbon*, vol. 51 (2009), pg. 1111-1150.
- [Roberts1931] B. H. Roberts, *The Truth, the Way, the Life*, originally written 1931, published by Smith Research Associates, Salt Lake City, UT, 1994.
- [Rogers2011] Alan R. Rogers, *The Evidence for Evolution*, University of Chicago Press, 2011.
- [Rolston2006] Holmes Rolston III, *Science and Religion: A Critical Survey*, Temple University Press, Philadelphia, PA, 1987, reprinted 2006.
- [Shubin2008] Neil Shubin, *Your Inner Fish: A Journey into the 3.5-Billion-Year History of the Human Body*, Pantheon Books, New York, 2008.
- [Smith1952] Joseph Fielding Smith, *Man: His Origin and Destiny*, Deseret Book, Salt Lake City, 1952.
- [Susskind2005] Leonard Susskind, *The Cosmic Landscape: String Theory and the Illusion of Intelligent Design*, Little, Brown and Company, New York, 2005.
- [Talmage1899] James E. Talmage, *The Articles of Faith*, originally published 1899, reprinted by Deseret Book, Salt Lake City, UT, 1966.
- [Talmage1931] James E. Talmage, "The Earth and Man," address delivered in the Salt Lake Tabernacle, 9 Aug 1931, and published by the LDS Church, available at <http://eyring.hplx.net/Eyring/faq/evolution/Talmage1931.html> (viewed 18 Dec 2013).
- [TS] John Taylor, *Times and Seasons*, vol. 4, pg. 46 (15 Dec 1842).
- [Vance2014] Ashlee Vance, "Illumina's DNA Supercomputer Ushers in the \$1,000 Human Genome," *Business Week*, 14 Jan 2014, available at <http://www.businessweek.com/articles/2014-01-14/illuminas-dna-supercomputer-ushers-in-the-1-000-human-genome> (viewed 20 Jan 2014).
- [Wiens2002] Roger C. Wiens, "Radiometric Dating: A Christian Perspective," 2002, available at <http://www.asa3.org/ASA/resources/Wiens2002.pdf> (viewed 18 Dec 2013).

[Wilde2001] Simon A. Wilde, John W. Valley, William H. Peck and Colin M. Graham, "Evidence from detrital zircons for the existence of continental crust and oceans on the Earth 4.4 Gyr ago," *Nature*, vol. 409 (2001), pg. 175-178, available at <http://www.geology.wisc.edu/%7EValley/zircons/Wilde2001Nature.pdf> (viewed 18 Dec 2013).

[Zimmer2001] Carl Zimmer, *Evolution: The Triumph of an Idea*, HarperCollins, New York, 2001.