PERSPECTIVES on Science and Christian Faith

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In This Issue …

"The fear of the Lord is the beginning of Wisdom."
Psalm 111:10

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Perspectives on Science and Christian Faith

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The pages of *Perspectives on Science and Christian Faith (PSCF)* are open to original, unpublished contributions that interact with science and Christian faith in a manner consistent with scientific and theological integrity. A brief description of standards for publication in *PSCF* can be found in the lead editorial of the December 2013 issue. This is available at www.asa3.org → PUBLICATIONS → PSCF Academic Journal. Published papers do not reflect any official position of the American Scientific Affiliation.

1. Submit all manuscripts to: **James C. Peterson, Editor, Roanoke College, 221 College Lane, Salem, VA 24153.** E-mail: jpeterson@roanoke.edu. Submissions are typically acknowledged within 10 days of their receipt.
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3. Use endnotes for all references. Each note must have a unique number. Follow *The Chicago Manual of Style* (16th ed., sections 14.1 to 14.317).
4. While figures and diagrams may be embedded within the Word text file of the manuscript, authors are required to also send them as individual electronic files (JPEG or PDF format). Figure captions should be provided as a list at the end of the manuscript text.

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COMMUNICATIONS are focused personal examples of how people are living out science and Christian faith. They have ranged from bringing computers to areas with no power, to being married to an experimental physicist, to an astronomer's sermon on the heavens telling the glory of God, to serving as president of a research university.

BOOK REVIEWS serve both to alert readers to new books that appear significant and to engage these books in critical interaction. When a subject area editor selects a book for review, the book is then offered to a scholar with the best match in expertise. ASA/CSCA members who would like to be considered as potential reviewers are welcome to express interest to **Stephen Contakes** (scontakes@westmont.edu) book review editor for inclusion in the reviewer database. Publishers may also contact the book review editor if they are not sure which subject area reviewer would best consider a particular book.

- **Arie Leegwater** (leeg@calvin.edu): cosmology, history of science, mathematics, and physical sciences.
- **Myron Penner** (myron.penner@twu.ca): philosophy and theology.
- **Derek Schuurman** (dschuurman@calvin.edu): computers, engineering, and technology.
- **Sara Sybesma Tolsma** (stolsma@nwciowa.edu): biology, environment, genetics, and origins.

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Thanks and a Promising Start

James C. Peterson

As our book review editor at *PSCF* for the last seven years, Patrick Franklin has shepherded close to 300 book reviews in *PSCF*. Many of those he has written, more commissioned, and yet more, has ably organized and coordinated with the subject area editors. He and his team have alerted us to books we should know, gleaned the key findings of others that we should know but would not have the time to pursue in full, and warned us off time wasters. That has required a breadth of field, discernment, mastery of detail, clear vision of the big picture, eloquence, and diplomacy. On behalf of our readers, ASA, CSCA, and colleagues at the journal, many, many, thanks.

The demands of creating a new issue every few months are relentless. Stephen Contakes has already been at the helm for book reviews for three months. Stephen is an associate professor of chemistry at Westmont College, Santa Barbara, California. He completed undergraduate degrees in chemistry and chemical engineering at Lehigh University, a doctorate in chemistry at the University of Illinois Urbana-Champaign, and a postdoc at Caltech. His research involves the synthesis of molecular assemblies and catalysts for water remediation applications. He has been a member of the ASA since 2008, a part of the Southern California local chapter since its founding in 2010, and helped organize the section's annual Winter Conferences from 2013–2019. These activities helped prepare him to participate in the 2014–2016 Oxford-Templeton Bridging the Two Cultures of Science and the Humanities program. As a reader of *PSCF* specifically, you will already know his name as author of two articles for *PSCF* and as a member of our Editorial Board for several years.

We are also welcoming with this issue Myron A. Penner. Myron is our new book review subject area editor for philosophy and theology. You might already know him as professor of philosophy and director of the Humanitas Anabaptist-Mennonite Centre for Faith and Learning at Trinity Western University in Langley, British Columbia. Penner started off with an MCS from Regent and a PhD from Purdue University. He has won fellowships at Oxford, Calvin, Ryerson, and Notre Dame, and co-wrote with Amanda Nichols the lead article in this issue of *PSCF*.

Contakes and Penner will, of course, not be alone in our book review section. Each year over forty reviewers explain and critique the contribution of new books. It is the subject area editors, now Myron, and continuing, Arie Leegwater, Sara Sybesma Tolsma, and Derek Schuurman who find the right experts to evaluate the most relevant and important books out of the hundreds of thousands that are published each year. The resulting reviews are honed to be well written, informative, and prompt. Arie taught chemistry at Calvin College and edited this journal. He watches and commissions cosmology, history of science, mathematics, and the physical sciences. Sara is a professor of biology at Northwestern College (Iowa). She looks out for the key new books in biology, environment, genetics, and origins. Derek holds the William Spoelhof Chair as a professor of computer science at Calvin University. He keeps track of computers, engineering, and technology.

As book review editor, Stephen takes the further step of coordinating the book choices since the subject areas often interact. He then marshals the readied reviews into categories to help readers find the ones that match their interests. He also maintains a database of potential reviewers. If you would like to lend your expertise to this crucial service of reviewing (and get free books!), do send him your contact information and a brief description of your expertise (scontakes@westmont.edu). He and the subject area editors also welcome recommendations of particular books that readers would like to see reviewed. These suggestions from engaged scholars who have appreciated a new title and think other readers would as well, usefully extend our awareness and reach. ♥

James C. Peterson
Editor-in-Chief

IN THIS FULL-COLOR BOOK, geologist Carol Hill examines how numerous apparent conflicts between Scripture and science can be resolved by understanding the ancient worldview of the scriptural authors and how it differs from our modern, scientific worldview. This framework opens the door to clearing up longstanding questions, such as:

- Are the Genesis patriarchs' ages real numbers?
- Are the days of creation actual 24-hour days?
- Where was the garden of Eden located?
- Was Noah's flood global or local?
- Were Adam and Eve real people?
- Is evolution a belief or a fact?

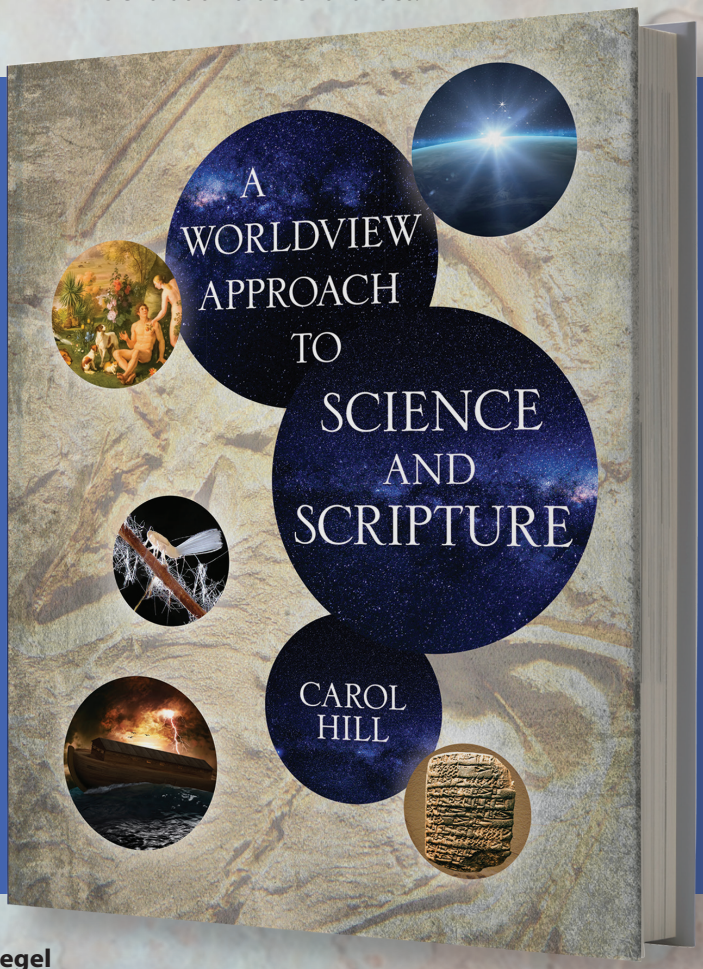
CAROL HILL is a geologist who has worked in the Grand Canyon and Carlsbad Caverns for more than forty years. She is the author of a number of books, and has been featured on NOVA and National Geographic TV. Carol teaches geology at the University of New Mexico.

Praise by theologians and scientists:

"Carol Hill takes both Scripture and science seriously, affirming the inspiration of the Bible and the evidence for biological evolution."
—**DEBORAH B. HAARSMA**, President of BioLogos

"This is one of the best one-volume works on the creation/evolution dialogue in print."
—**KENNETH KEATHLEY**, Southeastern Baptist Theological Seminary

"Carol Hill's worldview approach brings the reader face-to-face with archeological, biblical, and scientific data that enable one to gain a new appreciation for what the Bible is trying to teach. This approach is a very helpful tool!"
—**JAMES K. HOFFMEIER**, Trinity Evangelical Divinity School



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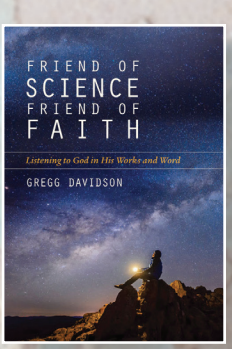

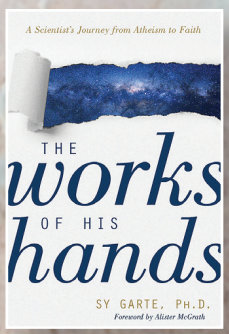

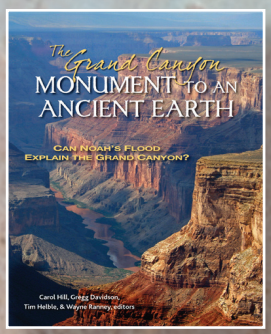

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Nuclear Chemistry and Medicine: Why "Young-Earthers" Cannot Have It Both Ways

Amanda J. Nichols and Myron A. Penner

Amanda J. Nichols

Myron A. Penner

Nuclear chemistry is the branch of chemistry that reflects our current understanding of the structure and chemical properties of the atom and its parts. Nuclear medicine applies nuclear chemistry to medical diagnoses and treatments. For example, radioisotope imaging and radioiodine therapy are successful medical applications of nuclear chemistry. We argue that the best explanation for the success of these medical applications is that our current framework of nuclear chemistry is, in the main, correct. We further argue that this framework also entails the prevailing models of radiometric dating, according to which the earth is approximately 4.6 billion years old. We thus conclude that "young-earthers" (those who think the earth is ten thousand years old or less) cannot have it both ways. That is, they need to either provide an alternative explanation for the success of nuclear medicine or accept a much older earth. Finally, we consider and reply to psychological, scientific, philosophical, and theological objections to our arguments.

Introduction

One underappreciated, but potentially important, tool for navigating tensions in science and religion dialogue is understanding the way in which scientific frameworks have applications that are appropriated across "party lines." Technological applications of scientific discovery produce smartphones, medical advances, and an ever-increasing number of conveniences that are appreciated and appropriated by those with differing perspectives on any hot-button science and religion issue. What is sometimes not recognized, however, is the connection between the piece of technology we can touch and see, and the scientific framework which made the creation of the technology possible.

For example, suppose that Sue gets thyroid cancer and her doctor prescribes radioiodine therapy as part of her treatment. Or suppose that Bob has symptoms of a gallbladder attack and his doctor recommends a radioisotope scan in order to give an image of the gallbladder that will aid diagnosis. Both of these features of modern medicine—radioisotope imaging and radioiodine therapy—are applications of a more fundamental framework of nuclear chemistry. But the applications of nuclear chemistry do not stop with medicine; the same scientific framework that results in radioisotope imaging and radioiodine therapy also generates radiometric dating, one of the pieces of information scientists use to determine that the earth is approximately 4.6 billion years old. Now it turns out

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that for religious reasons, Sue and Bob do not think that the earth is nearly that old—they think that it is much younger—somewhere between six thousand and ten thousand years old. Sue and Bob's experience with the benefits of nuclear medicine puts them in an intellectual tension, if not in an actual dilemma. On the one hand, they are benefiting from the application of a scientific framework which will assist doctors in treating their diseases. But on the other hand, that same scientific framework entails a result that conflicts with their religiously based beliefs about the age of the earth.

This article will show the way out of this tension; in it, we set out to do three things. First, we provide an accessible overview of the modern framework of nuclear chemistry and demonstrate the link between the science and the various applications it supports. Second, we present and defend two arguments that link the successful science of nuclear chemistry to certain applications of that science. Third, we consider and reply to several objections to our argument.

I. The Scientific Framework of Nuclear Chemistry

A. Modern Chemistry

Chemistry is the study of matter, the stuff out of which all physical objects are made. Going back to at least the pre-Socratic philosophers of ancient Greece, matter has been studied through careful observation, which includes classifying matter into constituent elements. One feature that separates modern chemistry from its roots in ancient Greek natural philosophy is the sophisticated tools we now have for observing and analyzing matter. Thus, a central feature of how chemists do their work is to subdivide elements into their constituent parts. In one sense, the story of modern chemistry is the story of greater and greater understanding of smaller and smaller things.

Chemistry as a discipline was making great strides by the end of the nineteenth century. Chemical reactions were an active area of research in university laboratories and in industry; chemists explored molecular structure in both organic and inorganic chemistry even before the discovery of the electron in 1897 by J. J. Thomson.[1] A year prior to Thomson's discovery, Henri Becquerel observed that uranium was emitting energy without interacting with any external source. While energy emissions had been previously observed, for example, in phosphorescence, what was new with uranium was the fact that the emission seemed spontaneous.[2] It was later understood that the energy emission is a result of change and decay in the nucleus. This spontaneous energy emission is radiation, a release of energy in the form of particles or electromagnetic waves.

Over the next few years, G. C. Schmidt, Pierre Curie, and Marie Curie worked with radioactive substances, discovering new elements such as radium and polonium. Ernest Rutherford and Robert J. Strutt figured out, before the turn of the century, that there were three types of radiation. Over the next decade, scientists catalogued nuclear radioactive chain reactions in which, through a process of radioactive decay, one element turns into another, which then turns into another. These early discoveries related to radiation occurred alongside the development of quantum mechanics. Since the 1930s, scientists have added to the knowledge about radioactivity, leading to the robust field of nuclear chemistry that has produced novel technology, including medical applications such as the ones utilized by Sue and Bob above.

B. Atoms and Isotopes

Chemists think of an element as a substance that is made up of one type of atom, in which an atom is the most basic unit of that element; the Periodic Table organizes the different types of known elements.[3] Each atom, regardless of the element, is made up of three types of particles: neutron, proton, and electron.[4] Elements on the Periodic Table are arranged in order of increasing atomic number; the atomic number is the unique number of protons in one atom of that element.[5] For example, a hydrogen atom has one proton, whereas a uranium atom has 92 protons. The structure of an atom is fundamental in explaining observed behavior of different elements and chemical reactions.

In 1913, Frederick Soddy discovered that an element can have more than one atomic weight.[6] Atoms of the same element always have the same number of protons, but can have a different number of neutrons. Soddy used the term "isotope" as a way of distinguishing between atoms of one element that differ in atomic weight. Isotopes are identified by their total number of protons and neutrons giving each type of isotope a unique mass,[7] and elements can be studied by understanding the properties of isotopes of that

element. The framework of nuclear chemistry centers on this important principle of isotopes.[8]

C. Isotopes and Radioactive Decay

Some isotopes are unstable: this means that they will undergo a process of decay during which they will give off radiation. Isotopes that decay in this manner are called "radioisotopes." The radioisotope that starts the process of decay is called the "parent" and the new isotope that is formed is called the "daughter." Suppose you have some quantity of a radioisotope that is undergoing a process of decay. When the process begins, the ratio of parent to daughter in the sample is 100% parent, 0% daughter. The time it takes for the quantity of parent isotope in the sample to be reduced by half, by turning from parent to daughter, is called a "half-life." Isotopes decay following the same pattern, called a "rate law."[9] This means that the time span for a half-life for an isotope will be consistent throughout the process of decay. As a result, the time it takes for the percentage of parent isotope in the sample to decay from 50% to 25% will be the same amount of time it took for the percentage of parent isotope to go from 100% to 50%. All isotopes follow the rate law, though the time span for half-lives will vary according to each isotope.[10] The process of decay and the corresponding change in amount of the parent isotope can be measured as a function of time, as with the graph in figure 1.

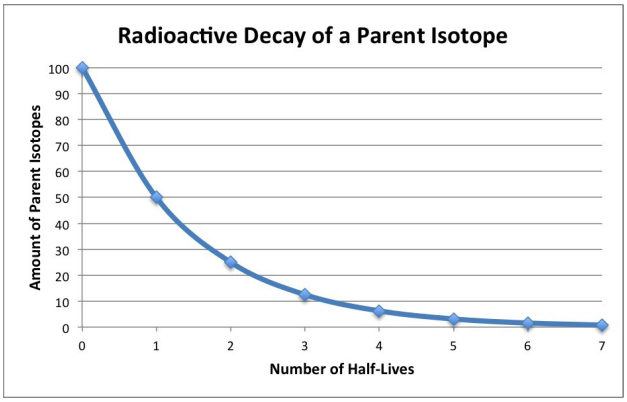

Figure 1: Radioactive decay of a parent isotope displaying exponential decrease of the amount of parent isotope over time.

Notice that the parent isotope curve begins at 100% and over time decreases toward zero. The graph represents the decreasing proportion of the parent isotope over time as the parent decays. The daughter isotope curve, as seen in the figure 2 graph, begins at zero and increases toward 100% over time. The line on the graph represents the increasing proportion of the daughter isotope as the parent isotope decays.[11] While the degradation rate looks the same for all decaying isotopes, what differs for each isotope is the length of its half-life.

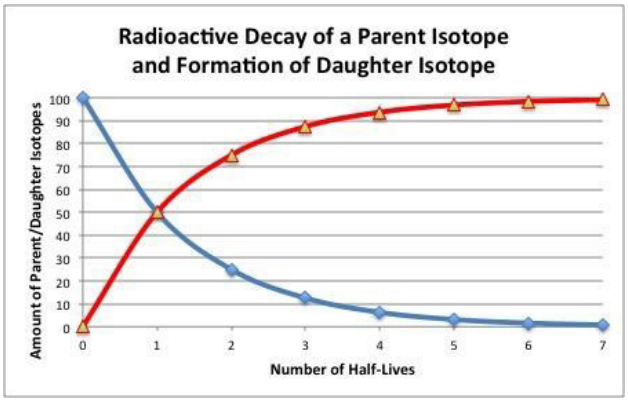

Figure 2: Radioactive decay of a parent isotope (diamond points) and formation of daughter isotope (triangle points). As the parent isotope exponentially decreases, the daughter isotope exponentially increases.[12]

D. Summary

In the nineteenth and twentieth centuries, chemists discovered the way in which atoms can emit energy, also called "radiation." Energy emission occurs because of certain changes in the nucleus of an atom. Atoms of one element can have different atomic weights, that is, nuclei of one element can differ in the number of neutrons while always having the same number of protons. Following Soddy, chemists use the term "isotope" as a way of distinguishing between atoms of one element that differ in atomic weight. Some types of radiation involve nuclear decay, in which changes in the nucleus result in an isotope of one element changing into another isotope (usually) of a different element. Regardless, the rate at which radioactive decay occurs is consistent for that element over time.

Simplifying even further, we can identify some key principles that constitute the framework of modern nuclear chemistry. First, nuclear chemistry is built on the understanding that the nucleus of atoms is composed of neutrons and protons. Second, atoms can emit energy due to changes in the nucleus. Third, atoms of an element can have different atomic weights called "isotopes." Fourth, some isotopes experience radioactive decay which occurs at a rate consistent for that element over time.

II. The Arguments

With the preceding overview of the basic framework of nuclear chemistry in hand, we are now in a position to present and defend the following two arguments: the framework argument and the radiometric dating argument.

A. The Framework Argument

Our first argument seeks to establish via inference that the best explanation that the basic framework of nuclear chemistry is correct.

The Framework Argument

1. We have successful radioisotope scans and radioiodine therapy.
2. The best explanation for the success of radioisotope scans and radioiodine therapy is that the basic framework of nuclear chemistry is correct.
3. Therefore, the basic framework of nuclear chemistry is correct.

1. *Defense of (1).* In the introductory section above, we gave hypothetical examples of Sue, who was diagnosed with thyroid cancer and requires radioiodine therapy, and of Bob, whose gallbladder symptoms prompt his doctor to require a radioisotope scan. Premise (1) merely states that radioisotope imaging and radioisotope therapy are a successful part of medical practice of the sort required by Sue and Bob. We will not spend a lot of time defending that claim—a cursory search of medical statistics shows the frequency with which these applications are used in diagnosis and treatment. For example, a 2013–2014 statistical report compiled by Britain's National Health Service (NHS) notes that during that year, imaging techniques arising from nuclear chemistry were utilized 446,365 times throughout Britain. Radioisotope imaging and radioiodine therapy fall under the category of nuclear medicine, which the NHS document describes as

> a branch of medicine and medical imaging that uses unsealed radioactive substances in diagnosis and therapy. These substances consist of radionuclides, or pharmaceuticals that have been labeled with radionuclides (radiopharmaceuticals). In diagnosis, radioactive substances are administered to patients and the radiation emitted is measured.[13]

The description of nuclear medicine continues, highlighting applications in both treatment and therapy:

> Nuclear medicine imaging tests differ from most other imaging modalities in that the tests primarily show the physiological function of the system being investigated, as opposed to the anatomy. It has both diagnostic and therapeutic uses, such as planning cancer treatments and evaluating how well a patient has responded to a treatment. It can be used with other diagnostic methods, including CT scans and MRI, where the images are superimposed to produce complex cross-sectional, three-dimensional scans.[14]

Nuclear medicine forms an integral part of various diagnostic and treatment protocols. Our knowledge of the structure of the atom and the framework of nuclear chemistry in which that knowledge is embedded makes this possible. In other words, we are able to conduct radioisotope scans and radioiodine therapy only if the broad principles of nuclear chemistry outlined above are correct. This leads us to claim, in (2), that the best explanation that we have for these highly successful medical applications is that the scientific framework on which they depend is correct. But why should we think that this is true?

2. *Defense of (2).* Defending "best-explanation" claims typically involves two steps: showing that the proposed explanation is indeed a good candidate for explaining the phenomenon in question, and then showing why this candidate explanation is better than the strongest rival explanations. In this section, we mainly do the former; we show how the principles of nuclear chemistry summarized at the end of Section I are linked with radioiodine therapy and radioisotope imaging.

2.1 *Radioisotope Imaging and Nuclear Chemistry*

A radioisotope used for a medical diagnosis, the kind that will be used in Bob's gallbladder scan, has three requirements. First, the chemistry of the radioisotope should be "versatile," meaning that the isotope can be combined with different chemicals that can control where in the body it goes. Second, as the radioisotope decays, it should give off the type of radiation that can escape the human body with minimal radiation exposure. Third, the radioisotope needs to have a relatively short half-life: something that will be sufficient to produce medical imaging, but will decay away at a predictable and consistent rate.[15]

A common radioisotope used for gallbladder malfunction is the metastable nuclear isotope,

technetium-99m (Tc-99m) that is injected into the human body. Tc-99m fulfills all the requirements for diagnosis in the human body. In Bob's case, Tc-99m can be combined with a chemical compound that is recognized by the biliary system for uptake.[16] Then Tc-99m decays, giving off gamma radiation that can penetrate the human body. The radiation can easily escape the body, be captured by a gamma camera, and processed into an image.

The decay of Tc-99m gives a comparatively low dosage of radiation to the human body.[17] Finally, Tc-99m has a half-life of about six hours. This means that in less than two days, there is less than 1% of the original amount of Tc-99m left in the body. Tc-99m decays into technetium-99, then into stable ruthenium-99.[18] The chemistry and use of this radioisotope is well studied. As of December 2017, 40 million procedures involving Tc-99m are performed each year in the world, making it a routine, safe medical application of nuclear chemistry.[19]

Recall our brief description of basic aspects of nuclear chemistry.

i. Atoms are composed of protons and neutrons.
ii. Atoms emit energy as a result of changes to the nucleus.
iii. Atoms of one element may have different atomic weights described as isotopes.
iv. Certain isotopes experience consistent radioactive decay according to the rate law for that isotope.

The example of Tc-99m above described a chain reaction in which Tc-99m turned into Tc-99 which decayed into ruthenium-99. We can map this process since we know that atoms are composed of protons and neutrons.[20] Moreover, Tc-99m is used because it emits energy, which is a particular instance of (ii) above. And finally, our knowledge of how the body processes Tc-99m is a function of understanding isotopes and radioactive decay [see (iii) and (iv) above].

2.2. *Radioiodine Therapy and Nuclear Chemistry*

The standard treatment of thyroid cancer of the sort Sue has, is administration of the radioisotope iodine-131 (I-131) due to its nuclear chemistry. When I-131 decays into xenon-131, it gives off beta radiation, which destroys thyroid tissue cells, including any cancerous cells present. This is an ideal treatment because of the function of a thyroid and the half-life of the radioisotope. First, the thyroid uptakes most of the iodine in the body, regardless of the isotope. Decreasing the amount of stable iodine into the body prior to treatment will ensure that the thyroid will uptake enough of the radioactive I-131.[21] The half-life of this radioisotope is only eight days, and much of the radioisotope is excreted from the body naturally. Dosage studies of I-131, taking into account age, thyroid activity, half-life of the radioisotope in the human body, and additional factors, have been well documented.[22] Thyroid cancer is just one type of cancer that can be treated in this manner.

As we can see in the cases of both radioiodine therapy and radioisotope imaging, the chemistry involved in guiding the use of these applications depends on our more basic understanding of the nature of the atom, radiation emission, and the rate of radioactive decay for isotopes—principles that are part of the foundation of nuclear chemistry. Clearly, the accuracy of our current understanding of nuclear chemistry is an excellent explanation for the success of the applications described in (1). Thus, given our defense of (1) and (2) of the framework argument, we have a good reason to accept its conclusion that the basic framework of nuclear chemistry is accurate.

B. The Radiometric Dating Argument

The soundness of the framework argument allows us to create the following argument which supports radiometric analysis as a means of determining the age of certain objects.

The Radiometric Dating Argument

3. The basic framework of nuclear chemistry is correct.
4. If the basic framework of nuclear chemistry is correct, then we can successfully use radiometric dating for objects.
5. Therefore, we can successfully use radiometric dating for objects.

1. *Defense of (4): Carbon-14.* The same principles of nuclear chemistry that explain why medical applications are used successfully also explain how radiometric dating functions. Building upon the active research in nuclear chemistry in the first half of the twentieth century, radiometric dating for objects has been taking place since 1950.[23]

To illustrate how scientists use radiometric dating, we will consider two materials on Earth and how their ages have been assigned. Let us first consider the cloth wrappings from a mummified bull found in a pyramid in Dashur, Egypt.[24] Carbon-14 (C-14) dating was used to assign an age to the cloth wrappings. All living things (organic things) uptake carbon dioxide, and therefore isotopes of carbon can be found in living things. Most of the carbon is the isotope carbon-12 (C-12), but a small percentage of the carbon isotopes is C-14. Therefore, the carbon in living things exemplifies a particular ratio of C-14 to C-12, and when there is an uptake of new carbon, it is in the same ratio. Thus the C-14 to C-12 ratio in living things generally stays stable over time. When a living thing dies, no more carbon is taken into the body; however, the radioactive isotope C-14 decays into nitrogen-14. The C-14/C-12 ratio is beginning to decrease because the C-14 isotope is decaying, but no more carbon is being taken into the body. Therefore, mummy cloth wrappings made out of plant material (something once living) have a ratio of radioactive C-14 isotope to the stable C-12 isotope that is different from the ratio found in living things. Because C-14 has a half-life of 5,730 years and, like all isotopes, follows the rate law in its decay, the mummy cloth wrappings are estimated to be 2,050 years old. This value is consistent with historical records of when the pyramids were built.[25]

2. *Defense of (4): Potassium-40 and Argon-40.* Due to the relatively shorter half-life of C-14 and the nature of inorganic materials such as rocks, other isotopes are used for radiometric dating in geology. Let us now consider the rocks found on the Hawaiian Islands. Plate tectonics is the current scientific theory that explains continental drift by seafloor spreading. The surface of the earth consists of plates that are constantly moving; continents and oceanic crust make up these plates. Plate movement is measured and monitored by scientists. New crust is made through volcanic activity under the ocean at mid-ocean ridges. As magma enters the ocean, it is pushed away from the ridge (similar to a conveyor belt system), and old crust is pushed down into the mantle of the earth through a process called subduction. Plate tectonics explains earthquakes, volcanoes, and mountain building. The study of plate tectonics also helps in understanding the underwater volcanic activity called "hot spots"[26] and the resulting volcanic islands, as seen with the Hawaiian Islands. Hot spots are areas on Earth where hot mantle rocks rise to the surface of the earth, initiating volcanic activity. There is a hot spot currently underneath the island of Hawaii responsible for the active volcanoes on the island. There are eight main Hawaiian Islands that include fifteen volcanoes that form a chain in the Pacific Ocean, all on the Pacific plate.

Noting plate movement and using plate tectonics, it follows that the Hawaiian Islands are geographically oriented in order of age. The oldest island was formed by volcanic activity over the hot spot, then the plate shifted, moving the island west-northwest off the hot spot. Then another island was formed above the hot spot, moved north, and the process continues today.[27] Radiometric dating of the rocks on the Hawaiian Islands confirms this model. Potassium-40 (K-40) is a radioactive isotope that decays into two isotopes: calcium-40 (Ca-40) and argon-40 (Ar-40). Ca-40 is an abundant isotope in the earth's crust, so when measuring Ca-40 in a sample, it would be difficult to know if all of the isotope resulted from the decay of K-40. As a result, Ar-40 is measured because it is a much less common isotope found in rocks, and more importantly, it remains by itself, not interacting or bonding to anything else.[28] When rocks are formed by molten magma solidifying, the atomic clock starts on the radioactive isotope because all of the argon that was originally in the sample would have been released into the atmosphere. Only daughter Ar-40 will result in the sample now.[29] The half-life of K-40 is 1.25 billion years. The ratio of the parent isotope K-40 to daughter isotope Ar-40 has been measured, confirming that the geographic orientation of the Hawaiian Islands are in order of age. The islands going from south to north have increasing radiometric dates with the volcano on the most northern island of the chain being 3.8 million years old.[30] Radiometric dating of volcanic islands fits with the other data that make up plate tectonics, including volcanic activity and plate motion.

It is at this point that the question might be raised: How much confidence do we have in accurately knowing the half-lives of isotopes, even the ones that are over one billion years? The answer goes back to the fact that isotopic decay follows a first-order rate law with no exception being found by scientists. The half-life can be calculated measuring the amount of K-40 that decays into Ar-40 in a short amount of time, since the decay rate is measured and the rate law is applied. As this area of science has progressed over the last fifty years or so, scientists have

compiled a growing body of evidence that the principles of nuclear chemistry can be accurately applied to radiometric dating.

C. Summary

Of course, a consequence of the conclusion of the radiometric dating argument is that we have a very good reason to think that the earth is over 4 billion years old, and not the much younger date of six to ten thousand years as is believed by those who hold to a "young earth." Young-earthers should feel a certain amount of epistemic pressure from the weight of a scientific claim endorsed by the scientific community concerning the age of the earth. Perhaps that weight can be mitigated, psychologically, by a young-earther who does not understand the science or have any connecting points to the science in her experience. However, folk like Sue and Bob, who have firsthand contact with the benefits of nuclear medicine, should feel an extra epistemic push toward accepting an old earth because the success of nuclear medicine depends on a scientific framework which also entails that the earth is very old. Young-earthers cannot have it both ways, at least with consistency. Young-earthers cannot accept the results of nuclear chemistry in one area, yet deny what it entails in another simply because those results do not fit with what they desire to be true.

III. Objections and Replies

In this section, we articulate and respond to seven objections that can be raised against our arguments. The first three are objections based on certain psychological factors that may be present among young-earthers. The next three are philosophical and scientific objections that might be raised regardless of whether one adopts a young earth view. The final objection is theological, and while it is specifically shaped in the context of this article as an objection in favor of a young earth view, the theological objection is a particular instance of a more general strategy adopted by those who wish to use theological arguments against scientific claims.

A. Psychological Objections

1. *The Ignorance Objection*. The ignorance objection amounts to a claim of plausible deniability: the objector states that she did not know that successful nuclear medicine depends on science that also confirms an old earth. However, this is not an objection so much as an explanation as to why one may have resisted the epistemic pressure from nuclear chemistry to this point. Moreover, after becoming acquainted with the framework and radiometric dating arguments, plausible deniability is no longer an option.

2. *The Psychological Burden Objection.* Similar to the ignorance objection, the psychological burden objection involves the objector's psychological self-reporting, in which the objector resists accepting an old earth because it would require giving up a host of beliefs that, to this point, have been quite important to her. The cognitive consequences of that kind of shift in beliefs is a burden that she feels is too great to bear.

Again, this is not an objection so much as an explanation as to why the objector is resisting change in beliefs. And while psychological pressure to resist proposition *p* is not (typically) a good reason or process that supports the belief that proposition *p* is false, the objector is to be commended for acknowledging the role that psychological pressure has in altering what we think is true about the world, and how we conduct our epistemic lives. Psychological research strongly suggests that human reasoning is subject to all sorts of biases which cause one to discount claims that contradict beliefs that are deemed important. Confirmation bias is a well-documented phenomenon, according to which we tend to seek out and endorse evidence that supports what we already believe to be true.[31] However, while psychological burdens can be heavy to bear, the weight can be mitigated over time.

3. *The Prudential Objection*. Although still motivated by psychological factors, the prudential objection is a slightly more principled objection than the previous two psychological objections. This objection takes a measured account of self-interest and counts the utility of serving one's self-interest as a reason for belief. Here the objector states something like the following:

> *It is not in my best interests to believe in an old earth – rejecting the young earth view would have serious negative consequences for me. I would probably get ostracized from my family and friends, and it is very possible that I could lose my job! As such, I have got strong prudential reasons to reject the key premises in both the framework argument and the radiometric dating argument.*

Some might initially respond to prudential objections with disdain, and claim that self-interest ought to have no role in one's quest for truth. However, we think that one ought not to be too hasty in rejecting prudential considerations out of hand. One reason is connected to our discussion of the psychological burden objection—namely, recognizing that influences of bias and self-interest are pervasive in reasoning; it is futile to assume that those influences are absent or easily overcome. Moreover, taking seriously the role of self-interest in our decisions about what to value, including beliefs about the world, can help reflective dialogue and informed decision making.

Another reason to take self-interest seriously pertains to the connection between self-interest and intellectual virtues in certain belief-contexts. For example, there are certain high-stakes situations in which what a cognitive subject believes is hugely relevant to her own self-interest such that, given the high-stakes circumstances, the agent is obligated both morally and intellectually to do more work than usual in seeking out evidence and engaging in intellectual best practices in order to support belief. Let us suppose that Bob is told that his daughter—whom he loves a great deal—may have been exposed to a life-threatening disease at a recent birthday party. The disease is such that it could be treated successfully but needs to be diagnosed quickly in order to have a reasonable chance of survival. Given Bob's great love for his daughter, it is in his best interest to believe that she did not contract the disease; he cannot bear the thought of losing her. Moreover, given the high stakes for both Bob and his daughter, Bob is obligated to do more than just casual intellectual work in determining whether his daughter has indeed been so exposed. Finally, suppose that Bob, in short order, amasses a large quantity of high-quality evidence that his daughter was not exposed to the potentially fatal disease. Bob calls every family at the party to see if any actually have the disease, and it turns out that none claim to have the disease—it seems to have been merely a rumor. But just to be sure, Bob takes his child to a physician who specializes in early diagnoses for this particular disease. All the testing turns out negative. So, here we have a situation in which prudential and evidential reasons coincide, and such that prudential reasons are epistemologically relevant in that prudential factors determine what is at stake epistemologically.

Notice the connection between prudence and evidence in the case of Bob's daughter: prudence alone is not enough. In terms of providing a basis for belief, prudential considerations do not lower or replace the requirement for best intellectual practice, including searching out good evidence. In fact, what high-stakes situations show is that prudential considerations can sometimes raise the standards for evidence. Thus, even if prudential reasons themselves do not directly confer justification, they can sometimes be relevant in determining whether some belief is justified.

Of all the premises in the framework and radiometric dating arguments, premise (1) which merely asserts that we have successful radioisotope imaging and radioiodine therapy is the least controversial. Thus, the most likely targets on the basis of prudential reasoning would be premises (2), (3), and (4), the content of which is:

2. The best explanation for the success of radioisotope scans and radioiodine therapy is that the basic framework of nuclear chemistry is correct.
3. The basic framework of nuclear chemistry is correct.
4. If the basic framework of nuclear chemistry is correct, then we can successfully use radiometric dating for objects.

Let's grant, for the sake of hypothesis, that one has strong prudential reasons for rejecting any or all of (2)–(4). Would that be a sufficient epistemological basis for rejecting any or all of these premises?

No. Let "PR*p*" stand for prudential support for *p*, and Let "EV*p*" stand for evidential support for *p*. Now consider the following list of possible combinations that define the relationship between prudential and evidential reasons for some proposition *p* believed by *S*:[32]

(A) *S* has strong PR*p* and strong EV*p*.

(B) *S* does not have strong PR*p* and does not have strong EV*p*.

(C) *S* has strong PR*p* and does not have strong EV*p*.

(D) *S* does not have strong PR*p* and does have strong EV*p*.

Of (A)–(D), only (A) and (D) put S in a strong epistemic position with respect to *p*. (A) shows the fortunate situation in which strong prudential and

strong evidential support for *p* coincide. (D) reflects a situation in which *S* has strong evidential support for *p*, but no strong prudential support for *p*. However, (A)–(D) does not quite capture the right relationship between prudence and evidence as far as the young-earther is concerned. For that, we need to consider the following:

(E) *S* has strong PR~*p*[33] and does not have strong EV*p*.

(F) *S* has strong PR~*p* and strong EV*p*.

(E) accurately describes the young-earther for whom belief that the earth is young strongly serves their perceived self-interest, but is not in possession of the strong evidence for any one of a myriad number of propositions which support an old earth. We leave it an open question whether someone in situation (E) can be justified in believing ~*p*.[34]

(F) describes the young-earther who has come into contact with strong evidence for the claim that the earth is much older than she believes to be the case based on her religious views. Assuming that our previous sections provide strong evidence for the claim that the earth is old (as a consequence of the conclusion of the radiometric dating argument), (F) describes a young-earther who has read our article thus far.

Now let us return to the lesson from the case of Bob's daughter and the relationship between prudence and evidence: all things being equal, prudential support for ~*p* is not enough to undermine evidential support for *p*. In some cases, prudential support for *p* may have moral and intellectual implications for *p*'s justification, but in those cases prudence increases, not decreases, the need for evidence. Thus, the prudential objection to the framework and radiometric dating arguments can be dismissed. Notice, however, that it is unlikely for young-earth objectors to advance one objection in isolation from the others. Thus, even if one is able to show that the prudential objection fails, one might still need to address the emotional and psychological burdens of the previous objections.

B. Philosophical and Scientific Objections

1. *The Anti-Realism Objection.* This objection to our argument arises from adopting some version of anti-realism with respect to science. One dominant issue in philosophy of science for the past several decades concerns the epistemic authority of science, particularly with respect to the picture science presents at the subatomic level. Though there are significant differences among philosophers within the scientific realist camp, scientific realists tend to think of the goals of science to include providing true descriptions and explanations of natural phenomena. This is why realists take the success of a scientific theory (where "success" is understood as success with respect to making novel predictions) as best explained by the truth or approximate truth of the theory—even when the theory involves postulating entities that are unobservable. While arguments based on the success of science are probably the strongest arguments in favor of scientific realism, the most common argument against scientific realism is based on lessons from the history of science. And again, while differences among historically sensitive anti-realists abound, one common feature is that they note that what was labeled "successful science" in previous periods in history—even successful with respect to making novel predictions—was later overturned; theories successful to some degree at one time were replaced by successor theories at a later time. This, so the objector says, should give us pause when looking at the epistemic status of current science, even the well-confirmed science of nuclear chemistry, and gives rise to the following objection to (3) of the framework and radiometric dating arguments. Recall according to (3):

3. The basic framework of nuclear chemistry is correct.

The anti-realist objector resists (3) with the following:

> *The theoretical content of science at any point in time is contingent and provisional, and the history of science is a graveyard of rejected theories—even theories that seemed to work well! Why have the confidence in the truth of contemporary nuclear chemistry even though it seems to "work"? The history of science gives us good reason to think our current science will probably be replaced at some point in the future, so I am perfectly within my rights to reject it (3).*

It is beyond the scope of this article to summarize all of the nuances in the realism/anti-realism debate in philosophy of science. We will merely note that much of what we say in our three responses to this particular objection reflects common realist strategies for responding to anti-realism in philosophy of science.

First, there is good reason to think that the history of science is not one of successive failed theories. According to Stathis Psillos:

> When a theory is abandoned, its theoretical constituents, i.e., the theoretical mechanisms and laws it posited, should not be rejected *en bloc*. Some of those theoretical constituents are inconsistent with what we now accept, and therefore they have to be rejected. But not all are. Some of them have been retained as essential constituents of subsequent theories.[35]

What we often see in exchanging one theory *T* for its successor *T** is that those truth-conducive theoretical constituents in *T* survive into the successor *T**. Thus, instead of history justifying skepticism about current science, it should actually give us greater confidence in current science because contemporary science has experienced the winnowing effect of theory revision over time.

This brings us to our second response to the anti-realism objection. Many of the high profile examples often cited in supporting historically based science skepticism involve examples from centuries ago. The shift from a Ptolemaic model of the solar system to a Copernican model that began in the sixteenth century is one such example. The development of the phlogiston theory of combustion in the seventeenth century and its eventual replacement in the eighteenth century is another such example. However, the experimental data supporting key components of physics, chemistry, and biology from the twentieth century and into the present day is of a quality and quantity vastly superior to the experimental support available at any other time in human history. This is not to say that contemporary science is beyond revision, either in principle or in practice. Rather, it is much, much more likely that revisions to current science will build upon the incredibly successful and precise theoretical framework of natural science that we have today, of which nuclear chemistry is a part.[36]

Our final response to the anti-realism objection is that (3), which appears as a premise in the radiometric dating argument, is also the conclusion of the framework argument. As such, the objector owes us a principled way of rejecting at least one of the premises of the framework argument. As we stated above, premise (1) which merely observes that we have successful radioisotope imaging and radioiodine therapy seems noncontroversial, in which case the objector will need to give us a reason for rejecting (2):

> 2. The best explanation for the success of radioisotope scans and radioiodine therapy is that the basic framework of nuclear chemistry is correct.

Until or unless the anti-realist objector can give us an equally good explanation for the success of radioisotope imaging or radioiodine therapy, (2) remains undefeated and (3) is secure.

2. *The Fluctuating Decay Objection*. According to the rate law, the rate of decay for an isotope will be uniform, and the duration of an isotope's half-life will be consistent throughout the process of decay. But the timescale being considered by radiometric dating goes into billions—a scale of time for which we, existentially, do not have a very good grip. As a result, the fluctuating decay objector asks,

> *How do we* know *the isotopes did not decay faster in the past? We cannot rule it out. There would not have been any human observers making observations and recording experimental results to confirm that isotope decay 4 billion years ago occurs at the same pace and in the same way as we observe today. And because we cannot rule out that possibility, we should not assume the uniformity that is prescribed by the rate law.*

However, while fluctuating rates of isotope decay at different times might be a possibility in logical space, it does not seem to be a live option in our concrete, physical space.[37] Science assumes that nature is uniform across spacetime. Uniformitarianism is the scientific principle that the natural laws and processes that we observe today were the same in the past. Working under this principle allows scientists to study the past in diverse disciplines, including geology, forensics, astrophysics, et cetera. If uniformitarianism is false, people could not trust that the world would work the same from one second to the next. As a result, it is more likely that the way isotopes decay is the same today as millions of years ago.

Moreover, the rate at which isotopes decay is directly related to the strength of both the strong and weak nuclear forces. So, an isotope of some element decaying at some previous time at a rate different from what we observe in the present would mean that the strength of the nuclear forces would have been different at that time as well. However, an ever-so-slight difference of the strength of nuclear forces would

mean that elements could not form in the first place.[38] So, we would need some alternate story explaining how it is that the strength of nuclear forces, which bond the basic matter of the universe, could possibly change over time. Absent any reason to think that the rate of isotope decay changes over time, the fluctuating decay objection can be dismissed.

3. *The Environmental Interference Objection*. While the previous fluctuating decay objection was based on logical considerations, the environmental interference objection is somewhat more grounded in empirical observation. In our response to the previous objection, we stated that "fluctuating rates of isotope decay at different times might be a possibility in logical space, but these do not seem to be a live option in our concrete, physical space." However, that is not completely accurate. There are rare instances in which the rate at which an isotope decays can be very slightly altered as a result of being bonded to another substance. For example, it has been shown that beryllium-7, when surrounded with palladium atoms, can induce an "electron capture decay" so that the half-life changes.[39] Or we know that when isotopes are used in the body for medical treatments, the effective half-life is of importance, taking into account the biologic half-life.[40] There seem to be different half-lives for the same isotope. This gives rise to the following objection:

> *We DO see examples in which the length of an isotope's half-life will vary depending on environmental factors such as the isotope's being bonded to substances that impact the rate of decay. So, it is possible that thousands of years ago (but not more than 10,000) there were environmental factors that made the rates of isotope decay much different than what we observe today.*

The two environmental interference examples cited are two ways it seems that the half-life of an isotope can change. In the beryllium-7 example above, the state of the electrons around the isotope nucleus can be altered (as seen in bonding). The change in half-life is very small; in the beryllium-7 case, the half-life was made longer by 0.9%. Other cases in which the electron environment around the isotope can be altered, changing the half-life, have shown to be very small.[41] Other examples cited in this style of objection consider how isotopes decay in biological systems. Extensive studies are done involving isotopes used in medical applications with good reason. It is important to understand how anything taken into the human body will affect that living system. Any substance, whether it is a drug or an isotope in the body, has a half-life. A drug or an isotope each has its half-life, but when put into a living system such as a human body, metabolism and the environment can alter the kinetics of the drug or isotope. We have extensive studies noting how an isotope, say iodine-131, will decay in the human body. Whether we are considering an instance in which the electrons around the isotope nucleus are altered or an event when the isotope is put into a biological environment, these examples of radioactive decay are different than the radioactive decay considered in radiometric dating. The decay in radiometric dating is nearly constant in nature because it is in a physical, closed system without interference of a high-energy system.[42]

So, while there are some known cases of fluctuating half-lives for isotopes, it is worth noting that they are very specialized cases in which isotopes are interacting with certain forces, the influences of which can be measured and observed. Second, note that the observed rate of fluctuation is very small, and in no way is of the magnitude that could undermine the implication radiometric dating has for the age of the earth, as far as a young-earth perspective is concerned.

C. Theological Superiority Objection

The final objection we consider is motivated by the sense that theology is a superior and more reliable means of forming beliefs about the world than science, and so if theologically based beliefs contradict science, it is the science that must give way. Here the objector says something like the following:

> *Science is not the only way of forming beliefs about the world. In fact, we have the Bible which is God's word revealed to us. And because of who God is, including loving and all-knowing, we can have much more confidence in God's word than in science. Truths revealed by God are eternal and unchanging, whereas science changes all the time. As a result, it would be foolish to change or give up my Bible-based theology because of pressure from science. So, even though the science of nuclear chemistry seems to suggest an old earth, my Bible-based theology says the earth is young. So, the earth must be young.*

The objector seems to be employing an instance of the following argument schema:

The Mohler schema[43]

(a) According to science, *p*.
(b) According to my Bible-based theology, ~*p*.
(c) So, ~*p*.

This argument schema can be used for any area of science, and more importantly, for any substitution value for *p*. For example, it seems to be employed by Baptist seminary president Al Mohler in his response to the 2015 detection of gravitational waves predicted by Einstein's general theory of relativity.

On September 14, 2015, scientists at the Laser Interferometer Gravitational-Wave Observatory (LIGO) in Washington and Louisiana detected the ripple effects of two black holes colliding 1.3 billion years ago.[44] The landmark nature of this discovery earned the 2017 Nobel Prize in physics for three physicists who were instrumental in developing LIGO.[45] And more recently, physicists and astronomers were able to witness the gravitational wave effects of two neutron stars colliding around 130 million years ago.[46] In responding to the 2015 discovery, and its corollary that the universe is at least 1.3 billion years old, Mohler stated:

> Now to be candid, I don't believe that the world is 1.3 billion years old, certainly not billions of years old. I don't even believe that it is actually millions of years old. But one of the interesting things we need to note here is that the scientists who believe that, believe it because they are looking at certain patterns that, to their observation, tell them that. And what we need to note is this, if we ourselves were operating from a simply materialistic and naturalistic worldview, we would probably come to the very same conclusions.[47]

However, cautions Mohler, Christians need to approach announcements such as those coming out of LIGO from an intentional Christian worldview. From Mohler, this means being totally committed to the Bible and the historicity of events recorded in the Bible, including the biblical account of creation in the first chapters of Genesis. On Mohler's view, it is understandable for scientists who assume a secular, materialistic naturalism to interpret scientific data in a way that conflicts with the biblical account. For Mohler, secular scientists must assume that the universe tells its own explanatory story about its origins and operations. But because Christians operate according to a different "grand story," they will not be able to accept putative information that conflicts with their understanding of the universe.

Mohler's response to LIGO's detection of gravitational waves provides a template for a theologically motivated objection to the framework argument. On a Mohler-style stance, one can reject the claim that the best explanation for the success of radioisotope imaging and radioiodine therapy is the basic correctness of nuclear chemistry because it conflicts with the content of one's "biblical worldview." Appealing to the cognitive effects of sin, one can understand that fallible and finite human knowers can come to false conclusions about scientific claims and have an incomplete picture of the universe. A proponent of the Mohler stance will hold that those false conclusions are a natural consequence of secular scientists approaching their work from a secular, naturalistic worldview.

The theological superiority objection raises larger issues in epistemology in general, and religious epistemology in particular. However, as a response to the framework argument, more work needs to be done. In order for an appeal to theology to trump well-established scientific consensus, theological objectors need to either provide alternative explanations for the phenomena in question or present strong reasons for thinking that the science is incorrect. Consider the following three observations.

First, proponents of the Mohler schema need to account for the fact that many Christian scientists in physics, chemistry, and biology accept the mainstream conclusions of their secular counterparts in ways that are consistent with their Christian faith—even a faith that takes seriously the possible epistemic authority of the Bible. Thus, rejecting a scientific claim is not the only option available to someone who wishes to have a biblically informed Christian worldview.

Young-earthers who are prone to distrust mainstream science and scientists might deny what we have claimed about the possibility of there being authentic, Bible-believing Christians who deny a literal interpretation of biblical texts, an interpretation that they see as obvious. "Those 'Christians,'" the young-earther might say, "have compromised their faith in order to be accepted by their non-Christian colleagues—that is why they deny biblical truth." While it is natural to attribute negative motives to people who disagree with one's deeply held convictions (like the young-earther is doing in this hypothetical case), one should not assume that negative motives such as succumbing to professional peer

pressure are involved simply because one accepts well-supported science. Many, many Christians in science who accept an old earth exhibit all of the external markers of Christian life and witness. Moreover, the charge of possibly letting peer pressure detract from truth could just as easily be leveled at the young-earther, as evidenced by our discussion of the psychological burden and prudential objections above.

In reviewing the LIGO data, Mohler sets up a strong dichotomy between a scientific explanation on the one hand, and a Christian worldview on the other: the faithful Christian, says Mohler, must choose. However, this is a false dichotomy—at least when it comes to accepting the results of either LIGO or nuclear medicine. Recall the Mohler schema:

(a) According to science, p.

(b) According to my Bible-based theology, $\sim p$.

(c) So, $\sim p$.

In order for the second premise of the Mohler schema to justify the conclusion, one's Bible-based theology should have more support than the scientific claim it is rejecting. But why should we think that is the case? Mohler himself made much about the fact that finite and fallible creatures need to check their confidence when it comes to conclusions we draw when "relying upon the world and our powers of observation to tell us the story of the universe."[48] But surely that should apply *in excelsis* to determining the content of a Bible-based theology.

Second, most theological traditions affirm epistemic authorities other than the Bible as important for Christians. Alongside scripture, the Wesleyan Quadrilateral names reason, tradition, and experience as possible sources of epistemic authority as well. The voices of theological tradition and one's own subjective experience carry epistemic weight—defeasible, but epistemic weight nonetheless. Similarly, if reason is a gift from God to aid creatures who bear God's image in making their way, reason (including science), too, should be acknowledged even by Christians as bearing epistemic weight—again, defeasible, but weight nonetheless.

Some, like Mohler, attempt to lift the Bible (and a Bible-based theology) as an epistemic authority over reason, tradition, and experience. Doing so may provide some internal justification for the Mohler schema's subordination of science to theology. However, there is no way either conceptually or practically to appropriate whatever epistemic authority the Bible may have without also engaging reason, tradition, and experience. Looking to "the Bible as a guide" is not done in a cognitive vacuum. Drawing theological conclusions from biblical texts requires several reasoning processes. These include drawing inferences from biblical texts to the meaning of those texts. They also include applying assumptions about the nature of the text itself to conclusions about what is being said. Moreover, each person will engage the biblical text from a particular interpretive vantage point that is influenced, at least in some ways, by the milieu of both tradition and culture. And finally, reading, interpreting, and reflecting theologically on biblical texts is engaged through the lens of subjective experience. There is no such thing as "the Bible alone," if that is intended to mean isolating biblical interpretation from reason, tradition, and experience. As a result, the biblical text and a Bible-based theology should not be placed in stark opposition to, say, reason. Rather, one should attempt to put all epistemic voices we have at our disposal in conversation with each other in order to determine how they can speak in harmony.

The voice of the Bible cannot speak in isolation—interpreting the Bible always brings the voices of reason, tradition, and experience along for the ride. Nor should the voice of the Bible be given the loudest volume, shouting and drowning out the others—at least if one wants to believe true things about most empirical phenomena. Science is built to do some things very well. The precision with which we are now able to understand events of cosmic magnitude such as those detected at LIGO, or the subatomic properties of radioactive decay which yield applications in medicine unimaginable a generation ago, should give theological objectors pause before easily dismissing scientific results merely because they conflict with one's version of biblical theology.

And third, the theological objector still owes us an alternative explanation for the success of medical applications such as radioisotope imaging and radioiodine therapy. We have claimed that the best explanation for the success of those applications is that the framework of nuclear chemistry that makes those applications possible is, in the main, correct. Until or unless the theological objector can give us a better explanation, the framework argument remains untouched.

Conclusion

Scientific understanding of the properties and structure of the atom provides the well-confirmed framework of nuclear chemistry. Nuclear medicine is the application of nuclear chemistry in service of medical diagnosis and treatment. Two such widely practiced applications are radioisotope imaging and radioiodine therapy, the success of which is best explained by the accuracy of the framework of nuclear chemistry. This framework also yields the application of radiometric dating of objects, according to which the earth is at least 4.6 billion years old. ♥

Notes

[1]Bodie E. Douglas and Darl H. McDaniel, *Concepts and Models of Inorganic Chemistry* (Waltham, MA: Blaisdell Publishing, 1965), 338.

[2]Energy emission in phosphorescence requires electrons to absorb energy from an external source prior to emitting energy in the form of visible light.

[3]Eric R. Scerri discusses how chemists think of "elements," whether that is "as simple substances that can be isolated and whose properties can be examined experimentally" or "as unobservable basic substances." Eric R. Scerri, "Some Aspects of the Metaphysics of Chemistry and the Nature of the Elements," *HYLE – International Journal for Philosophy of Chemistry* 11, no. 2 (2005): 135. The Periodic Table of Elements has changed over time, and there is still some debate about the arrangement of elements. See ___, *The Periodic Table: Its Story and Its Significance* (New York: Oxford University Press, 2006).

[4]The neutrons and protons are found in the nucleus of the atom while the electrons surround the nucleus in spaces called shells. Most of the mass of an atom is made up by the protons and neutrons that are packed together in the nucleus. Protons have a positive charge, electrons have a negative charge, and neutrons are neutral in charge. All neutrons have the same mass, regardless of which element's nucleus it is located in. The same is true for protons and electrons.

[5]Atoms combine to form molecules; some molecules are compounds and are composed of atoms of more than one element.

[6]Marion Clyde Day Jr. and Joel Selbin, *Theoretical Inorganic Chemistry* (New York: Reinhold Publishing, 1962), 369.

[7]Isotopes are called by their element name and mass, e.g., Carbon-12, with 6 protons and 6 neutrons.

[8]For example, when considering the elements present in paper, there is a certain amount of carbon. All materials that were once alive, even plants that make up paper, carry carbon. There are fifteen known carbon isotopes. Therefore, a sample of paper could be made up of different isotopes of carbon (but not all fifteen isotopes since many of them are unstable): this means that the atoms of carbon in the paper will probably have different numbers of neutrons.

[9]A rate law describes the relationship between the reaction rate (i.e., how fast reactants are converting into products) and the concentrations of the reactants and products. Rate laws can be experimentally determined for all chemical reactions and nuclear reactions. See Rate Laws, *LibreTexts* (2016), last updated June 23, 2019, https://chem.libretexts.org/Core/Physical_and_Theoretical_Chemistry/Kinetics/Rate_Laws.

[10]Radioisotopes decay following a first order rate law. First order reactions have rates that are dependent on the concentration of one reactant and follow exponential decay. The half-life of a first order reaction is not dependent on the initial amount of reactant (in this case, the parent isotope). There are other types of rate laws (e.g., second order), but radioisotopes decay by first order only. See "First-Order Reactions," *LibreTexts* (2017), last updated June 5, 2019, https://chem.libretexts.org/Core/Physical_and_Theoretical_Chemistry/Kinetics/Reaction_Rates/First-Order_Reactions.

[11]Thanks to an anonymous reviewer, it should be pointed out that the daughter isotope will increase to 100% only if it is a stable, not radioactive, isotope.

[12]While figures 1 and 2 are original, the graphs follow a standard way of representing half life. See, for example, David McConnell and David Steer, *The Good Earth: Introduction to Earth Science*, 4th edition (New York: McGraw Hill, 2018), 230.

[13]NHS England Analytical Services (Operations), "Diagnostic Imaging Dataset: Annual Statistical Release 2013/14," November 6, 2014, https://www.england.nhs.uk/statistics/wp-content/uploads/sites/2/2014/06/Annual-Statistical-Release-2013-14-DID-pdf-1118KB.pdf, 26.

[14]Ibid.

[15]"Radioisotopes in Medicine," World Nuclear Association, last updated February 2019, http://www.world-nuclear.org/information-library/non-power-nuclear-applications/radioisotopes-research/radioisotopes-in-medicine.aspx.

[16]Jayanth Keshavamurthy et al., "Cholescintigraphy," *Radiopaedia,* 2017, https://radiopaedia.org/articles/cholescintigraphy.

[17]As opposed to a high-energy beta emission. See "Radioisotopes in Medicine."

[18]Seven half-lives for Tc-99m is roughly 42 hours with 0.78% of the parent isotope left. Technetium-99 has a half-life of 211,000 years. There is no gamma ray emission during that decay into ruthenium-99. While the half-life of radioisotopes (called the physical half-life) can change slightly when placed in a biological environment (called the biological half-life), the effective half-life of Tc-99m is even less than its physical half-life. See "Technetium 99: A Pure Gamma Emitter Widely Used in Nuclear Medicine," *Radioactivity.eu.com,* February 20, 2018, http://www.radioactivity.eu.com/site/pages/Technetium_99.htm; and "Biological Half-Life," *EDP Sciences* (February 20, 2018), http://hyperphysics.phy-astr.gsu.edu/hbase/Nuclear/biohalf.html.

[19]"Radioisotopes in Medicine."

[20]The chain reaction that describes Tc-99m is as follows:

Tc-99m with 43 protons and 56 neutrons gives off gamma radiation and decays into Tc-99 (same number of protons and neutrons, but they are no longer in their excited state).

Tc-99 decays into ruthenium-99 which has 44 protons and 55 neutrons.

[21]"Information for Patients Administered Radioactive Iodine (I-131)," *U.S.NRC (United States Nuclear Regulatory Commission)* (2017), last updated May 28, 2019, https://www.nrc.gov/materials/miau/patient-release.html.

[22]Edward B. Silberstein et al., "The SNM Practice Guideline for Therapy of Thyroid Disease with ^{131}I 3.0*," *Journal of Nuclear Medicine* 53, no. 10 (2012): 1–19.
[23]"Radiometric Time Scale," *USGS*, last updated June 13, 2001, https://pubs.usgs.gov/gip/geotime/radiometric.html.
[24]H. E. Gove et al., "Radiocarbon Dating with Tandem Electrostatic Accelerators," *Radiocarbon* 22, no. 3 (1980): 785–93.
[25]"Radiometric Time Scale." We want to note that the earliest study on the mummy wrappings was done prior to the 1960s before a more accurate half-life of C-14 was established. Gove et al., "Radiocarbon Dating with Tandem Electrostatic Accelerators," measured and calculated the age of the mummy wrappings as 2,200 years old based on the then current data that C-14 had a half-life of 5,568 years.
[26]Hot spots have the technical name "mantle plumes."
[27]"Evolution of Hawaiian Volcanos," *USGS*, last updated April 12, 2017, https://volcanoes.usgs.gov/observatories/hvo/hawaiian_volcanoes.html.
[28]Argon is a noble gas.
[29]Scientists are aware that this is not a perfect process and that some argon does get left in the sample at solidification. Methods have been developed to correct for any argon that was present before daughter argon was formed. See Ian McDougall and T. Mark Harrison, *Geochronology and Thermochronology by the 40Ar/39Ar Method* (New York: Oxford University Press, 1988).
[30]"Evolution of Hawaiian Volcanos."
[31]Aiden P. Gregg, Nikhila Mahadevan, and Constantine Sedikides, "The SPOT Effect: People Spontaneously Prefer their Own Theories," *Quarterly Journal of Experimental Psychology* 70, no. 6 (2017): 996–1010.
[32]This is not an exhaustive list; for ease of simplicity, we have carved this region of logical space with broad strokes. Subdividing the categories in terms of having/not having strong support fails to account for having support of varying strengths or having no support whatsoever. We could certainly accommodate what we say in the sequel to take those nuances into account and nothing substantive would be changed—the main epistemological points carry through.
[33]"~p" is shorthand for "it is not the case that p."
[34]Though, depending of course on the circumstances which give rise to *S*'s belief that ~*p*, it seems possible for *S* to have a measure of justification for ~*p* given that she has no strong evidence for *p*.
[35]Stathis Psillos, *Scientific Realism: How Science Tracks Truth* (London, UK: Routledge, 1999), 108.
[36]See Eric R. Scerri, "Just How Ab Initio Is Ab Initio Quantum Chemistry?," *Foundations of Chemistry* 6, no. 1 (2004): 93–116, https://doi.org/10.1023/B:FOCH.0000020998.31689.16 .
[37]Except in rare circumstances to be discussed in the next objection.
[38]Note that the precise and limited values that could be had by the nuclear forces in order to give rise to a life-permitting universe is often a feature of fine-tuning arguments.
[39]B. Wang et al., "Change of the ^{7}Be Electron Capture Half-Life in Metallic Environments," *The European Physical Journal A – Hadrons & Nuclei* 28, no. 3 (2006): 375–77.
[40]Silberstein et al., "The SNM Practice Guideline for Therapy of Thyroid Disease with ^{131}I 3.0*."
[41]Christopher S. Baird, "Can the Decay Half-Life of a Radioactive Material Be Changed?," *Science Questions with Surprising Answers*, April 27, 2015, http://wtamu.edu/~cbaird/sq/2015/04/27/can-the-decay-half-life-of-a-radioactive-material-be-changed/. Physics gives an accessible general overview about the different ways that electrons around the isotope can be altered, changing the half-life.
[42]Thanks to an anonymous reviewer, it should be pointed out that even in the cases in which isotopes are bombarded by high energy particles, these cases are not relevant because the isotopes affected are not used for dating. These cases are also rare and well understood. For a more detailed discussion, see Roger C. Wiens, "Radiometric Dating: A Christian Perspective," *The American Scientific Affiliation*, revised 2002, http://www.asa3.org/ASA/resources/Wiens.html.
[43]Named for Albert Mohler, the president of Southern Baptist Theological Seminary for reasons that will become apparent below.
[44]Adrian Cho, "Gravitational Waves, Einstein's Ripples in Spacetime, Spotted for First Time," *ScienceMag.org*, February 11, 2016, http://www.sciencemag.org/news/2016/02/gravitational-waves-einstein-s-ripples-spacetime-spotted-first-time.
[45]"Press Release: The Nobel Prize in Physics 2017," *NobelPrize.org* [Nobel Media AB 2019, August 7, 2019], https://www.nobelprize.org/prizes/physics/2017/press-release/.
[46]Adrian Cho, "Merging Neutron Stars Generate Gravitational Waves and a Celestial Light Show," *ScienceMag.org*, October 16, 2017, http://www.sciencemag.org/news/2017/10/merging-neutron-stars-generate-gravitational-waves-and-celestial-light-show.
[47]Albert Mohler, "The Briefing 02-12-16," *AlbertMohler.com*, February 12, 2016, https://albertmohler.com/2016/02/12/the-briefing-02-12-16/.
[48]Ibid.

Philip J. Senter

Article

Leviathan, Behemoth, and Other Biblical *Tannînim*: Serpents, Not Dinosaurs

Philip J. Senter

An extensive and growing body of young-earth creationist literature treats the Bible as a science textbook and claims that the Bible mentions dinosaurs and other Mesozoic reptiles. Such literature equates the Hebrew term tannîn (often translated "dragon") with dinosaurs and/or Mesozoic marine reptiles. Accordingly, it misidentifies the tannîn Leviathan as a literal fire-breathing dinosaur or marine reptile. It also misidentifies the monster Behemoth as a dinosaur. These misidentifications have been incorporated into grade-school science textbooks that teach students that ancient reptiles breathed fire.

Numerous clues from the Bible and other ancient sources falsify those misidentifications. Such clues reveal that tannîn means "serpent," that the ancient Hebrews envisioned Leviathan (and possibly Behemoth) metaphorically as a serpent, and that Leviathan's fire-breathing is not literal but metaphorical. Leviathan and Behemoth are not natural animals, but rather supernatural entities with important roles in ancient Hebrew eschatology.

The Bible is not a science textbook. Nevertheless, advocates of the young-earth creationist (YEC) worldview treat it as one. According to the YEC view, the biblical book of Genesis is an accurate record of past events that took place exactly as Genesis describes them, so its descriptions of events can be treated as scientific data. This view rejects the abundant physical evidence that organic evolution has occurred and that billions of years have passed.[1] It claims that the earth was created approximately 6,000 years ago in accordance with the biblical timeline, and that all kinds of organisms were independently created during a single week at the beginning of that time span, in accordance with the wording of Genesis.[2]

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A corollary of the YEC view is that humans and dinosaurs once coexisted, because they were created during the same week. To support that corollary, an enormous and ever-growing body of YEC literature claims that the Bible mentions dinosaurs, pterosaurs, and other reptiles that are known today only from Mesozoic fossils. Below, for concision, that position is called the DIBV (the Dinosaurs-In-the-Bible View) and the authors of literature promoting it are called DIBV authors. DIBV literature has existed since the nineteenth century, but its publications have exploded in number and popularity in the most recent five decades. In the current century, the DIBV has even been incorporated into some grade-school science textbooks.[3]

DIBV authors frequently cite Job 40 and 41, which respectively describe the monstrous beings named בְּהֵמוֹת (*Bᵉhēmōth*, anglicized as "Behemoth") and לִוְיָתָן (*Livyāthān*, anglicized as "Leviathan").

Elsewhere, the Hebrew scriptures identify Leviathan as a תַּנִּין (*tannîn*) (Ps. 74:13–14; Isa. 27:1), a word that the King James Version of the Bible usually translates as "dragon."[4] Most DIBV literature proposes that Behemoth is a dinosaur and that Leviathan and other biblical *tannînim* (the plural of *tannîn*) are dinosaurs, plesiosaurs, or mosasaurs. The plesiosaurs were Mesozoic marine reptiles that included long-necked, small-headed forms and short-necked, large-headed forms. The mosasaurs were large marine lizards of the Mesozoic Era, with elongate bodies. Both groups had limbs that were modified into flippers.

In contrast to DIBV authors, many other past and present commentators consider Behemoth a hippopotamus or elephant.[5] They consider *tannîn* to be the ancient Hebrew word for a species of mythical sea monster,[6] or for crocodiles or whales, and identify Leviathan as such.[7] As I will show below, all of the above interpretations of Behemoth, Leviathan and the word *tannîn* are incorrect. The word *tannîn* means "serpent," and Behemoth and Leviathan are malevolent supernatural entities whom the ancient Hebrews envisioned as a pair of serpents, much as the devil is envisioned as a serpent in Revelation 12:9 and 20:2.

DIBV Conceptions of Behemoth, Leviathan, and the *Tannîn*

The misidentification of Behemoth and Leviathan as dinosaurs began even before the word "dinosaur" was coined. In 1824, William Buckland published the earliest scientific description of a dinosaur, the carnivore *Megalosaurus*.[8] Gideon Mantell described the teeth of the herbivorous dinosaur *Iguanodon* in 1825.[9] In 1833, Mantell described more of its skeleton,[10] in addition to the skeleton of the armored dinosaur *Hylaeosaurus*.[11] In 1842, Sir Richard Owen gave the name Dinosauria to the group of animals that the reptilian trio represented.[12] By then, in an 1835 article, the English politician Thomas Thompson had already misidentified *Megalosaurus* and *Iguanodon* as the biblical Leviathan and Behemoth.[13] Soon thereafter, the surgeon Charles Burnett endorsed Thompson's misidentifications in publications of his own.[14] After that, the DIBV was quiescent for several decades. A few YEC authors argued that humans and Mesozoic reptiles were contemporaries, but they did so without claiming that such reptiles were mentioned in the Bible.[15]

The DIBV awakened with great vigor after the 1961 publication of *The Genesis Flood* by John Whitcomb and Henry Morris.[16] Whitcomb and Morris suggested that after the Flood, dinosaurs "may have persisted for a long time, possibly accounting for the universal occurrence of 'dragons' in ancient mythologies."[17] Subsequent YEC authors also suggested that human encounters with dinosaurs were the inspiration for dragon legends, but at first they did so without making the connection with biblical dragons.[18]

Frederick Beierle made that connection in his 1974 book *Giant Man Tracks*. Therein, he suggested that Behemoth was a dinosaur and that Leviathan was a "swimming dinosaur,"[19] possibly a reference to plesiosaurs and/or other Mesozoic marine reptiles, which nonspecialists often mistake for dinosaurs. In the 1975 book *The Great Dinosaur Mistake*, Kelly Segraves also suggested that Behemoth and Leviathan were dinosaurs, without specifying what kind.[20]

In the 1976 book *In Six Days*, Charles McGowen went further, specifying that Behemoth was most likely a sauropod.[21] Sauropods, herbivores with small heads on long necks, were the largest dinosaurs. After McGowen's assertion, the YEC literature exploded in publications claiming that the description of Behemoth in Job 40 indicated a sauropod. That explosion included children's books,[22] in addition to books and journal articles written for adults,[23] and it now includes seventh-grade biology textbooks from Bob Jones University Press.[24]

The identification of Behemoth as a dinosaur is founded mainly on misinterpretations of the Hebrew text of Job 40. The most oft-repeated of those misinterpretations is that the tail of Behemoth is "like a cedar,"[25] a misconception that began with Thomas Thompson's 1835 article. A second misinterpretation that began with that article is that the phrase "chief of the ways of God" (Job 40:19) means "the largest land animal that God created."[26] As I will show below, the Hebrew text of Job 40 implies neither that Behemoth's tail is like a cedar nor that he is a large animal.

Behemoth is associated with watery habitats (Job 40:20–23), which several DIBV authors mistake for the typical habitat of sauropods.[27] This is understandable, because for decades sauropods were mistakenly thought to have been too heavy to support their own

weight on land. However, it is now known that sauropod dinosaurs were terrestrial, not aquatic. Their skeletons are constructed to support weight out of water,[28] their footprints are found only in sediments that were emergent or under very shallow water,[29] and their skeletons, nests, and tracks are often found in sediments that indicate semi-arid environments.[30]

Job 41 locates Leviathan in water. Accordingly, in his 1977 children's book *Dinosaurs: Those Terrible Lizards*, Duane Gish identified Leviathan as a lambeosaurine.[31] The lambeosaurines were crested members of the Hadrosauridae, the family of wide-snouted herbivorous dinosaurs that are commonly nicknamed duckbills. The duckbills were once thought to be aquatic, because a specimen with mineralized soft tissues appeared to have webbed fingers.[32] Every other aspect of duckbill anatomy indicates terrestrial habits, and in 1986 the "web" was finally recognized as a digital pad, such as terrestrial animals have beneath their palms.[33] However, the view of the duckbills as aquatic dinosaurs was still predominant in 1977. Taking the biblical description of Leviathan's fire-breathing (Job 41:18–21) literally, Gish proposed that the hollow crests of lambeosaurines housed a fire-production mechanism.[34] DIBV authors in each subsequent decade followed Gish's lead, asserting that lambeosaurine crests may have been involved in producing fire.[35] In the twenty-first century, that assertion made its way into seventh-grade biology textbooks from Bob Jones University Press.[36]

Other DIBV authors disagreed with Gish's equation of Leviathan with lambeosaurines. Some considered Leviathan a fire-breathing reptile without specifying what kind.[37] Others proposed that Leviathan was a fire-breathing dinosaur without specifying that it was a lambeosaurine.[38] One proposed that it was a marine member of the Theropoda, the carnivorous dinosaur taxon that includes *Megalosaurus* and the famous *Tyrannosaurus rex*[39]—and which has no known marine members. Another specified that Leviathan was *T. rex* itself,[40] despite the lack of any known evidence of aquatic habits in *T. rex* or any other non-avian dinosaur at the time of the publication. Soon after a 2014 study by mainstream paleontologists interpreted the anatomy of the theropod dinosaur *Spinosaurus* as indicative of semiaquatic habits,[41] one DIBV author proposed that Leviathan was *Spinosaurus*.[42]

Various DIBV authors also suggested nondinosaurian Mesozoic reptiles as candidates for Leviathan. Some, without suggesting literal fire-breathing, proposed that Leviathan may have been a plesiosaur[43] or a mosasaur.[44] Others proposed that Leviathan was a fire-breathing plesiosaur[45] or a fire-breathing mosasaur.[46] In 2005, one author identified *Sarcosuchus*, a gigantic Cretaceous relative of crocodilians, as Leviathan and proposed that its enlarged nostrils housed a fire-production mechanism.[47] Several subsequent DIBV authors repeated that suggestion.[48] The authors of one children's book identified Leviathan as a possible mosasaur but then inexplicably extended Leviathan's fire-breathing to terrestrial dinosaurs: "So it is possible that some dinosaurs like *Dilophosaurus* could spit venom or even some type of 'fire.'"[49]

Leviathan's fire-breathing (Job 41:18–21) should not be taken literally.[50] Fire-breathing or fire-spitting is an ancient Hebrew idiom that was used as a figure of speech for intent to harm. An angry God emits fire from his mouth and smoke from his nostrils in Psalm 18:8, and in verse 3 his angry voice is fire and hailstones. Military aggression by the nation of Judah is described as fire-breathing in Isaiah 33:11. In Revelation 11:5, two human witnesses consume their enemies with fire from their mouths. Proverbs 16:27 and 26:23 describe insincere words as fire from one's mouth or lips.

The late twentieth-century explosion of DIBV literature began incorporating discussion of the Hebrew term *tannîn* in the 1980s. Opinions differed among DIBV authors as to what sort of reptile the *tannîn* is. Noting that various biblical passages speak of *tannînim* in the sea,[51] some DIBV authors identified *tannînim* as marine reptiles,[52] often specifically plesiosaurs[53] or mosasaurs.[54] Others noted that some biblical passages speak of *tannînim* in terrestrial environments[55] and proposed that the term includes both marine reptiles and terrestrial dinosaurs.[56] One author proposed that the *tannînim* additionally included the pterosaurs,[57] the flying reptiles of the Mesozoic.

Tannîn: Evidence That It Means "Serpent"

The Hebrew scriptures provide ample evidence that *tannîn* is one of several ancient Hebrew words for snakes. As shown in the next sections, objections to

tannîn as a word for "serpent" are easily answered, and biblical references to a *tannîn* or *tannînim* in the sea are references not to literal sea creatures but to supernatural entities that were metaphorically envisioned as serpents imprisoned beneath the waters.

The Hebrew scriptures use both *tannîn* and *nāḥāsh* as a general term for snakes, rather than for a particular category or species of snake. In contrast, ancient Hebrew terms such as אֶפְעֶה (*ʾephʿeh*), פֶּתֶן (*pethen*), and צֶפַע (*tsephaʿ*) refer specifically to venomous species.[58] In most prose passages, the word נָחָשׁ (*nāḥāsh*) is used instead of *tannîn*,[59] whereas the word *tannîn* is used about as often as *nāḥāsh* in poetic (including prophetic) passages[60] and is rarely used in prose passages.[61] *Nāḥāsh* is therefore roughly equivalent to the English word "snake" and *tannîn* to the English word "serpent."

One of the many lines of evidence that point to *tannîn* as a term for serpents is the wording of Exodus 7. In verses 8–12, Aaron's staff becomes a *tannîn*, and in verses 15–21, God calls Aaron's staff "the staff that had become a *nāḥāsh*," which indicates that the words *nāḥāsh* (snake) and *tannîn* are equivalent. Similarly, Isaiah 27:1 calls Leviathan a *tannîn* and a *nāḥāsh*, further indicating that the two terms are equivalent.

A second line of evidence that *tannîn* is equivalent to "serpent" is that it is usually translated as *drakōn* in the Septuagint[62] and *draco* in the Vulgate.[63] *Drakōn* is "serpent" in ancient Greek, and *draco* is "serpent" in Latin. A *drakōn*/*draco* is present in a plethora of ancient Greek and Roman myths, and the creature is depicted as a snake in all ancient Greek and Roman art that depicts such myths.[64] In ancient Greek literature, *drakōn* was often used interchangeably with ὄφις (*ophis*), the generic ancient Greek term for "snake." Some ancient authors even called a serpent a *drakōn* on one line and an *ophis* on the next. For example, this occurs in Homer's *Iliad*, Hesiod's *Theogony*, Apollodorus' *Library*, and the New Testament book of Revelation.[65] After the time of Aristotle, there was a general tendency among Greek-speakers to use the term *ophis* for snakes in ordinary contexts and to use *drakōn* for snakes in religious or mythical contexts.[66] Much ancient Greek usage of *ophis* versus *drakōn* was therefore analogous to the English usage of "snake" versus "serpent."

In Isaiah 27:1, the Septuagint twice translates *tannîn* as *ophis*, the generic ancient Greek word for "snake." In both cases in the same verse, the Vulgate translates *tannîn* as *serpens*, a generic Latin word for "snake." Likewise, in Exodus 7:9 and 7:10, the Vulgate translates *tannîn* as *coluber*, another generic Latin word for "snake."

The foregoing is sufficient to confirm that *tannîn* means "serpent," but other lines of evidence provide further support for that confirmation. The *tannîn* is described as venomous (Deut. 32:33) and scaly (Ezek. 29:3–4), attributes that are consistent with snakes. En-Rogel, the spring near Jerusalem that was associated with the local landmark called the "Stone of the Snake (Zoheleth)" (1 Kings 1:9), was also called the "Spring of the *Tannîn*" (Neh. 2:13).[67]

Further confirmation of the equivalence of *tannîn* with "serpent" is found in the pairing of *tannîn* with other Hebrew terms for snakes in poetic couplets. Ancient Hebrew literature frequently contains couplets in which the author makes a statement and then repeats it with different words for things in the same category. For example, to say "the teeth of lions" twice, the couplet "the *shen* of an *ʾărî*, the *məthallaʿah* of a *labî*" (Joel 1:6) pairs two words for teeth (*shen*, *məthallaʿah*) and two words for lions (*ʾărî*, *labî*). Similarly, the couplet "rise like a *labî* and lift himself like an *ʾărî*" (Num. 23:24) pairs "rise" with "lift" and *labî* (lion) with *ʾărî* (lion). Such couplets do not always pair two words for exactly the same thing, but they usually pair words for things that are in the same category. For example, some couplets and triplets pair wolves with lions and/or leopards (members of the large, mammalian predator category) and pair sheep with goats and/or cattle (members of the hoofed mammal category) (Isa. 11:6, 65:25; Jer. 5:6). The couplet "you shall tread upon the lion and the *pethen*, the young lion and the *tannîn* you shall trample underfoot" (Ps. 91:13) pairs *tannîn* with *pethen*. So does the couplet "the poison of *tannînim*, the cruel venom of *pethenim*" (Deut. 32:33). Biblical references show that the *pethen* was venomous (Deut. 32:33; Job 20:14, 20:16; Isa. 11:8) and was used by snake charmers (Ps. 58:4); these references suggest cobras (members of the genus *Naja*). A triplet in Isaiah 27:1 pairs *tannîn* with *nāḥāsh* (snake): "In that day, the Lord … shall punish Leviathan the crooked *nāḥāsh*, Leviathan the twisted *nāḥāsh*, and shall slay the *tannîn* that is in the sea." These examples show that the *tannîn* was considered to belong to the same category of thing as a *pethen* or a *nāḥāsh*. That is, a *tannîn* is a snake.

The Hebrew scriptures make much mention of *tannînim* in the sea (Gen. 1:21; Ps. 74:13; Isa. 27:1, 51:9–10; Ezek. 32:2), which has led some authors to conclude that the term refers to a species of mythical sea monster.[68] However, that conclusion is mistaken.[69] As shown in the next section, ancient Hebrew writings speak of a pair of supernatural entities that are imprisoned beneath the waters, and it metaphorically calls them "serpents" (*tannînim*) in the same way that the author of the biblical book of Revelation metaphorically calls the devil a *drakōn* (serpent) and an *ophis* (snake) (Rev. 12:9, 20:2).

The Hebrew word for "jackal" (תַּן: *tan*) is similar to *tannîn*. It is therefore possible that some overlap exists in the usage of the two words in the Hebrew scriptures. Accordingly, some authors accept "jackal" as an alternate translation for *tannîn* in some passages.[70] For example, Micah 1:8 characterizes the *tannîn* as an animal that howls, which is more consistent with jackals than serpents, because the latter lack vocal cords and therefore cannot howl. Similarly, Lamentations 4:3 characterizes the *tannîn* as an animal that suckles its young, which is more consistent with jackals than serpents. However, some of the alleged jackal passages are consistent with serpents. For example, according to English translations of Isaiah 13:22, *tannînim* will "cry" or "howl" in the houses of Babylon after its impending destruction. The verb that Isaiah uses here is עָנָה (ʿanah), which means to reply to a question or to provide testimony.[71] Isaiah is therefore not saying that *tannînim* vocally howl but that their presence in Babylon's houses will testify to its destruction. It is also worth considering that the *tannîn* that suckles its young in Lamentations 4:3 is part of a list of ways in which the world has been turned topsy-turvy (Lam. 4:1–8): gold has stopped being shiny, neatly collected gems have been scattered, mothers do not feed their children, the rich are starving, and consecrated Nazarites have become impure.[72] The context of the statement that the *tannîn* suckles its young is therefore consistent with *tannînim* as creatures that did not normally suckle their young. However, even if the word *tannîn* does mean "jackal" in those passages, it should be noted that jackals are not dinosaurs. It should further be noted that even if the *tannîn* in Lamentations 4:3 is not a serpent, it is also not a dinosaur, because as reptiles, dinosaurs did not suckle their young.[73]

Some of the alleged jackal passages use *tannîm* instead of *tannînim* as the plural of *tannîn*,[74] and some scholars accept *tannîm* as the plural of "jackal" in such passages.[75] However, some of the passages that use the word *tannîm* are clearly referring to serpents. For example, Ezekiel 29:3 and 32:2 figuratively refer to Egypt as *tannîm* in the waters. That figure of speech does not apply to jackals, and it echoes the characterization in other passages (Isa. 27:1, 51:9) of Egypt as a *tannîn* in the waters, with context that clearly shows that *tannîn* means "serpent" in those passages. Moreover, the Septuagint and Vulgate usually[76] translate *tannîm* as *drakōn* and *draco*. It therefore stands to reason that *tannîm* is a short version of *tannînim* and can mean "serpents." Even if it can also mean "jackals," it is worth repeating that jackals are not dinosaurs.

In Job 41:12, in reference to the *tannîn* Leviathan, the narrator states, "I will not conceal his *bad* (בַּד), his strength and comely form." The Hebrew word *bad* in Job 41:12 is often mistranslated "limbs" in English-language Bibles; this seems to contradict the interpretation of Leviathan as a serpent. However, *bad* is a broader term than "limbs." It refers to body parts in general. "I will not conceal …" is a poetic way to say "I shall proclaim …" Verse 12 is therefore a poetic way for the narrator to announce that he is about to expound upon Leviathan's body parts and his strength. After completing the couplet, the narrator does exactly that. In verse 13, the couplet is completed by coupling verse 12's "I will not conceal his body parts" (which speaks of a figurative nonconcealing of the body) with "Who can see his clothing?" (speaking of a literal nonconcealing of his body), and then by coupling "his strength and comely form" with "Who can approach him with a bridle?" (which brings strength into the nonclothing theme by implying that Leviathan is too strong to be clothed with an item that suggests he can be subdued). The following verses expound upon Leviathan's body parts: teeth (verse 14), scales (verses 15–17), eyes (verse 18), mouth (verse 19), nostrils (verse 20), mouth again (verse 21), neck (verse 22), flakes of muscle (מַפָּל: *mappāl*: flakes of flesh, as in the flaky muscle units of fishes and reptiles) (verse 23), and heart (verse 24). This exposition on Leviathan's body parts is consistent with "I will not conceal his *bad*" as a reference to an upcoming exposition on body parts in general. It is inconsistent with "I will not conceal his *bad*" as a reference to an upcoming exposition on limbs, because the narrator's exposition on body parts does not include limbs. Furthermore, the conspicuous lack

of limbs in this list of body parts supports the interpretation of Leviathan as a serpent.

As will be shown below, Leviathan is a supernatural being who is metaphorically described as a serpent. That Leviathan was represented as a serpent is confirmed by Isaiah 27:1, which calls Leviathan not only a *tannîn* (serpent) but also a *nāḥāsh* (snake). It is further confirmed by the rendering of the name "Leviathan" as *drakōn* (serpent) in the Septuagint[77] and *draco* (serpent) in the Vulgate,[78] and by the probable identity of the *nāḥāsh* of Amos 9:3 as Leviathan (see below). Leviathan is described as covered in scales (Job 41:15) and having a toothy mouth (Job 41:14), attributes that are consistent with a serpent.

Pre-DIBV Conceptions of Leviathan and Behemoth

Leviathan is a Hebrew cognate of *Ltn* (Litan or Lotan), the name of a being mentioned in a Canaanite myth recorded on tablets from Ugarit. The inscriptions on the tablets were written between 1400 and 1200 BC.[79] According to the myth, an assembly of gods offered the god Baal to Yam (the sea) as a prisoner, but Baal fought and defeated Yam. Anat, Baal's sister, also fought and defeated Yam. As punishment for defeating the sea, Baal was swallowed by Death, but Anat later defeated Death to rescue Baal.[80] *Ltn* is mentioned in two parts of the myth. In a speech to emissaries of Baal after the defeat of the sea, Anat mentions that she had defeated *Ltn*. When Death summons Baal to be swallowed, Death mentions that Baal had defeated *Ltn*. In those speeches, *Ltn* is described as a *btn* (snake) and a *tnn* (serpent),[81] which are cognates of the Hebrew *pethen* and *tannîn*. *Ltn* is further described in those speeches as seven-headed and is called a twisting/coiling/writhing serpent, a fleeing serpent,[82] and an encircler.[83]

It is sometimes presumed that *Ltn* is an entity other than the sea, a mere henchman of Yam.[84] However, as previous authors have noted,[85] it is more likely that *Ltn* the serpent is an epithet of the sea itself, a name interchangeable with Yam. The epithet "encircler" supports this idea, for it appears to refer to the ancient concept of the sea as a river that encircles the globe.[86] In numerous passages elsewhere in the myth, the sea is called Yam (Sea) on one line and River on the next.[87] In Anat's speech to the emissaries of Baal, she says that she has defeated the Sea, the River, the *tnn*, the coiling *btn*, the encircler with the seven heads.[88] The structure of that passage suggests that all those epithets refer to a single entity: the sea. *Ltn* the serpent, therefore, was originally a metaphor for the sea.

Ancient Hebrew literature retains *Ltn,* the multi-headed *tnn,* as Leviathan the multi-headed *tannîn*, but the Hebrews changed the story.[89] Scholars have long recognized that Hebrew cosmology incorporates elements of other Near Eastern cosmologies in such a way as to turn them on their heads. The creation narrative of Genesis 1 presents the earth, sea, and heavenly bodies as nondivine entities created by a single God, in contradistinction to other Near Eastern cosmologies that present the earth, sea, heavenly bodies, and forces of nature as deities that emanate from each other.[90] Hebrew kings are listed as nondivine descendants of a nondivine human that the one God created, in contradistinction to other Near Eastern genealogies that list kings as divine heirs or manifestations of gods.[91] The general theme in Hebrew alterations of other nations' narratives is that there is but one God, who rules over everything, and the other entities that other nations consider divine are not divine. Accordingly, the Hebrews altered the *Ltn* myth along similar lines. Whereas the Canaanite myth represents the sea as a deity in the form of the serpent *Ltn*, the Hebrews described the sea as a nondivine container for the nondivine serpent Leviathan. Whereas the Canaanite myth portrays the sea and his slayer as deities and brothers whose father is another deity, the Hebrews portrayed Leviathan as both created and slain by the one God. Whereas Canaanite myth portrays the slaying of *Ltn* as part of the story of the annual fertility cycle, the Hebrews portrayed the slaying of Leviathan as an eschatological event.

The Hebrew scriptures preserve fragments of the Hebrew version of the Leviathan story. In Isaiah 27:1, God slays Leviathan, who is described as a *tannîn* within the sea (not a *tannîn* who is the sea). In Psalm 104:26, the psalmist says that Leviathan is within the sea and is mocked by God (a way to express that God defeats Leviathan). In Psalm 74:14, the psalmist mentions God's breaking of the plural heads of Leviathan (cf. the seven-headed *Ltn*), using it as a metaphor for the drowning of the Egyptian army after the parting of the sea during the exodus. In Amos 9:3, God says poetically that if the wicked flee even to the bottom of the sea, God will command

"the snake" (*ha-nnāḥāsh*) there to bite them. The use of the definite article suggests that God has in mind a specific snake in the abyss, plausibly Leviathan.

The *tannînim* in the waters in Genesis 1:21 and Psalm 74:13 may be Leviathan alone, in which case the plural noun "*tannînim*" is an intensive plural: a way to call Leviathan a mighty "Serpent" rather than a mere "serpent" (just as the intensive plural Ĕlōhîm is used in Genesis 1 to call the deity "God" rather than a mere "god"). Another possibility is that the plural *tannînim* in the waters in Genesis 1:21 and Psalm 74:13 are meant as Leviathan and a second serpent, the former in the sea and the latter beneath the fresh water on land (cf. Job 40:21–22). If the word *tannînim* in those two passages was originally meant as an intensive plural reference to Leviathan alone, then the understanding of its meaning as a reference to two serpents is a later development.

Three post-Septuagint works (Enoch 60:4–23; 4 Esd. 6:38–52; 2 Bar. 29:1–30:5)[92] record a later version of the Leviathan story in which there are ornate elaborations, including the imprisonment and subsequent slaying of two serpents instead of one. Those writings name Behemoth and Leviathan as two *tannînim* that God made and imprisoned on the fifth day of creation (cf. Gen. 1:21, in which God creates the *tannînim* on the fifth day). According to those writings, God imprisoned Leviathan in the sea and Behemoth in the wilderness on land, and both will remain hidden until he releases them at the end of time, upon which he will defeat them and feed them to the faithful in an eschatological banquet (cf. Ps. 74:14). The book of Job contains some of the roots of this later version of the story. Job speaks of being under guard like an imprisoned *tannîn* or the sea (7:12). He mentions the rousing of Leviathan as a means to erase a day in the past (3:8), a reference to the eschatological erasure of time when Leviathan will be released to be defeated. Job 40 and 41 describe Leviathan as in the sea and Behemoth as in the wilderness on land. Also, it is in Job 40 that Behemoth, who has no antecedents in Canaanite mythology, makes his first literary appearance.

According to Levitical regulations, reptile meat is unclean (Lev. 11:29–31, 11:41–44). Accordingly, the Rabbis of the Christian Era portrayed Leviathan as a fish and Behemoth as an ox-like creature, in an apparent attempt to identify them as kosher, to make the eschatological banquet consistent with Mosaic Law.[93] The idea of Leviathan as a fish may have led, in turn, to his later identification as a whale, the biggest "fish."

Non-Jewish scholars of the seventeenth century treated Behemoth and Leviathan as natural animals. They debated whether Leviathan and other biblical *tannînim* were whales or crocodiles[94] and whether Behemoth was the elephant or the hippopotamus.[95] Subsequent scholars have continued such debates to this day.[96] However, such debates are moot for four important reasons.

1. Job portrays Behemoth and Leviathan as creatures that humans cannot capture (Job 40:24, 41:1–8, 41:26–29), whereas the ancients did capture and slaughter hippos and crocodiles.[97]
2. Behemoth and Leviathan are names of individuals, not species.
3. Leviathan and Behemoth are not natural animals but supernatural beings. This is evident in the story of God's slaying of Leviathan, because it would make little sense for God to slay an ordinary snake. It is also evident in the post-Septuagint version of the story, in that the lifespans of Leviathan and Behemoth—made at the beginning of creation and kept alive until the end of time—are unrealistic for natural animals.
4. According to the post-Septuagint version of the story, Leviathan and Behemoth are not creatures that any human has ever seen. They have been hidden since their creation on the fifth day (the day before God made humans) and will remain hidden from human sight until the end of time (Enoch 60:7–8, 60:20; 2 Bar. 29:3–5; 4 Esd. 6:47–52). Job 40:15 begins "Behold now Behemoth," but the Hebrew word that is translated "behold" (הִנֵּה) (*hinneh*) does not imply that Job was granted to see Behemoth. Rather, *hinneh* means "Listen! I am about to say something important!"

Behemoth's Anatomy

Some DIBV authors have misinterpreted Job 40:16 as implying that Behemoth has a bulbous midsection and powerful hindlimbs.[98] The verse says nothing of the kind. Instead, the series of couplets that begins in verse 16 and continues through verse 18 quite possibly describe the opposite: a limbless being with a narrow, wreath-like shape.

The first part of the couplet in verse 16 says that Behemoth's strength (כֹּחַ: *ko-aḥ*) is in his waist (מָתְנָיו: *mothen*). That is a striking statement, because it is at odds with the ancient Hebrew conception of *ko-aḥ*. The Hebrew scriptures describe *ko-aḥ* (strength) as located in the arms and hands—literally, in the case of a blacksmith (Isa. 44:12) or a strong man (Deut. 8:17; Job 26:2, 30:2; Eccles. 9:10), and figuratively, in the case of a ruler or a deity (Exod. 15:6, 32:11; Deut. 9:29; 1 Chron. 29:12, 20:6; Neh. 1:10; Isa. 10:13; Dan. 11:6; Jer. 32:17). The *mothen* is the slender section of the body above the hips, between the arms and the legs.[99] What, then, is so unusual about Behemoth's arms and legs that they do not contain his *ko-aḥ*? There is a possible answer that is worth considering but has not dawned upon postmedieval scholars before now: Behemoth has no arms or legs in which to store his *ko-aḥ*.

The second part of the couplet in verse 16 is another revealing turn of phrase that is consistent with a limbless creature. It says that Behemoth's power (אוֹן: *ʾōn*) is "in the muscles" (בִּשְׁרִירֵי: *bi-shərirei*) "of his belly" (בִּטְנוֹ: *bithənō*). The *ʾōn* is the virile, generative power of the loins or an individual's power to produce creative work,[100] that is, to accomplish deeds. As with the first part of the couplet, the second part emphasizes that Behemoth's ability to accomplish deeds lies not in limbs but in his midsection, between where limbs normally are.[101] That a creature's power is in its belly muscles (as opposed to its limbs) is a curious thing to say of a limb-propelled creature, but it is a natural thing to say of a serpentiform creature that propels itself upon its belly.

In the couplet of verse 17, the themes "tail" and "cedar" are consistent with a serpentiform creature. The first part of the couplet says יַחְפֹּץ זְנָבוֹ כְּמוֹ־אָרֶז (*yaḥəpōts zənāvō ḥəmō-ʾārez*): "He delights in [is pleased by, cherishes, admires, prizes] his tail, like a cedar." A creature with limbs is more likely to be said to prize its arms or legs or talons or hooves, the sources of its *ko-aḥ* and its *ʾōn*. Like the other parts of verses 16–17, this part of verse 17 is consistent with Behemoth as limbless.

The first part of verse 17 is consistently misunderstood and mistranslated. Translators usually treat it as if the phrase *ḥəmō-ʾārez* (like a cedar) refers to Behemoth's tail. However, it does not. It refers to Behemoth or to his delighting. It can therefore be correctly rendered "like a cedar, he prizes his tail." Behemoth's tail is the object, not the subject. Translators also tend to misunderstand the verb חָפֵץ (*ḥaphēts*), which means to be delighted or pleased by something or to prize it.[102] To translate *ḥaphēts* as "to move" (e.g., in the King James Version) or "to stiffen" (e.g., in the English Standard Version) is to force upon the verb an idiomatic meaning that the context neither suggests nor supports and which has no equivalent or precedent anywhere else in the Hebrew scriptures. Nor does the word for "tail" (זָנָב: *zānāv*) mean or imply "penis." There is no known ancient Hebrew passage in which *zānāv* is used as a euphemism for "penis," so the supposition that the phrase is a reference to penile erection[103] is without supporting evidence. The word *zānāv* refers to the hind end of something[104]—in an animal, the tail (Exod. 4:4, Judg. 15:4). However, it can also mean the tail-like tip of something, such as the stump of a spent firebrand (Isa. 7:4) or the frond or branch of a plant (Isa. 19:15). Verse 17 is therefore saying that Behemoth prizes (*yaḥəpōts*) his tail (*zənāvō*), just like (*ḥəmō*) a cedar (*ʾārez*) prizes (*yaḥəpōts*) its branches (*zənāvō*).[105]

The second part of the couplet in verse 17 repeats the themes of "tail" and "cedar" by saying גִּידֵי פַחֲדָו יְשֹׂרָגוּ (*gîdei paḥədāvō yəsōrāgō*): the sinews (*gîdei*) at the base of his tail (*paḥədāvō*: his pelvic region) are interwoven (*yəsōrāgō*). The use here of the verb שָׂרַג (*sārag*: interweave) is a pun on the concept of cedar branches, for it refers to the interweaving of branches to make a wreath.[106] This part of the couplet is therefore a play on words that incorporates a continuation of the cedar-branch theme with an image of a serpent's body: tightly woven into an elongate and narrow shape, like cedar branches that are interwoven to make a wreath. This second part of the couplet confirms that, in the first part of the couplet, it is not Behemoth's tail that is like a cedar. Rather, Behemoth is like a cedar, and his tail is like its branches after they have been interwoven into a wreath.

Verse 18 is a couplet that says that Behemoth's bones (עֲצָמָיו: *ʿetsem*) are like tubes of bronze, then says his bones (גְּרָמָיו: *gerem*) are like bars of iron. Some translators mistake the word *gerem* for a reference to limbs.[107] However, it is another word for "bone"[108] and is therefore not an indication that Behemoth has limbs.

Behemoth as a Demonic Entity

Even if my interpretation of Job 40:16–18 as a description of serpentiform anatomy is incorrect, there is still no good reason to consider Behemoth a dinosaur. His "tail like a cedar" evaporates upon examination, and there are no other specifically dinosaurian traits in his description in Job 40. More importantly, Behemoth is not a natural animal. According to Job 40, he is a supernatural being of extraordinary power.

For centuries, scholars have mistaken the imagery in verses 15 and 19–24 of Job 40 for a description of an aquatic, herbivorous animal, because the ancient meaning of that imagery was long forgotten. However, tablets with Babylonian and Canaanite incantations against demons and diseases, discovered at the ancient Canaanite city of Ugarit, have recently clarified its meaning. In the cultures that produced the tablets, demons were thought to be the causes of numerous diseases,[109] and disease was often described as a demon feeding on its victim.[110] The imagery in the incantations on the tablets from Ugarit describes an attacking demon as arising from the earth, often in mountains. Next, it may continue its progress by sickening and/or killing vegetation (grass, woods, reeds, etc.), which is described as its feeding upon the vegetation. Then, it culminates its assault by attacking livestock and people, sickening and/or killing them, which may be described as feeding on their blood or bones.[111] Its refusal to remain still is likened to the restless movement of a serpent.[112] The incantation to dispel it may request a deity to transplant it into the heavens or the netherworld, or may send it into the mountains to feed on the vegetation there.[113] The running water of a river was thought to aid in the dispelling of disease-causing evil. Some healing rituals involved immersing oneself or ritual implements in a river so that the river would carry away the evil,[114] and at least one incantation figuratively requests divine agents to carry away the evil with a flood.[115]

Using imagery that closely mirrors that in the tablets from Ugarit, Job 40 paints a verbal picture of Behemoth as a demon who has been dispelled to the mountains to feed on vegetation, which prevents him from attacking livestock, which rejoice that they are not his targets. Verse 15 states that Behemoth is eating grass like an ox (as a dispelled demon does), and verses 21–22 portray him as surrounded by vegetation to eat. Verse 20 says that the mountains produce food for Behemoth, and the beasts rejoice (שָׂחַק: *shāḥaq*: to rejoice or to express joy by laughter, derision, or play).[116] The Septuagint renders verse 20 as a statement that the quadrupeds in Tartarus rejoice when Behemoth ascends a mountain peak (to which he has presumably been dispelled). The quadrupeds in Tartarus may be his victims, rejoicing at his comeuppance, or they may be livestock that have been offered to Behemoth to consume, sacrificed as part of a ritual to attract the demon to the netherworld and rejoicing because Behemoth will now feed on mountain vegetation instead of feeding upon them in the netherworld.

Verses 22–23 state that Behemoth fears no river and that not even one as powerful as the Jordan can move him. That is a reference to the use of rivers to remove evil agents and an indication that, unlike ordinary demons, Behemoth is too powerful to be dispelled by human rituals that use rivers for exorcism. Verse 24 continues that theme by ridiculing the notion that any human effort can overcome Behemoth. Only God, his maker (verse 15) is powerful enough to "approach him with the sword" (i.e., to dispel him) (verse 19).

Verse 19 also refers to God's early creation of Behemoth by calling Behemoth the רֵאשִׁית (*reʾshîth*) of God's ways. The word *reʾshîth* refers to a beginning or something that happens first in a series. Its use here implies that Behemoth is one of the earliest things that God created. That is consistent with the elaborated versions in the post-Septuagint works that state that Behemoth was created on the fifth day and that God banished Behemoth soon thereafter, keeping him from human contact in a land east of Eden (Enoch 60:7–10; 2 Bar. 29:4; 2 Esd. 6:47–52). The rich imagery of Job 40 thus describes Behemoth not as a literal animal but as a dangerous supernatural entity who is too powerful for anyone but God to dispel and whom God fortunately did dispel shortly after making him.

Behemoth's Name

Bᵉhēmōth is the plural of בְּהֵמָה (*bᵉhēmah*), the ancient Hebrew word for "beast." The common assertion that Behemoth's name is derived from an Egyptian term, *pʾ-iḥ-hw*—which allegedly means "water ox" (i.e. hippopotamus)—is incorrect, because there is no such term in any ancient Egyptian language.[117] The Hebrew scriptures often use the word

bᵉhēmah specifically for cattle. They also use it as a more generic term that not only includes cloven-hoofed mammals but also carnivorous mammals (Prov. 30:30) and herbivorous mammals without cloven hooves (Lev. 11:26). It is used in contrast to fishes, birds, and "swarming/creeping creatures" (Gen. 1:20–25, 2:20, 6:20, 7:8–23, 8:20, 9:10; Lev. 11:46) and is therefore equivalent to "mammalian beast" when used in its generic sense. As an intensive plural, the name Behemoth can be translated "Great Bull," "Great Ox," or "Great Beast."[118] As an ordinary plural, "Behemoth" can be translated "Cattle," "Oxen," or "Beasts." Accordingly, in place of a transliteration of the name Behemoth, the Septuagint has θηρια (Beasts).

Even if Behemoth is named after mammals, this does not mean that he was originally envisioned as a mammal. "Behemoth" is not a species designation but a personal name. This is underscored by the fact that the verbs and possessive-case nouns that refer to Behemoth in Job 40 all do so in the masculine singular, even though his name is a feminine plural. As a personal name, the word "Behemoth" in this case does not identify its bearer's species any more than someone named Rachel (Hebrew for "female sheep"), Ariel (Hebrew for "lioness of God"), or Achsah (Hebrew for "ankle bracelet") is a sheep or a lioness or an ankle bracelet. Nonetheless, it is plausible that Behemoth's name was meant to suggest livestock, as a play on words, because both livestock and demons were thought to consume vegetation, including grass. This is emphasized by the wordplay at the beginning of the Behemoth passage, which introduces Behemoth by name and then immediately says that he "is eating grass like an ox." That is a poetic double entendre in reference to Behemoth's name and his demonic diet, not a description of a literally grass-eating mammal.

Conclusions

It is a mistake to treat the Bible as a science text and its descriptions of supernatural entities as natural animals. The biblical word *tannîn* means "serpent," and the biblical Leviathan and Behemoth are supernatural entities of which at least Leviathan (and possibly Behemoth) was figuratively envisioned as a serpent. Leviathan's fire-breathing is not literal but metaphorical. Biblical references to Leviathan, Behemoth, and other *tannînim* are therefore not evidence that ancient humans encountered live, fire-breathing dinosaurs. ♥

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Notes

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[8]William Buckland, "Notice on the Megalosaurus or Great Fossil Lizard of Stonesfield," *Transactions of the Geological Society, Second Series* 1 (1824): 390–96.

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[20]Kelly L. Segraves, *The Great Dinosaur Mistake* (San Diego, CA: Beta Books, 1975), 31.

[21]Charles H. McGowen, *In Six Days* (Van Nuys, CA: Bible Voice, 1976), 76–77.

[22]Duane T. Gish, *Dinosaurs: Those Terrible Lizards* (San Diego, CA: Creation-Life Publishers, 1977), 16–17; Paul S. Taylor, *The Great Dinosaur Mystery and the Bible* (Colorado Springs, CO: Cook Communications, 1987), 18–19; David W. Unfred, *Dinosaurs and the Bible* (Lafayette, LA: Huntington House Publishers, 1990), 6–8; Duane T. Gish, *Dinosaurs by Design* (Green Forest, AR: Master Books, 1992), 20; Ken Ham, *Dinosaurs of Eden* (Green Forest, AR: Master Books, 2001), 38; Larry Dye, *Bible Dinosaurs Revealed* (Victoria, BC: Trafford, 2008), 17; Ken Ham, *Dinosaurs for Kids* (Green Forest, AR: Master Books, 2009), 48; Mace Baker, *The Real History of Dinosaurs*, 5th ed. (Redding, CA: New Century Books, 2010), 49; Dave Woetzel, *Chronicles of Dinosauria: The History and Mystery of Dinosaurs and Man* (Green Forest, AR: Master Books, 2013), 69; Timothy Clarey, *Dinosaurs: Marvels of God's Design* (Green Forest, AR: Master Books, 2015), 19; and Institute for Creation Research, *Guide to Dinosaurs* (Eugene, OR: Harvest House, 2015), 14, 113.

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[49]Institute for Creation Research, *Guide to Dinosaurs*, 78.

[50]For a delineation of how data from physics, chemistry, biology, and paleontology refute every proposed mechanism of dinosaurian fire-breathing that creationist authors have suggested, see Philip J. Senter, *Fire-Breathing Dinosaurs? The Hilarious History of Creationist Pseudoscience at Its Silliest* (Cambridge, UK: Cambridge Scholars Publishing, 2019).

[51]Gen. 1:21; Ps. 74:14; Isa. 27:1.

[52]Gilmer, *100-Year Cover-Up Revealed*, 38.

[53]Taylor, *Great Dinosaur Mystery and the Bible*, 18; Lyons and Butt, *The Dinosaur Delusion*, 112; Woetzel, *Chronicles of Dinosauria*, 68; and Thomas, *Dinosaurs and the Bible*, 48.

[54]Thomas, *Dinosaurs and the Bible*, 48.

[55]Pss. 44:19, 148:7; Job 30:29; Isa. 13:22, 34:13, 35:7, 43:20; Jer. 9:11, 10:22, 49:33, 51:37.

[56]J. D. Morris, *Tracking Those Incredible Dinosaurs*, 64–65; H. M. Morris, *Biblical Basis for Modern Science*, 351–53; Charles V. Taylor, "Dinosaurs in the Bible," *Creation* ex nihilo *Technical Journal* 7 (1993): 169–71; Phillips, *Dinosaurs: The Bible, Barney and Beyond*, 55; Ham, *Great Dinosaur Mystery Solved!*, 39, 47; Gibbons, *Missionaries and Monsters*, 49–50; Baker, *The Real History of Dinosaurs*, 39; Vance Nelson, *Untold Secrets of Planet Earth: Dire Dragons* (Red Deer, AB: Vance Nelson, 2011), 18; Glenn L. Wilson, *Behold Now Behemoth: Dinosaurs all over the Bible* (Bloomington, IN: WestBow, 2011), 50–61; Vance Nelson, *Untold Secrets of Planet Earth: Dire Dragons*, 2nd ed. (Red Deer, AB: Vance Nelson, 2012), 18; Clarey, *Dinosaurs: Marvels of God's Design*, 21; and Institute for Creation Research, *Guide to Dinosaurs*, 14.

[57]Nelson, *Dire Dragons*, 18; and Nelson, *Dire Dragons*, 2nd ed., 18.

[58]Hart, *The Animals Mentioned in the Bible*; and Jeff A. Benner, *Ancient Hebrew Lexicon of the Bible* (College Station, TX: Virtualbookworm, 2005.

[59]Gen. 3:1, 3:2, 3:4, 3:13, 3:14; Exod. 4:3, 7:15; Num. 21:6, 21:7, 21:9; Deut. 8:15; 2 Kings 18:4.

[60]*Nāḥāsh*: 15 times (Gen. 49:17; Job 26:13; Pss. 58:4, 140:3; Prov. 23:32, 30:19; Eccles. 10:8, 10:11; Isa. 14:29, 27:1, 65:25; Jer. 46:22; Amos 5:19, 9:3; Micah 7:17). *Tannîn*: 12 times (Deut. 32:33; Job 7:12; Pss. 74:13, 91:13, 148:7; Isa. 27:1 (twice), 51:9, 51:34; Lam. 4:3; Ezek. 29:3, 32:2; the two verses in Ezek. use *tannîm* as an alternate form of *tannînim*).

[61]The Bible's only prose passages that use *tannîn* are Gen. 1:21, Exod. 7:9-12, and Neh. 2:13.

[62]Exod. 7:9-12; Deut. 32:33; Neh. 2:13; Job 7:12; Pss. 74:13, 91:13, 148:7; Isa. 27:1, 51:9; Lam. 4:3; Jer. 51:34.

[63]Exod. 7:12; Deut. 32:33; Neh. 2:13; Job 7:12; Pss. 74:13, 91:13, 148:7; Isa. 51:9; Jer. 51:34. The Vulgate is a translation that was produced centuries after the Septuagint and therefore further removed in time from the original Hebrew writing. It therefore may be less reliable as regards the meanings of the Hebrew words.

[64]Daniel Ogden, *Drakōn: Dragon Myth and Serpent Cult in the Greek and Roman Worlds* (Oxford, UK: Oxford University Press, 2013); and Phil Senter, "Dinosaurs and Pterosaurs in Greek and Roman Art and Literature? An Investigation of Young-Earth Creationist Claims," *Palaeontologia Electronica* 16, no. 3 (2013): 1–16.

[65]Phil Senter, Uta Mattox, and Eid E. Haddad, "Snake to Monster: Conrad Gessner's *Schlangenbuch* and the Evolution of the Dragon in the Literature of Natural History," *Journal of Folklore Research* 53 (2016): 67–124.

[66]Liliane Bodson, *Hiera Zoia. Contribution à l'Étude de la Place de l'Animal dans la Religion Grecque Ancienne* (Brussels, Belgium: Académie Royale de Belgique, 1975), 72 n. 94.

[67]Rudolf Kittel, *Studien zur Hebräischen Archäologie und Religionsgeschichte* (Leipzig, Germany: J. C. Hinrichs, 1908), 159–88; and Karen R. Joines, *Serpent Symbolism in the Old Testament* (Haddonfield, NJ: Haddonfield House, 1974), 92.

[68]Kiessling, "Antecedents of the Medieval Dragon"; Wakeman, *God's Battle with the Monster*; Day, *God's Conflict with the Dragon and the Sea*; and Heider, "Tannin."

[69]It is a mistake that I, too, made in a previous publication (Senter et al., "Snake to Monster," 80).

[70]Hart, *The Animals Mentioned in the Bible*, 80; Pinney, *The Animals in the Bible*, 120, 201; Wakeman, *God's Battle with the Monster*; Mark Ziese, "Jackal," in David N. Freedman, ed., *Eerdmans Dictionary of the Bible* (Grand Rapids, MI: William B. Eerdmans, 2000), 665–66; and Slifkin, *Sacred Monsters*, 165–66. In addition, one DIBV author (Baker, *The Real History of Dinosaurs*, 56) equated the "howling" of dragons in Isa. 13:22 with vocalization by lambeosaurine dinosaurs.

[71]Benner, *Ancient Hebrew Lexicon*, 298.

[72]It is also possible that this is a reference not to a literal *tannîn* but to Egypt, a way to scold Jerusalem by way of an unfavorable comparison to a traditional enemy nation. The Hebrew scriptures use "*tannîn*" as a derogatory figure of speech for Egypt and Egyptians in a number of places (Ps. 74:13–14; Isa. 27:1, 51:9; Ezek. 29:3, 31:2).

[73]One DIBV author claimed that Lam. 4:3 indicates that dinosaurs had mammary glands and suckled their young. For the rest of that story, see Philip J. Senter, "Dead Varmint Vision at Its Funniest. An Alleged Dinosaur with Breasts in a Medieval Carving," *Skeptical Inquirer* 42 no. 4 (2018): 53–55.

[74]Job 30:29; Ps. 44:19; Isa. 13:22, 34:13, 35:7, 43:20; Jer. 9:11, 10:22, 14:6, 49:33, 51:37; Ezek. 29:3, 32:2; Micah 1:8.

[75]For example, Slifkin, *Sacred Monsters*, 165–66.

[76]In some cases, in place of *tannîm* the Septuagint uses στρουθός (ostrich) (Jer. 10:22, 49:33) or σειρὴν (siren) (Job 30:29; Isa. 34:13, 43:20) and the Vulgate uses *siren* (siren) (Isa. 13:22). This makes it seem as though the term *tannîm* refers to some sort of bird. However, such cases represent substitutions, not translations, of the word *tannîm*. The creators of the Septuagint were more concerned with transmitting the spirit of the Hebrew scripture than with producing a literal translation. Accordingly, although much of the Septuagint is as nearly a word-for-word translation of the Hebrew as one can produce in Greek, the Septuagint contains some passages for which the wording has been altered so that its point does not get lost in translation. The substitution of "ostrich" or "siren" in place of *tannîm* emphasizes the point that the city or land that hosts such creatures has been devastated. The Near Eastern subspecies of ostrich (*Struthio camelus syri-*

acus) inhabited desert areas before its extinction in 1939 (Terence J. Robinson and Conrad A. Matthee, "Molecular Genetic Relationships of the Extinct Ostrich, *Struthio camelus syriacus*: Consequences for Ostrich Introductions into Saudi Arabia," *Animal Conservation* 2 (1999): 165–71), making it an appropriate symbol of an abandoned area, and the siren connoted death to the inhabitants of Hellenistic Egypt, the source of the Septuagint. The Egyptians depicted the human soul after its departure from the body as a human-headed bird called the *ba*. After the Greek conquest, the *ba* became integrated with the siren of Greek mythology, which was also depicted as a human-headed bird and was portrayed on Hellenistic Egyptian tombs. See Marjorie S. Venit, *Visualizing the Afterlife in the Tombs of Graeco-Roman Egypt* (Cambridge, UK: Cambridge University Press, 2016). Thus, for the writers of the Septuagint, to say that a place was inhabited by sirens was to call it a place of death, an appropriate idiom in reference to desolation.

[77]Pss. 74(73):14, 104(103):26; Job 41:1 (40:20); Isa. 27:1.

[78]Pss. 74(73):14, 104(103):26.

[79]Johannes C. De Moor, *An Anthology of Religious Texts from Ugarit* (Leiden, The Netherlands: Brill, 1987), viii.

[80]De Moor, *Anthology of Religious Texts*; Nick Wyatt, *Religious Texts from Ugarit*, 2nd ed. (London: Sheffield Academic, 2002); and Michael D. Coogan and Mark S. Smith, *Stories from Ancient Canaan*, 2nd ed. (Louisville, KY: Westminster John Knox, 2012).

[81]De Moor, *Anthology of Religious Texts*, 11.

[82]De Moor, *Anthology of Religious Texts*, 11, 69, 71; Wyatt, *Religious Texts from Ugarit*, 79, 115, 120; Coogan and Smith, *Stories from Ancient Canaan*, 120, 139–40.

[83]Wyatt, *Religious Texts from Ugarit*, 79, 115.

[84]For example, Christoph Uehlinger, "Leviathan," in *Dictionary of Deities and Demons in the Bible,* ed. van der Toorn, Becking, and van der Horst, 956–64.

[85]Coogan and Smith, *Stories from Ancient Canaan*, 106.

[86]Wyatt, *Religious Texts from Ugarit*, 88.

[87]Coogan and Smith, *Stories from Ancient Canaan*, 111–15, 127.

[88]De Moor, *Anthology of Religious Texts*, 11; Wyatt, *Religious Texts from Ugarit*, 79; Coogan and Smith, *Stories from Ancient Canaan*, 120.

[89]That the Hebrews altered the Canaanite myth and not vice versa is demonstrated by the dates of the relevant biblical passages. All such passages were written centuries after the demise of Ugarit, which occurred about 1200 BC. Genesis 1:21 was written by the priestly author, no earlier than the eighth century BC. See Richard Friedman, *Who Wrote the Bible?* (New York: HarperCollins, 1997). Isaiah and Amos were written no earlier than the eighth-century BC reign of Uzziah of Judah (Isa. 1:1; Amos 1:1). Ezekiel was written after the sixth-century BC defeat of Jerusalem by Babylon (Ezek. 1:1). Psalm 104 was probably written during the sixth or seventh century BC (Samuel L. Terrien, *The Psalms: Strophic Structure and Theological Commentary* [Grand Rapids, MI: William B. Eerdmans, 2003], 718–19), and Psalm 74 is post-exilic (Terrien, *The Psalms*, 542). Job's references to iron tools (19:24, 20:24, 28:2) place its composition no earlier than the eleventh century BC (James D. Muhly, "Metalworking/Mining in the Levant," in *Near Eastern Archaeology. A Reader*, ed. Suzanne Richard [Winona Lake, IN: Eisenbrauns, 2003], 174–83), its references to domesticated camels (Job 1:3, 1:7, 42:12) place its composition no earlier than the tenth century BC. See Peter Rowley-Conwy, "The Camel in the Nile Valley: New Radiocarbon Accelerator (AMS) Dates from Qaṣr Ibrim," *Journal of Egyptian Archaeology* 74 (1988): 245–48; Lidar Sapir-Hen and Erez Ben-Yosef, "The Introduction of Domestic Camels to the Southern Levant: Evidence from the Aravah Valley," *Tel Aviv* 40 (2013): 277–85). Its references to mounted cavalry (Job 39:18, 39:21–25) place its composition no earlier than the invention of mounted cavalry by the Assyrians in the ninth century BC and more likely after the Assyrians began to extensively use cavalry in the following century. See Robert Drews, *Early Riders: The Beginnings of Mounted Warfare in Asia and Europe* (New York: Routledge, 2004); and Robin Archer, "Chariotry to Cavalry: Developments in the Early First Millennium," in *New Perspectives on Ancient Warfare*, ed. Garrett G. Fagan and Matthew Trundle (Leiden, The Netherlands: Brill, 2010), 57–79).

[90]George Hart, *Egyptian Myths* (Austin, TX: University of Texas Press, 1990), 11–15, 20–21; Manfred Hutter, "Earth," in *Dictionary of Deities and Demons in the Bible,* ed. van der Toorn, Becking, and van der Horst, 517–22; Fritz Stoltz, "Sea," in *Dictionary of Deities and Demons in the Bible,* ed. van der Toorn, Becking, and van der Horst, 1390–1402; and Stephanie Dalley, *Myths from Mesopotamia* (Oxford, UK: Oxford University Press, 2000), 233, 278–80.

[91]Hart, *Egyptian Myths*, 28–40; and Dalley, *Myths from Mesopotamia*, 51.

[92]See English translations in E. Isaac, trans., "1 (Ethiopic Apocalypse of) Enoch," in *The Old Testament Pseudepigrapha, Vol. 1. Apocalyptic Literature and Testaments,* ed. James H. Charlesworth (Peabody, MA: Hendrickson, 1983), 5–89; A. F. J. Klijn, trans., "2 (Syriac Apocalypse of) Baruch," in *The Old Testament Pseudepigrapha, Vol. 1,* ed. Charlesworth, 615–52; B. M. Metzger, trans., "The Fourth Book of Ezra," in *The Old Testament Pseudepigrapha, Vol. 1,* ed. Charlesworth, 517–59; John R. Kohlenberger III, *The Parallel Apocrypha* (New York: Oxford University Press, 1997); Daniel M. Gurtner, *Second Baruch: A Critical Edition of the Syriac Text* (New York: T&T Clark, 2009); and George W. E. Nickelsburg and James C. VanderKam, trans., *1 Enoch: The Hermeneia Translation* (Minneapolis, MN: Fortress Press, 2012).

[93]Jefim Schirmann, "The Battle between Behemoth and Leviathan According to an Ancient Hebrew *Piyyut*," *Proceedings of the Israeli Academy of Science and Humanities* 4 (1970): 327–69; and Slifkin, *Sacred Monsters*, 173–74, 184. Behemoth's identification as an ox-like creature may also have been at least partly inspired by his name (see the following section on Behemoth's name).

[94]For example, Diodati, *Sacra Bibbia*, 472; Kirchmeyer, *Disputationum zoologicarum*; and Bochart, *Hierozoici*, 49, 52, 136. In addition, *tannîn* is translated "whale" in a few passages in two seventeenth-century English translations of the Bible: Ezek. 32:2 in the King James Version, Isa. 27:1 in the Douay-Rheims Version, and Gen. 1:21 and Job 7:12 in both versions.

[95]For example, Diodati, *Sacra Bibbia*, 471; Kirchmeyer, *Disputationum zoologicarum*; and Bochart, *Hierozoici*, 49.

[96]For example, Pinney, *The Animals in the Bible*, 97; Walvoord and Zuck, *The Bible Knowledge Commentary*, 771–73; Harris, "The Doctrine of God in the Book of Job"; Bright, *Beasts of the Field*, 28–29, 35–39; Habtu, "Job"; Habtu, "Ezekiel"; and Slifkin, *Sacred Monsters*, 185–90.

[97]Thompson, "An Attempt to Ascertain the Animals Designated in the Scriptures"; Day, *God's Conflict with the*

Dragon and the Sea, 65, 77; Dale J. Osborn, *The Mammals of Ancient Egypt* (Warminster, UK: Aris and Phillips, 1998), 146; and Paul, "Behemoth and Leviathan in the Book of Job."

[98]J. D. Morris, *Tracking Those Incredible Dinosaurs*, 65; H. M. Morris, *The Biblical Basis for Modern Science*, 357; Petersen, *Unlocking the Mysteries of Creation*, 138–40; J. D. Morris, *Dinosaurs, the Lost World, and You*, 36; and Petersen, *Unlocking the Mysteries of Creation*, premier ed., 150–51.

[99]Benner, *Ancient Hebrew Lexicon*, 371.

[100]Ibid., 57.

[101]An alternate interpretation of the second part of the couplet in verse 16 is that it locates Behemoth's virile, generative power internal to his belly muscles—in other words, his testes are within his abdomen. This interpretation emphasizes Behemoth's reptilian nature, because reptilian testes are within the abdomen, unlike mammalian testes, which hang in an external scrotum. The interpretation in the previous paragraph is more likely to represent the author's intent, because it more closely parallels the meaning of the first part of the couplet, but either interpretation is consistent with Behemoth's anatomy as serpentiform and inconsistent with it as mammalian.

[102]Benner, *Ancient Hebrew Lexicon*, 340.

[103]For example, Stephen Mitchell, *The Book of Job* (New York: Harper Perennial, 1987), 85.

[104]Benner, *Ancient Hebrew Lexicon*, 326.

[105]In other words, Behemoth thinks highly of his tail. The implication seems to be that he thinks so highly of his tail that he considers it sufficient, that is, he feels no need for limbs.

[106]Benner, *Ancient Hebrew Lexicon*, 396.

[107]For example, in the New International and New American Standard versions of the Bible.

[108]Benner, *Ancient Hebrew Lexicon*, 317.

[109]JoAnn Scurlock and Burton Anderson, *Diagnoses in Assyrian and Babylonian Medicine. Ancient Sources, Translations, and Modern Medical Analyses* (Urbana, IL: University of Illinois Press, 2005); Walter Farber, "Lamaštu—Agent of a Specific Disease or a Generic Destroyer of Health?," in *Disease in Babylonia,* ed. Irving L. Finkel and Markham J. Geller (Leiden, The Netherlands: Brill, 2007), 137–45; J. V. Kinnier Wilson and E. H. Reynolds, "On Stroke and Facial Palsy in Babylonian Texts," in *Disease in Babylonia,* ed. Finkel and Geller, 67–99; and Marten Stol, "Fevers in Babylonia," in *Disease in Babylonia,* ed. Finkel and Geller, 1–39.

[110]Scurlock and Anderson, *Diagnoses*, 421, 472; and Gregorio del Olmo Lete, *Incantations and Anti-Witchcraft Texts from Ugarit* (Boston, MA: Walter de Gruyter, 2014), 55, 60.

[111]del Olmo Lete, *Incantations*, 43, 46, 53–56, 60.

[112]Ibid., 55.

[113]Ibid., 43, 53–56, 60.

[114]JoAnn Scurlock, *Sourcebook for Ancient Mesopotamian Medicine* (Atlanta, GA: SBL Press, 2014), 219, 220, 438, 688.

[115]del Olmo Lete, *Incantations*, 54.

[116]Misunderstanding a description of a demonic entity as that of a natural animal, a few DIBV authors have supported their identification of Behemoth as a sauropod by claiming that Job 40:20 implies that he is docile, for the beasts play near him. However, there is no fossil evidence that sauropods were docile. Nor does Job 40:20 imply docility or even the safety of animals in Behemoth's presence. Rather, it expresses the opposite: animals are unsafe in his presence. The Hebrew text says that they rejoice (often translated as "play") when he is fed, implying that they are happy that he is not feeding on them. The Septuagint says that they rejoice when he leaves them to go up a mountain, indicating that what makes them rejoice is Behemoth's departure, not his presence.

[117]Bernard F. Batto, "Behemoth," in *Dictionary of Deities and Demons in the Bible,* ed. van der Toorn, Becking, and van der Horst, 315–22.

[118]Compare, Day, *God's Conflict with the Dragon and the Sea*, 76–80.

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Christy Hemphill

All in a Week's Work: Using Conceptual Metaphor Theory to Explain Figurative Meaning in Genesis 1

Christy Hemphill

In origins discussions, many people appeal to the "figurative" nature of the account of creation week without really knowing how figurative language is processed. An introductory understanding of conceptual metaphor theory (a subdiscipline of cognitive linguistics) can equip people to discuss the figurative language of Genesis 1 more accurately and to defend figurative biblical interpretations that accommodate scientific realities. Specifically, identification of underlying conceptual metaphors and resulting source domain mapping can help explain how an account of a week of "normal" days does not automatically entail a literal interpretation. Since multiple conceptual metaphors can simultaneously be involved in conceptual mapping in a single text, identifying one metaphor does not rule out the presence of other metaphors, and any new metaphors which are uncovered can provide potential lines of inquiry for future work in biblical interpretation.

1. Introduction and Rationale

The discipline of biblical interpretation is gradually incorporating modern insights from communication theory and applied linguistics, fields which have recently seen paradigm shifts in several areas. Some of these shifts have been driven by advances in cognitive science, in which emerging technology for enhanced neuroimaging has allowed researchers to study brain activity during language processing in new ways. It often takes time for what is considered established theory in one field to influence ideas and methodologies in another field.

In biblical interpretation, it is not uncommon to see people relying on assumptions that are based on a model of communication and approaches to meaning that have been mostly discarded in the fields of cognitive psychology and linguistics. Ideas cross over slowly, but eventually have impact. Some current scholarship in biblical interpretation and theology is endeavoring to apply more-recent insights from various linguistic subdisciplines. For example, Bible scholars and theologians have begun incorporating insights from speech act theory,[1] relevance theory,[2] discourse analysis,[3] and cognitive linguistics.[4] This article is offered in that interdisciplinary spirit, to encourage application of an established cognitive linguistic model for analyzing figurative language to the discipline of biblical interpretation.

In discussions of how to interpret the days of creation week in Genesis 1, people are usually defending one of three options: the word "day" has a normal, literal sense, and the whole passage conveys literal meaning; the word "day" has a figurative sense and the whole passage conveys figurative meaning; or the word "day" has a normal, literal sense,

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but the whole passage conveys figurative, not literal, meaning.[5]

Many Christians' skepticism of the mainstream scientific consensus in several scientific disciplines stems from an "option 1" reading that interprets the creation week as a literal historical account of the events of seven calendar days. Christians who believe Genesis can accommodate the findings of science that necessarily call into question this literal interpretation usually counter that the creation week of Genesis 1 should be interpreted "metaphorically" or "figuratively," and offer some version of "option 2" or "option 3." This is often seen as dismissive hermeneutical hand-waving by those who read Genesis 1 as a straightforward account of a week of normal days. "If the day is a metaphor, what is the day a metaphor of?" the literalists ask.

Even though many people recognize intuitively that the creation week of Genesis 1 is not meant to be "taken literally," they often do not know much about how human brains process figurative meaning in language, and they often resort to defending their figurative interpretations based on intuition. This article offers a defense of "option 3" (normal days; figurative interpretation), but defends the interpretation with an argument based on cognitive science. It is an argument that applies knowledge of a well-attested, experimentally confirmed cognitive process (conceptual domain mapping) to explain *how* primary sense words contribute to figurative meaning, and therefore, how using the primary, "literal" sense of "day" in Genesis 1 contributes to the overall figurative meaning of the passage.

2. Overview

Research over several decades in the field of cognitive linguistics has led to refined understandings of the function of metaphor in human language and cognition. Extensive research has shown that metaphorical thinking is central to human thought processes, and that *conceptual metaphors* (see section 3.2) are routinely used to understand and to reason, not just to describe. Humans are especially likely to rely on conceptual metaphors when thinking about things that are removed from their embodied, everyday experiences. Throughout history and in every culture, people tend to use their understanding of familiar, concrete concepts from everyday experience to reason about other concepts that are more abstract or less experientially accessible.[6] It is not surprising then that human attempts to explain and reason about spiritual and supernatural things rely on conceptual metaphors.

Understanding in two areas proves valuable for explaining *how* the creation week account in Genesis 1 works as figurative language: (1) how conceptual metaphors are different from the traditional idea of the literary metaphor (literary metaphors are called *image metaphors* within conceptual metaphor theory); and (2) how mapping of conceptual domains works (see section 3). Also, with a good grasp of how mapping works, tangential arguments about a figurative sense of the word יוֹם/*yom*/day[7] are shown to be irrelevant to the discussion of the overall figurative meaning of the passage (see section 4). Since many science-minded Christians are interested in supporting their biblical interpretations with language-based arguments, they should avail themselves of ones that are grounded in current thinking about how figurative language processing works. An examination of Roy Clouser's treatment of figurative language in his *PSCF* article "Reading Genesis"[8] is critiqued for ways in which it might be improved by using linguistic terms more precisely and by avoiding assertions about how language works that are unsupported from a linguistic perspective.

This article applies conceptual metaphor theory to defend three assertions: First, an underlying conceptual metaphor in Genesis 1 is CREATION IS WORK[9] (see section 3). God's supernatural creative acts of the target domain are mapped onto the more familiar and experiential source domain of human work. When hearers fail to recognize the underlying conceptual metaphor and cannot reproduce the conceptual mapping involved in processing the resulting figurative expressions, they may mistakenly take the text "literally" and infer a meaning not intended by the author. Second, in the context of Genesis 1, "day" is used in its primary sense to refer to a normal calendar day; it is not used in a figurative sense referring to a long era in that passage. This is not a problem because mapping does not require the mapped words for elements of the source domain to have figurative senses (see section 4). Although conventionalized metaphorical thinking can lead to words taking on figurative senses in addition to their primary "literal" sense, this process should not be invoked when discussing the days of Genesis 1, because it does not apply. Third, since multiple conceptual metaphors can be mapped simultaneously in figurative discourse, the

conceptual metaphor framework allows interpreters to affirm different insights proposed by Bible scholars about the meaning of the creation week passage at the same time (see section 5). Human language and cognition allow for mapping of elements of correspondence with not only the conceptual metaphor CREATION IS GOD'S WORK, but also others, such as THE COSMOS IS GOD'S TEMPLE, HUMANS ARE GOD'S IMAGE, or GOD'S REST IS GOD'S RULE. Affirming the presence of one underlying conceptual metaphor in no way asserts that it must be the only underlying conceptual metaphor in operation. This leaves open interesting avenues of exegetical investigation, as research into the cognitive environment of the ancient Near East can potentially uncover multiple conceptual metaphors that are realized in the figurative language of scripture.

3. Image Metaphors, Conceptual Metaphors, and Conceptual Mapping: Creation is God's work

3.1 Metaphor in cognitive linguistics

In conceptual metaphor studies, there is an important distinction made between *image metaphors* and *conceptual metaphors*. Image metaphors correspond to most English-speaking people's ideas of the classical literary metaphor, in which one noun is described with reference to another that has a salient point of similarity. "Image metaphor" can refer to any linguistic expression that accomplishes this kind of comparison, including what would traditionally be labeled metaphors, similes, or analogies. George Lakoff gives an example from a poem, "My wife … whose waist is an hourglass."[10] To understand this image metaphor, the mental image of the shape of an hourglass is mentally linked, or *mapped,* to the mental image of the wife. Any hearer familiar with the conventional shape of hourglasses will infer that the wife has a tiny waist.

In the image metaphor above, the speaker's concept of his wife's waist is independent of his concept of hourglasses. The mental connection, or *mapping*, between the two images is temporary for the purpose of the description. The meaning of an image metaphor can be expressed in descriptive, nonfigurative language that has no metaphor. One could simply say, "My wife has a tiny waist." Image metaphors can be novel expressions that no one has thought of before, as long as the source image (in this example, hourglass) is conventional enough that all the members of the culture/language group have similar ideas about its qualities and can easily infer the point(s) of similarity between the target (wife's waist) and the source that the speaker intends the hearer to infer. In other words, hearers must be able to successfully map the two images.

3.2 A conceptual metaphor in English: Love is a journey

In contrast to image metaphors, conceptual metaphors are not merely literary devices used for rhetorical or poetic purposes to *describe* a target. Conceptual metaphors are involved when a person *understands* conceptual domain A in terms of conceptual domain B. Whereas image metaphors make a connection between a salient feature of *one* image and a similar feature of another image, conceptual metaphors involve making *multiple* connections across entire conceptual domains. A conceptual domain is "a body of knowledge within our conceptual system that organizes related ideas and experiences."[11] In a conceptual metaphor, the target domain is *understood* by means of making systematic connections between corresponding members of another domain, the source.[12] This is easiest to understand by considering an illustration.

The conceptual domain LOVE would involve a set of concepts that may include such things as lovers, relationship status, commitment, positive feelings, shared life goals, close proximity/togetherness, intimacy, progress toward life goals, conflict, and conflict resolution. The conceptual domain JOURNEY would involve a set of concepts that may include things such as travelers, vehicles, roads, road conditions, landmarks, speed of travel, obstacles, scenery, destinations, and stops. In a conceptual metaphor, multiple members of the set of source domain concepts are mapped onto members of the target domain in a systematic way. With regard to conceptual metaphors, mapping refers to making these mental connections between corresponding elements of two different conceptual domains. A whole set of conventionalized mental connections between two domains is called a "mapping," and this is what forms a conceptual metaphor.[13] These conventionalized mappings, that is, conceptual metaphors, license a whole range of figurative linguistic expressions.[14]

To illustrate how such mapping works, consider the following expressions that rely on the concep-

tual metaphor LOVE IS A JOURNEY.[15] A conceptual metaphor is conventionally labeled by a proposition that relates the target (LOVE) and source (JOURNEY) domains. Research shows that the mappings that constitute conceptual metaphors are not temporary: they are stored in long-term memory.[16] All the linguistic realizations that derive from an underlying conceptualization of one domain in terms of another are referred to as "metaphorical expressions."[17] The following sentences illustrate metaphorical expressions of LOVE IS A JOURNEY.

> When we first got married, the road was pretty smooth.
>
> Things got rocky after the kids were born.
>
> We got back on track eventually.
>
> We eventually came to a crossroads.
>
> We knew we were stuck in a rut.
>
> Our relationship had stalled, and we had come to a dead end.
>
> We decided we needed to get out and go our separate ways.

The love relationship involved in this marriage is the target domain. In order to facilitate understanding about the experience of the two people involved in the relationship, the experience of traveling (the source domain) is mapped onto the experience of love (the target domain). Love is not just compared to a journey descriptively, but it is also understood and conceived of in terms of a journey. Instead of mapping a single image onto another image (as in an image metaphor), a whole set of concepts from one domain is mapped onto a set of corresponding concepts from another domain: travelers map onto lovers, destinations map onto shared life goals, roads and terrain map onto life events and their circumstances, obstacles map onto relational difficulties, and the vehicle maps onto the relationship.[18]

It is not possible to convert the mapped elements of the implicit conceptual metaphor LOVE IS A JOURNEY into a series of explicit image metaphors that simply *describe* the marriage and still convey an equivalent meaning. The speaker is not trying to say marriage is similar to a car, life is similar to a road, problems are similar to rocks, major decisions are similar to crossroads, and a failed relationship is similar to a dead end. Rather, the speaker is conceptualizing the abstract complexities of a relationship in terms of something that is experientially familiar and more concrete.

Within conceptual metaphor theory, "metaphor is treated as a general cognitive mechanism, not as a specifically linguistic one that works on the level of individual expressions."[19] What makes it conceptual rather than purely linguistic is the idea that the motivation for the metaphorical expressions exists at the level of conceptual domains.[20] Conceptual metaphors have been a topic of prolific investigation over the last several decades and conceptual metaphor theory is currently one of the most highly developed, empirically tested and refined, and cross-culturally researched subfields of cognitive linguistics.[21]

3.3 A conceptual metaphor in scripture: PEOPLE ARE PLANTS

Conceptual metaphors are ubiquitous in human communication because they are necessary to think about and understand human life experiences. They give rise to many linguistic expressions that are considered idiomatic, or figures of speech. Research in cognitive psychology has demonstrated that conceptual metaphors are conceptual before they are expressed in language. In other words, they are foundational to the thought that is being communicated. Unlike image metaphors, which can be expressed using nonmetaphorical language ("my wife has a tiny waist"), there is no more basic literal or nonfigurative meaning underlying metaphorical expressions derived from conceptual metaphors. They are grounded in everyday physical and social/cultural experiences, and they are so common and unconscious that people are often unaware they are relying on them.[22]

An example of an underlying conceptual metaphor in scripture is PEOPLE ARE PLANTS.[23] One specific realization of this metaphor occurs in metaphorical expressions about reproduction. In the ancient world, reproduction was not understood as modern scientific cultures understand it, as the meeting of two gametes resulting in the union of genetic information from both parents and the formation of a new organism. Instead, reproduction was conceptualized in the more concrete and experiential terms of agriculture. Members of the conceptual domain of agriculture were mapped onto corresponding members from the conceptual domain of reproduction. Humans were commanded by God to be fruitful.[24] A man planted his seed[25] in a woman's womb, which was either fertile or barren.[26] Children were referred to as the fruit of their mother's womb[27] and the fruit of their father's loins.[28] Offspring and descendants

were seeds.[29] Jesus was the shoot from Jesse's stump and the branch that grew out of Jesse's root.[30] These metaphorical expressions about reproduction reflect the underlying conceptual metaphor that was used in order to conceive of pregnancy, ancestry, and descendance. These expressions are not novel or poetic descriptive comparisons about a point of similarity between humans and plants; they are ordinary, everyday expressions that reflect metaphor-based cognitive processing.

Both the conventional images used in image metaphors and the underlying conceptual metaphors that give rise to metaphorical expressions can differ between cultures. The typical mappings that exist in the minds of people of one culture may not exist in the minds of people from another culture. Therefore, it is an important exegetical exercise to recognize and analyze both kinds of metaphors when they are used in scripture. Because conceptual metaphors are implicit, identifying them and determining whether they are accessible in a receptor culture is a more difficult task than analyzing the accessibility of explicit image metaphors used as literary devices. Considering the previously given examples of metaphorical expressions that rely on LOVE IS A JOURNEY (see section 3.2), it is conceivable to think of a culture or language in which people who did not have ready access to the underlying metaphor might not replicate the mapping it relies on and would interpret the translated metaphorical expressions "literally." They might assume the speaker was simply speaking of the source domain, a journey. But that would clearly be a misinterpretation.

3.4 Creation is work in Genesis 1

Turning to Genesis 1, there is ample evidence in scripture that CREATION IS WORK was an underlying conceptual metaphor in the biblical cultures. The familiar domain of human work is often mapped onto God's creative work: forming pottery,[31] working metal,[32] setting up a tent and hanging curtains,[33] gardening,[34] skilled handcrafting,[35] and governing,[36] to name a few examples.

The structure of the Genesis 1 creation account is stylized and poetic, and those literary features have been analyzed by numerous scholars. One other aspect to analyzing the figurative language in the account of creation week in Genesis 1 is to look for corresponding members of the source domain WORK that are being mapped onto the target domain CREATION (a domain which would include concepts such as Creator, acts of creation, domains of creation, functionaries, and unbounded time). The source domain is a set of concepts and experiences related to the human work of an artisan and ruler. The artisan/ruler is mapped onto God. The conventional work activities of decreeing, making things, separating, naming, evaluating results, delegating responsibilities, commanding, and providing resources are mapped onto God's acts of creation. The ruler's realm is mapped onto the domains of creation (day and night, sea and sky, land and vegetation) and the ruler's subjects are mapped onto the functionaries in those domains (sun, moon, and stars; fish and birds; animals and humans). In the Hebrew cognitive environment, human work operated within the constraints of the unique Jewish cultural practice of a six-day work week followed by a Sabbath rest; therefore, the work week is mapped onto the unbounded time of creation.[37]

As was the case with the hypothetical example of the translation of the LOVE IS A JOURNEY expressions, those who do not access the implicit conceptual metaphor will fail to understand the figurative meaning of the mapped elements and may interpret the metaphorical expressions "literally." This would lead to mistakenly understanding the creation work week to be the actual time frame of creation instead of a member of the set of correspondences from the source domain of human work.

4. Discussing Figurative Meaning with Reference to Established Concepts in Semantics, Pragmatics, and Communication Theory

4.1 Literal and figurative meaning

Because human thought is often foundationally metaphorical, some cognitive linguists do not believe that there is a meaningful distinction between literal and figurative language.[38] However, most people still have a notion of literality, and the word "literal" is often used in discussions of biblical interpretations. In order to discuss literal and figurative language in the context of biblical interpretation productively, a basic understanding of some foundational concepts in semantics and pragmatics is necessary. For much of the history of linguistic thought, a model of communication called "the code model" prevailed. This model assumed that words were arbitrary sym-

bols that encoded meaning. When words were put together according to the rules of a language's grammar, the individual meaning units added up to a calculable meaning that could be decoded. Language and meaning were studied primarily as abstractions, divorced from social use.

Over time it became apparent that many of the rules developed by formal semantics did not explain how hearers arrived at the meanings they understood when language was used in natural ways. The linguistic subdiscipline of pragmatics seeks insights into aspects of meaning that are communicated by the social use of language by real people in real contexts. Pragmatics has expanded into an immensely fruitful and complex field of linguistic inquiry. The rise of pragmatics led to new models of language processing and meaning construction, and the code model of communication has largely been abandoned in favor of "an inference-based model."[39] In this model, words are seen as triggers that activate mental representations in a person's cognitive environment (their knowledge, memories, and beliefs). Speakers rely on the common ground they share with hearers (shared concepts, shared cultural frames and linguistic conventions, and shared context) to trigger the hearer's inferences about the speaker's intended meaning. Inferences work in predictable ways based on relevance to the shared context.

A sentence's "literal meaning" is the meaning calculated from the combination of the conventional meanings of the words used, independent of any pragmatic inferences that would result if the sentence were used by a speaker in a specific context.[40] For example, the literal meaning of the sentence "I am starving" is that the subject is dying of malnourishment. If the sentence were spoken as someone perused a menu at a restaurant, most hearers would infer a nonliteral meaning instead, that the subject is hungry and looking forward to a good meal.[41] When we are talking about the interpretation of natural texts, linguists are usually concerned about the speaker's intended meaning and the hearer's inferred meaning, not the literal meaning of the sentences.

Formal semantics involves treating language as an abstraction that can be studied independent of its use in a social, communicative context. Unfortunately, the code model of communication, combined with the idea of literal sentence meaning is sometimes misappropriated by some Bible translators and biblical interpreters to assert that the "truth" of the biblical text lies in some decontextualized abstraction, instead of in what the author intended to communicate and what the original audience would have inferred. In biblical interpretation, the concern should be the intended and inferred meaning of the original speakers and hearers, not the literal meaning of decontextualized sentences.

4.2 Polysemy and figurative senses

In semantics, "polysemy" is a single word that has multiple related meanings or *senses*. This is represented in dictionaries under a single word entry, with the first definition giving the primary sense (what many people associate with the "literal meaning"), and other secondary senses following in a numbered list. For example, a "hawk" is a bird of prey, but a secondary sense refers to a combative person quick to promote aggressive military solutions.[42] Over time, conventionalized conceptual metaphors often lead to words developing a secondary figurative sense related to a frequently associated target domain.[43] When linguists refer to "senses," they are referring to conventional meanings in the lexicon—in other words, definitions that speakers of the language would be able to provide if asked what the word means.

In discussions of possible interpretations of Genesis 1, there is often confusion between the *figurative meaning* of a text and the *figurative sense* of an individual word used in the text. It is a mistake to conflate the figurative or literal sense of a single word used in a text with the overall figurative or literal meaning of the text in which it is found. When corresponding ideas from the source domain are mapped in a metaphorical expression, the lexical items themselves do not necessarily have a conventionalized figurative sense in the lexicon that corresponds to the target domain. That is to say, the individual words referring to elements of the source domain are usually used in their primary senses even though the overall meaning of the text is calculated as figurative via mapping.

For example, in the New Testament passage where Jesus relies on the conceptual metaphor JESUS IS A SHEPHERD,[44] a set of concepts related to shepherding is mapped onto a corresponding set of concepts related to Jesus and his followers. The sense of the word ποιμήν in the passage is the primary sense

"shepherd," a worker who cares for sheep. The same word ποιμήν can be used with a figurative sense "pastor" in Koine Greek, as seen in Ephesians 4:11. But in the Good Shepherd passage, the word ποιμήν that is mapped onto Jesus is not the figurative sense "pastor," it is the primary sense "caretaker of sheep." The passage is interpreted figuratively because of the mapping between the two domains, not because a polysemous word with a figurative sense was used.

4.3 Primary sense of a single word does not rule out a figurative interpretation of the text

An analysis similar to the Good Shepard passage applies to the word יוֹם/*yom*/"day" in Genesis 1. Among Christians interested in origins, a significant amount of time and effort has been invested in debating whether יוֹם/*yom*/"day" in Genesis 1 is used in its primary ("literal") or figurative sense. On nearly every origins-focused organizational website or personal blog, a person can find entries dedicated to "the meaning of 'day' in Genesis 1," often with arguments that either try to establish that the word has a figurative sense or try to prove it is used in its primary sense. The assumption seems to be that if it can be shown that the word "day" is used in a figurative sense, it will prove that the entire text should be interpreted figuratively, and conversely, if it can be shown that "day" is used in a primary sense, then the text necessarily records "literal history."

Hebrew scholars generally agree that the word for "day" in Genesis 1 is being used in the primary sense; a normal day, not the figurative sense referring to an era of time.[45] However, it is a fallacy to conclude that, because the word יוֹם/*yom*/"day" is being used in its primary sense, the text in which it is found therefore cannot have a figurative meaning and must be interpreted "literally." It is expected that words related to source domains invoke primary, "literal" senses, not abstract, figurative ones. The reason humans rely on conceptual metaphors in the first place is that they need concrete, experiential source domains to understand more abstract target domains. Recalling the figurative expressions derived from the conceptual metaphor LOVE IS A JOURNEY (section 3.2), there is no need to invoke special figurative definitions of the individual words "rocky," "crossroads," or "dead end" to process the figurative meaning of the sentences. What is necessary is access to the implicit conceptual metaphor, LOVE IS A JOURNEY, which licenses the metaphorical expressions based on the mapping. The mapping involved in constructing the figurative meaning makes use of the normal, primary senses of the words. Even though it is clear that the speaker is talking about relationship problems, decisions affecting the relationship's fate, and relationship failure, those meanings are not necessarily part of the conventional senses of the words "rocky," "crossroads," or "dead end" from the source domain.[46] If the journey words eventually develop figurative senses associated with relationships, it is only because the mapping has become conventional, not because the mapping requires the figurative senses to exist for it to work.

4.4 Basing conclusions on intuition instead of on the science of language and language processing

In "Reading Genesis," an article which touches on the figurative language of Genesis 1, Clouser illustrates the fact that many people discussing figurative meaning do not avail themselves of the tools linguistics provides to analyze it.[47] Using linguistic terms in imprecise ways and making unsupported claims about how language works weakens an argument. Although Clouser's assertion that the reference to "literal" days in Genesis 1 contributes to an overall figurative meaning is sound, his arguments in support of this conclusion are flawed from a linguistic perspective. He uses an idiosyncratic definition of literal meaning, he assumes all metaphorical expressions function like image metaphors (and claims "day" is part of one), and he seems to claim that the word "day" can have both a literal and figurative sense in single use.

When fundamentalists appeal to "literal meaning," they are usually equating "literal meaning" with the assumption that Genesis describes historical facts.[48] Clouser rightly rejects this misconception, but counters it by using "literal meaning" to refer to the author's intended meaning. This misuse of the term leads to claims such as "if a text is figurative, symbolic, metaphorical, anthropomorphic, or poetic, then its prima facie literal meaning is figurative, symbolic, metaphorical, anthropomorphic, or poetic."[49] This makes no sense from a linguistic perspective, because literal meaning and figurative meaning are considered mutually exclusive. If a text has a figurative meaning, it means that pragmatic inferences prevent a relevant literal interpretation in the context.[50]

Clouser asks questions that reveal confusion about how the sense of individual words relates to the overall literal or figurative intended meaning of the entire text. He asks:

> (1) Why take the days as literal in the midst of an account that is from the outset so thoroughly figurative? (2) What could justify the claim that we must switch back and forth between the anthropomorphism of God speaking and a literal understanding of the days of his creating? and (3) How can such switches avoid being wholly arbitrary?[51]

In fact, as demonstrated in section 4.3, words are commonly used with primary, literal senses, even though the intended meaning of the whole text is figurative. Human brains seem to use conceptual domain mapping quite effortlessly to process figurative language that uses primary sense words. Figurative language in Genesis 1 (which does include anthropomorphic imagery about God, since it relies on the source domain of human work) does not in any way entail that the word "day" is used in a figurative sense in the passage. It does indicate that "day" should be processed as part of an overall intended figurative meaning because it is a member of a set of correspondences to the conceptual domain of human work. It is better to talk about how figurative meaning is constructed in terms of the cognitive processing of language, instead of simply asserting that the figurative meaning is intuitively obvious and that switches to primary sense words would be "arbitrary." Such switches prove to be quite systematic and common to human communication.

Clouser also claims that "the literal meaning of 'day' is not incompatible with its also having a metaphorical meaning."[52] If Clouser is talking about the meaning of the word, this is incorrect. Individual words can be used only with one sense at a time unless a person is intentionally making a pun.[53] The sense of the word "day" is not figurative; rather, the intended meaning of the text in which it is found is figurative. This is a more precise and more accurate claim than saying individual words can be used with two intended meanings at the same time.

Clouser also makes the mistake of claiming that "day" functions as a metaphor for God's timeless accomplishment of his purposes. Biblical literalists are right to call foul on this kind of assertion, because there is no such metaphor in the text. The passage does not say, explicitly or implicitly, that a day is God's timeless accomplishment of his purposes. If it did, what would such a metaphor mean? Image metaphors rely on a salient point of similarity when two images are compared. In order for the intended meaning to be easily inferred, image metaphors rely on conventional images. Most people in the culture/language group must associate similar qualities with the source domain image. Image metaphors describe a characteristic of the target based on something everyone readily envisions about the source. What conventional qualities did most Hebrews associate with the image of a day? What would the point of similarity be between the conventional qualities of a day and God's timeless accomplishment of his purposes? What specific quality would supposedly be in view? What underlying literal description would this alleged metaphor be asserting? The figurative nature of the metaphorical expressions in the passage derives from the underlying conceptual metaphor CREATION IS WORK not from an image metaphor that descriptively compares a day to something else.

5. Simultaneous Mapping Is Allowed and Expected and Useful in Exegesis

One potentially interesting application of conceptual metaphor theory for biblical exegesis and hermeneutics is the identification of underlying implicit metaphors that may not translate well, either culturally or linguistically. John Sanders offers an introduction to the field of cognitive linguistics and its implications for biblical interpretation and theology in his book *Theology in the Flesh: How Embodiment and Culture Shape the Way We Think about Truth, Morality, and God*.[54] His book is a challenge to those involved in biblical interpretive work to focus more consciously on the identification of conceptual metaphors and issues that surface with cross-cultural translation. It is a challenge worth accepting because the potential for study in this area is boundless; asserting that one underlying conceptual metaphor is expressed in a text does not assert that it is the only conceptual metaphor used to process a given text in the way the original audience would have understood it. There is always more to uncover.

More than one underlying metaphor can surface in a discourse, especially in highly literary texts. Lakoff explains that simultaneous mappings are very common in poetry:

> Take for example, the Dylan Thomas line "Do not go gentle into that good night." Here *go* reflects

> DEATH IS A DEPARTURE, *gentle* reflects LIFE IS A STRUGGLE, with death as defeat. *Night* reflects a LIFETIME IS A DAY, with death as night. This one line has three different metaphors for death, each mapped onto different parts of the sentence.[55]

Bible scholars who specialize in Genesis have examined interpretive implications of underlying conceptualizations such as THE COSMOS IS GOD'S TEMPLE,[56] HUMANS ARE GOD'S IMAGE,[57] and GOD'S REST IS GOD'S RULE.[58] The vocabulary and descriptions of cognitive processes offered by conceptual metaphor theory can add strength to these interpretations because they provide exegetes with a model for making explicit the correspondences that they assert were accessible to the original audience. Making ancient Near East conceptual metaphors explicit, equips Christians in a different cultural context to better process figurative language, and to avoid misinterpretations that result from taking metaphorical expressions about the source domain literally instead of mapping correspondences onto the target domain.

6. Conclusion

One does not need to be a linguist to use conceptual metaphor theory to analyze the way people mentally process figurative language. Since all Christians presumably want to get the most meaning possible from scripture and avoid misinterpretation, any tools that help people understand cross-cultural, translated texts better will be beneficial.

To summarize and reiterate, this was the argument presented: Conceptual metaphors are distinct from image metaphors; they are important for understanding and communicating complex, abstract ideas. Underlying conceptual metaphors in the mind are expressed in figurative language, in which a more concrete, experiential conceptual source domain maps onto another more complex, abstract conceptual target domain. In Genesis 1, the conceptual domain of WORK is mapped onto CREATION and results in metaphorical expressions. The individual word "day" used in the passage is a member of the set of mapped elements from the conceptual domain of WORK. Words can have primary and figurative senses, and the word "day" in Hebrew has both. However, words do not have to be used in their figurative sense to be a member of mapped correspondences. In fact, it is usually primary sense words that are mapped onto a target domain because they are more concrete. Concrete words are to be expected in source domains derived from embodied human experience. The word "day" may be used in its primary sense and still contribute to overall figurative meaning. The figurative meaning results from conceptual domain mapping, not from the semantics of the word "day."

Hopefully, these insights from cognitive linguistics will equip science-minded Christians to better defend their figurative interpretations of Genesis 1. ♥

Notes

[1]Richard Briggs, *Words in Action: Speech Act Theory and Biblical Interpretation* (London, UK: T&T Clark, 2004).
[2]Karen H. Jobes, "Relevance Theory and the Translation of Scripture," *Journal of the Evangelical Theological Society* 50 (2007): 773–97.
[3]Steven E. Runge, *Discourse Grammar of the Greek New Testament: A Practical Introduction for Teaching and Exegesis* (Bellingham, WA: Lexham Press, 2010).
[4]John Sanders, *Theology in the Flesh: How Embodiment and Culture Shape the Way We Think about Truth, Morality, and God* (Minneapolis, MN: Fortress Press, 2016).
[5]For example, see J. Ligon Duncan III, David Hall, Hugh Ross, Gleason Archer, Lee Irons, and Meredith Kline, *The Genesis Debate: Three Views on the Days of Creation,* ed. David G. Hagopian (Mission Viejo, CA: Crux Press, 2000).
[6]Barbara Dancygier and Eve Sweetser, *Figurative Language* (Cambridge, UK: Cambridge University Press, 2014), 62–67.
[7]Hugh Ross, *A Matter of Days: Resolving a Creation Controversy*, 2nd expanded ed. (Covina, CA: Reasons to Believe, 2015).
[8]Roy Clouser, "Reading Genesis," *Perspectives on Science and Christian Faith* 68, no. 4 (2016): 241–45.
[9]It is a convention in cognitive linguistics to label conceptual metaphors with a proposition in small capitals.
[10]George Lakoff, "Image Metaphors," *Metaphor and Symbolic Activity* 2, no. 3 (1987): 219–22.
[11]Vyvyan Evans and Melanie Green, *Cognitive Linguistics: An Introduction* (Mahwah, NJ: Lawrence Erlbaum Associates, 2006), 14.
[12]Sanders, *Theology in the Flesh*, 49.
[13]Zoltan Kövecses, *Metaphor: A Practical Introduction,* 2nd ed. (New York: Oxford University Press, 2010), 8.
[14]Evans and Green, *Cognitive Linguistics: An Introduction,* 164.
[15]For further investigation of this conceptual metaphor, see George Lakoff, "Conceptual Metaphor," in *Cognitive Linguistics: Basic Readings*, ed. Dirk Geeraerts (Berlin, Germany: Mouton de Gruyter, 2006), 189–96.
[16]Evans and Green, *Cognitive Linguistics: An Introduction,* 295.
[17]Lakoff, "Conceptual Metaphor," 185–86.
[18]Sanders, *Theology in the Flesh*, 191.
[19]Dirk Geeraerts, "A Rough Guide to Cognitive Linguistics," in *Cognitive Linguistics: Basic Readings*, 11.
[20]Evans and Green, *Cognitive Linguistics: An Introduction*, 295.
[21]Raymond W. Gibbs Jr., "Evaluating Conceptual Metaphor Theory," *Discourse Processes* 48, no. 8 (2011): 556.

[22]Geeraerts, "A Rough Guide to Cognitive Linguistics," 27; and Sanders, *Theology in the Flesh,* 51.
[23]Lakoff discusses how this underlying metaphor also affects many of the ways in which English speakers speak figuratively about life and death in "Conceptual Metaphor," 218.
[24]Gen. 1:28.
[25]Gen. 38:9.
[26]Gen. 11:30, 20:18, 25:21.
[27]Deut. 28:11; Luke 1:42.
[28]Acts 2:30.
[29]Gen. 3:15, 4:25; Lev. 18:21; 1 Sam. 1:11; 2 Kings 11:1; 2 Chron. 20:7; Ezra 9:2; Esther 10:3; Isa. 6:13; Jer. 2:21.
[30]Isa. 11:1, 10.
[31]Isa. 29:16, 45:9, 64:8.
[32]Job 37:18.
[33]Isa. 40:22.
[34]Gen. 2:8; Isa. 5:6–7.
[35]Pss. 8:3, 139:13–14; Eph. 2:10.
[36]Job 38:11; Prov. 8:29.
[37]Inherent in this explanation are some assumptions about the compilation and editing of Genesis over time, and that the six-day work week and Sabbath rest were established culturally in Judaism before the Genesis creation account was completed in the form available now. For a discussion of the cultural and religious significance of the Sabbath in relation to the creation account, see Bruce Waltke, *Genesis: A Commentary* (Grand Rapids, MI: Zondervan, 2001), 71–73. Obviously, if someone takes the written creation account itself as the origin of the unique Jewish cultural practice of six days of work followed by one day of Sabbath rest, he or she will have problems with the explanation provided here. Evaluating arguments for the origins of Jewish Sabbath practices in relation to the dating of Genesis 1 is beyond the scope of this article.
[38]Evans and Green, *Cognitive Linguistics: An Introduction,* 287.
[39]For example, see Dan Sperber and Deirdre Wilson, *Relevance: Communication and Cognition* (Oxford, UK: Blackwell, 1986) and Thomas Scott-Phillips, *Speaking Our Minds* (New York: Palgrave Macmillan, 2015).
[40]Paul Kroegter, *Analyzing Meaning: An Introduction to Semantics and Pragmatics* (Berlin, Germany: Language Science Press, 2018), 2.
[41]Raymond Gibbs identifies four definitions of "literal meaning": *conventional literality* (literal use is contrasted with poetic use, exaggeration, etc.); *nonmetaphorical literality* (no word or concept is understood in terms of another); *truth conditional literality* (the language refers objectively to things existing in the world and can be rated true or false); and *context-free literality* (the literal meaning is the meaning that does not depend on a communicative situation). The last definition is the one used in this article, but cognitive linguists point out that even when a sentence is interpreted without reference to a communicative context, interpreting words depends on the background knowledge of the hearer, which itself constitutes a cultural and linguistic context. Raymond W. Gibbs, *The Poetics of Mind* (Cambridge, UK: Cambridge University Press, 1994), 75; Evans and Green, *Cognitive Linguistics: An Introduction*, 289–93.
[42]Polysemy is not the same thing as homonymy, which occurs when a word has multiple unrelated meanings. A homonym for the noun "hawk" is the verb "hawk," which means to sell wares, typically by calling out in the street. Homonyms are represented by separate entries in a dictionary.
[43]Kroeger, *Analyzing Meaning*, 54–55.
[44]John 10:11–18.
[45]John H. Walton, *The Lost World of Genesis One* (Downers Grove, IL: InterVarsity Press, 2009), 90–91.
[46]Lakoff, "Conceptual Metaphor," 194. "Mappings should not be thought of as processes, or as algorithms that mechanistically take source domain inputs and produce target domain outputs. Each mapping should be seen instead as a fixed pattern of correspondences across domains that may, or may not, be applied to a source domain knowledge structure or a source domain lexical item. Thus, lexical items that are conventional in the source domain are not always conventional in the target domain. Instead, each source domain lexical item may or may not make use of the static mapping pattern. If it does, it has an extended lexicalized sense in the target domain, where that sense is characterized by the mapping. If not, the source domain lexical item will not have a conventional sense in the target domain but may still be actively mapped in the case of a novel metaphor."
[47]Clouser, "Reading Genesis," 241–45.
[48]Simon Turpin, "Is Genesis Literal, Literalism, or Literalistic?" (Answers in Genesis, May 2, 2016), https://answersingenesis.org/hermeneutics/is-genesis-1-literal-literalism-or-literalistic.
[49]Clouser, "Reading Genesis," 241.
[50]John I. Saeed, *Semantics,* 3rd ed. (West Sussex, UK: Wiley-Blackwell, 2009), 15.
[51]Clouser, "Reading Genesis," 243.
[52]Ibid.
[53]Kroeger, *Analyzing Meaning,* 6.
[54]Sanders, *Theology in the Flesh*.
[55]Lakoff, "Conceptual Metaphor," 203.
[56]Walton, *The Lost World of Genesis One*, 77–85.
[57]J. Richard Middleton, "The Liberating Image? Interpreting the *Imago Dei* in Context," *Christian Scholar's Review* 24, no. 1 (1994): 8–25.
[58]Walton, *The Lost World of Genesis One*, 72–76.

Alan Dickin

The Table of Nations and the Spread of Human Civilization: New Genetic Evidence

Alan Dickin

Adam is regarded as either the biological or the spiritual father of the human race. However, since all of Adam's descendants except Noah and his family were annihilated by the Flood, the biblical account of humanity's dispersal over the earth begins in the Table of Nations (Genesis 10). On the other hand, scientific evidence describes two episodes of mass human migration, when small groups of modern humans spread out geographically to cover much of the earth. The first of these was the "out of Africa" migration around 55,000 years BC, while the second was a lesser-known agriculturalist migration from the Middle East beginning around 8000 BC.

The objective of this article is to compare genetic evidence for the second of these two migrations with the biblical Table of Nations. Dating Noah's Flood to the Neolithic Period is a key step to bringing the Table of Nations and the agriculturalist dispersal event into harmony. Genomic evidence shows that the outward spread of agriculturalists from southeast Anatolia began slightly earlier than the most likely date of Noah's Flood in Mesopotamia. However, the outward migration of agriculturalists probably left behind deserted villages in southeast Anatolia and Northern Mesopotamia that resembled the ruined settlements of Southern Mesopotamia devastated by the Flood. Hence, it was natural that ancient peoples attributed the outward migration of Neolithic agriculturalists to the spread of Noah's descendants, conflating these movements out of Mesopotamia. It is concluded that Genesis contains a remarkably accurate picture of the Neolithic origins and spread of human civilization in the Middle East.

There have been many attempts to reconcile Genesis with a scientific account of origins. One approach envisages biblical Adam and Eve as the first modern humans, and hence as the biological ancestors of the human race. An African origin for the human race has long been implied by fossil evidence, and in the 1980s this was supported by mitochondrial DNA evidence, requiring a common origin of all human mitochondria from a single African woman who lived around 200,000 years ago.[1] Since that time there has been a flood of genetic and anatomical data that point to the origins of modern humans (*Homo sapiens*) in Africa around 300,000 years ago.[2] Nearly a quarter of a million years later, the principal exodus of humans from Africa occurred around 55,000 years ago,[3] but a smaller exodus that led to the populating of Australia may have occurred about 20,000 years earlier.[4]

In recent articles attempting to reconcile the genetic evidence with a view of Adam as the biological father of the human race, David Wilcox placed biblical Adam in Africa around 150,000 years ago.[5] He suggested that Adam might have emerged from a demographic bottleneck that allowed a small society of humans to undergo divine enculturation, when

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"divine revelatory activity programmed a new cultural operating system into the brain(s) of one (or a few) humans."[6] Wilcox speculated that this was also the point at which human sin entered the picture, as a conscious decision to disregard God's authority.

Theologically, it has been argued that common descent from Adam is necessary to preserve the "common dignity of all people."[7] However, this model raises problems of both a temporal and spatial nature. Temporally, it situates Adam in the remote prehistoric past, tens of thousands of years before the agricultural setting of his sons Cain and Abel. Spatially, it moves Eden from Mesopotamia to Africa, requiring Adam's descendants to be dispersed from there around the world. This is a problem because the Bible contains no hint of an epic migration out of Africa that led to human dispersal over the earth. On the other hand, Genesis does claim a major human dispersal event, beginning after Noah's Flood and commonly referred to as the Table of Nations (Genesis 10).

The Table of Nations comprises a family tree of Noah's three sons—Shem, Ham, and Japheth—who are claimed to be the ancestors of all Middle Eastern peoples. This account of human dispersal from Noah's sons could be connected with the migration out of Africa around 55,000 years ago. However, recent genetic evidence records a less well-known but equally dramatic migration event that occurred in the Neolithic Period after 9000 BC. This new evidence, published in the past five years, includes genome-wide DNA signatures obtained from hundreds of modern and ancient individuals. Hence, it seems logical to see whether this new evidence can help us understand the story of human dispersal told in the Table of Nations.

The Origins of Human Civilization

A Neolithic human dispersal event would be consistent with the more recent setting for Adam proposed by Denis Alexander, "God in his grace chose a couple of Neolithic farmers in the Near East, or maybe a community of farmers, to whom he chose to reveal himself in a special way."[8] If this view is correct, Adam cannot be the biological father of the human race. However, John Walton has argued that Adam's unique biblical status derives not from his biological parenthood, but from his election by God as a *priestly representative* of humankind.[9] In this way, all of humanity would have inherited the spiritual consequences of Adam's sin without being his biological descendants.

Placing Adam in a Neolithic setting suggests that Genesis is describing events associated with the origins and spread of human *civilization* rather than the human race as a whole. For example, several lines of evidence suggest that Adam's sons were not alone on the earth in Genesis 4: Cain fears retribution from unknown assailants; he mysteriously finds a wife; and he becomes a city builder, implying a significant number of people living together. The description of Cain as a city builder is critical because civilization literally means "life in cities." If Genesis is describing the origins of human civilization, this implies that the Table of Nations is describing the spread of civilization after the Agricultural Revolution. However, Genesis also claims that this spread of civilization was interrupted by Noah's Flood. Therefore, if the Flood was a real event, it is critical to understand its time and place in the story of human origins.

The Significance of Noah's Flood

The Great Flood is an important reference point in human history because it is reported in three different Mesopotamian accounts, allowing detailed comparison with the biblical Flood story. Since the nineteenth century, the common origins of the biblical and Mesopotamian accounts have been understood, based on minute similarities such as the sending out of birds to test the abatement of the floodwaters.[10] Based on this commonality, there has been strong reliance on Mesopotamian literary evidence to date Noah's Flood.

The most well-known version of the Sumerian King List (the Weld-Blundell prism) has been widely used to date Noah's Flood to around 2900 BC, at the beginning of the Early Dynastic Period of Sumerian history.[11] However, an earlier version of the Sumerian King List contains no mention of the Flood or the ante-diluvian dynasties that were supposed to have ruled Mesopotamia before the Flood.[12] Furthermore, these ante-diluvian dynasties are known to be mythical, since archaeological evidence shows that Uruk was the dominant city of ancient Mesopotamia prior to the Early Dynastic Period.[13] Therefore, it is evident that the King List does not provide any reliable evidence to date the Flood. However, both the biblical

and Mesopotamian literary sources provide indirect evidence for its date.

All of the ancient sources agree that there were no known survivors of the Flood outside the Ark, and these claims of human annihilation are supported by the New Testament letters (Heb. 11:7; 1 Pet. 3:20; 2 Pet. 2:5) and the quoted sayings of Jesus (Matt. 24:38–39; Luke 17:26–27). Hence, these sources validate the ancient belief expressed in the Table of Nations that the earth was repopulated by Noah's sons after the Flood. This is important because this belief is credible only if the Flood is placed in the remote prehistoric past, not at the mature stage of civilization that is implied by the Weld-Blundell prism.

A Neolithic date for the Flood is supported by archaeological evidence, which reveals a complete continuum of mud-brick architecture in several cities of ancient Mesopotamia, going back to around 5500 BC.[14] It is highly unlikely that such architecture could have survived prolonged inundation without signs of water damage. When this evidence is coupled with the complete interruption of human civilization described in both biblical and Mesopotamian Flood stories, it points to a date for Noah's Flood before 5500 BC. This is supported by geological and paleoclimate evidence for a period of intense rainfall events in the first half of the sixth millennium BC, in the Late Neolithic period.[15] However, evidence that the Flood occurred in the Late Neolithic period has led some scholars to suggest that it was not the result of a catastrophic river flood, but was caused by sea-level rise after the last glacial period. One of the most widely known of these alternatives is the Black Sea deluge theory.

The Black Sea Deluge Theory

The Black Sea was isolated from the Mediterranean during the last Ice Age, when global sea-level dropped below the bottom of the Bosporus Strait (BS, fig. 1). During much of this time, the level of the Black Sea was maintained by river flow from the north. However, based on evidence for a period of aridity during the Younger Dryas event beginning around 11,000 BC, the level of the Black Sea could have dropped at that time. As a result, settlements might have been established on the ancient shoreline at depths up to 100 m below present-day sea-level (locations marked RP in fig. 1). Therefore, when rising sea-level overtopped the Bosporus Strait, any such settlements would have been submerged when the Black Sea was refilled. Since the level of the Black Sea could have risen by up to 10 cm per day, this might have led to ancient Flood myths.

Proposed by Ryan and Pitman,[16] the Black Sea deluge theory led to a vigorous debate that has continued over many years. Ryan has continued to defend the original model in several papers, including recent geophysical investigations.[17] However, the model has been weakened in several ways. Firstly, all authors now agree that the initial entry of Mediterranean water into the Black Sea had already begun by 7300 BC, and possibly as early as 7600 BC, approximately 2,000 years earlier than originally proposed.[18] This suggests that seawater incursion was much slower than originally thought.[19] In fact, seawater could have entered the Black Sea by seeping along the bottom of the Bosporus Strait, even if there was a net outflow of fresh water from the Black Sea at the same time.[20] This flow pattern exists at the present day, with brackish water flowing southwards along the Bosporus at the surface while salt water flows northwards at the sea bed.

These lines of evidence greatly weaken the idea that the flooding of the Black Sea caused catastrophic loss of human life. However, there is even more critical

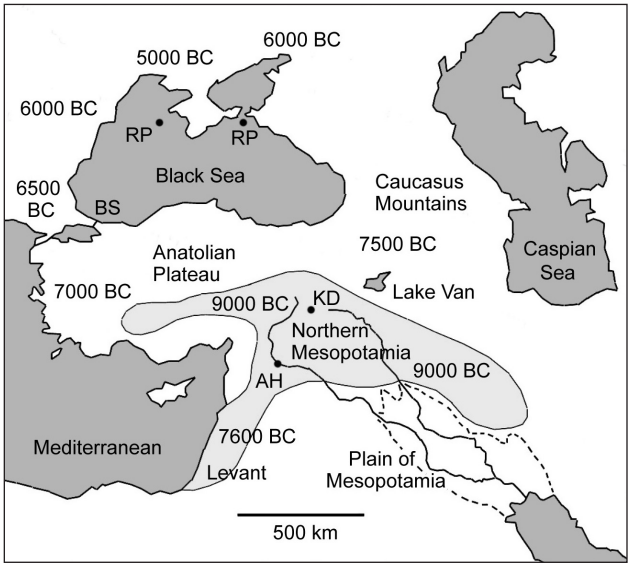

Figure 1. Map of the Middle East showing alternative sites of a Neolithic Flood (the Black Sea and Mesopotamia) relative to approximate dates for the appearance of Neolithic culture in different regions. Locations mentioned in the text: BS = Bosporus Strait; RP = sites examined by Ryan and Pitman; KD = Karaca Dag; AH = Abu Hureyra. Modified after Broushaki et al.[21]

literary evidence against the idea that the flooding of the Black Sea inspired the story of Noah's Flood. After the incursion of sea-water, the level of the Black Sea never subsequently went down, whereas the receding floodwaters and the drying of the earth are vitally important parts of the story of Noah's Flood. Therefore, given that the preceding and following chapters in Genesis are set in Mesopotamia, it is clear that Noah's Flood was a catastrophic river flood on the Mesopotamian plain. This location for the Flood is also closely adjacent to the earliest appearance of Neolithic culture arising from the Agricultural Revolution (grey shading in fig. 1).

The Agricultural Revolution

Although some claims have been made for early forms of agriculture in isolated populations during the last Ice Age, there is little doubt that the Agricultural Revolution as a world-changing event began around 9000 BC, initiating the Neolithic Period. Around this time, the first signs of animal husbandry are indicated by a change in the age and sex distribution of sheep and goat skeletons from ancient settlements.[22]

Based on skeletal remains, it was observed that earlier societies had focused their hunting efforts on the largest mature specimens of prey animals. During the Younger Dryas period, wild populations were probably stressed by the adverse cold, dry conditions.[23] In response, it appears that Neolithic humans reacted by beginning to manage wild sheep and goat populations, targeting young males and sparing females until they had reached menopause. This change in the skeletal assemblages suggests that domestication of sheep and goats began around 9000 BC, the former in northwestern Mesopotamia (SE Anatolia) and the latter to the east (Zagros Mountains), with an overlap in the Lake Van area of Eastern Turkey (fig. 1).

A short time later, around 8500 to 8000 BC, the domestication of pigs and cattle is also identified near the upper reaches of the Tigris and Euphrates rivers of Northern Mesopotamia (fig. 1). Subsequently, these domesticated groups spread out along the Fertile Crescent, which is the zone with sufficient rainfall to conduct subsistence farming without the need for irrigation. For example, domesticated goats reached the Levant around 7600 BC, followed shortly by sheep, pigs, and cattle.

Evidence for the domestication of cereal crops is recorded in a somewhat different form, by the selection of grain morphology that made cereals more suitable for harvesting and threshing.[24] In wild varieties of wheat and barley, the seed is weakly attached to the rachis (stem) of the ear, allowing individual grains to be easily detached, while the husk is strongly attached to the seed, promoting wind dispersal. In contrast, domesticated varieties have seeds that are more strongly attached to the ear (preserving it intact until harvesting), while the husk is more readily detached during threshing. In the earliest domesticated wheat variety, called Einkorn, the readily detached husk leads to what are called "naked" seeds. These seeds are also larger than wild wheat seeds, providing better nutrition. These changes in grain morphology (particularly the appearance of naked seeds) allow the appearance of domesticated cereals to be detected around 9000 BC at Abu Hureyra in Northern Mesopotamia (fig. 1).[25]

Because wild cereal populations persist to the present day as weeds, their genetic diversity is more readily compared with domesticated varieties than is possible for domestic animals (whose wild populations are depleted). This allows the geographical site of cereal domestication to be determined from genomic data on modern cereal varieties. The evidence suggests that cereal crops also originated from the region of Northern Mesopotamia. In the case of einkorn wheat, the genetic evidence suggests that all domesticated varieties arose from a single branch of the wild population (fig. 2). The wild einkorn population most closely related to domesticated wheat comes from the region of Karaca Dag, located in southeast Turkey between the headwaters of the

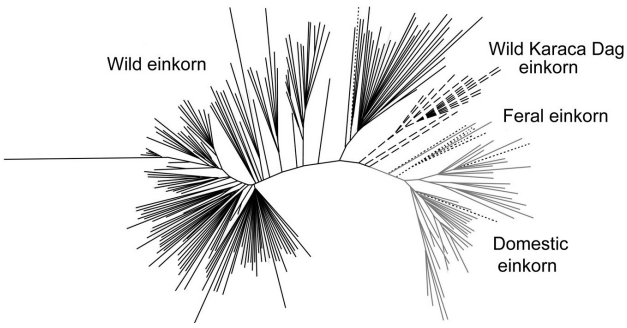

Figure 2. Genetic tree of einkorn wheat, showing the common origin of all domesticated varieties (grey lines) from wild Karaca Dag wheat (dashed lines). Feral wheat varieties (dotted lines) are a secondary mixture of wild and domesticated wheat. Modified after Salamini et al.[26]

Tigris and Euphrates (fig. 1). Therefore, it is inferred that the domestication of wheat occurred in this mountainous area of Northern Mesopotamia.

Human Genetic Studies

Archaeological evidence suggests that the practice of agriculture spread across the world in the millennia after the Agricultural Revolution. This spread was particularly dramatic in Europe, where it appeared to move from Eastern to Western Europe in an enormous wave of human migration.[27] Hence, this model was very attractive for testing using genetic analysis.

With the first developments of nuclear (autosomal) DNA analysis in the 1970s, it was realized that information from a large number of different gene loci on several chromosomes could be combined using the statistical method of principal component analysis (PCA). This technique identifies the greatest degrees of genetic variation (polymorphism) across a large number of chromosomal locations. The individual genetic variations are called single nucleotide polymorphisms (SNPs), commonly referred to as "snips," whereas the principal components of variation are termed "eigenvectors."

A genome-wide study of genetic variation in modern Europeans found large-scale trends along the axes of the principal eigenvectors, suggesting large-scale genetic mixing that was best explained by the spread of agriculture across Europe.[28] More recent principal component analysis of genome-wide SNP variations in modern human populations is shown in figure 3. This figure shows that the extremes of the distribution are present in relatively isolated people-groups, whereas less-isolated people groups are the products of genetic mixing. For example, the Turkish population field (dashed envelope) shows evidence of mixing with groups to the north and east, with additional mixing trends toward the Greek and Cypriot fields that are not shown in figure 3.

Although the genomic data from modern people are clearly indicative of population mixing, there is substantial ambiguity about the nature and date of mixing processes. For example, it is not clear whether the spread of agriculture across Europe and consequent genetic mixing was caused by mass human migration, or by "word of mouth" communication of the *idea* of agriculture, coupled with multiple local population mixing events. Genomic analysis of modern individuals cannot distinguish between these models, which can be resolved only by sampling ancient human DNA.

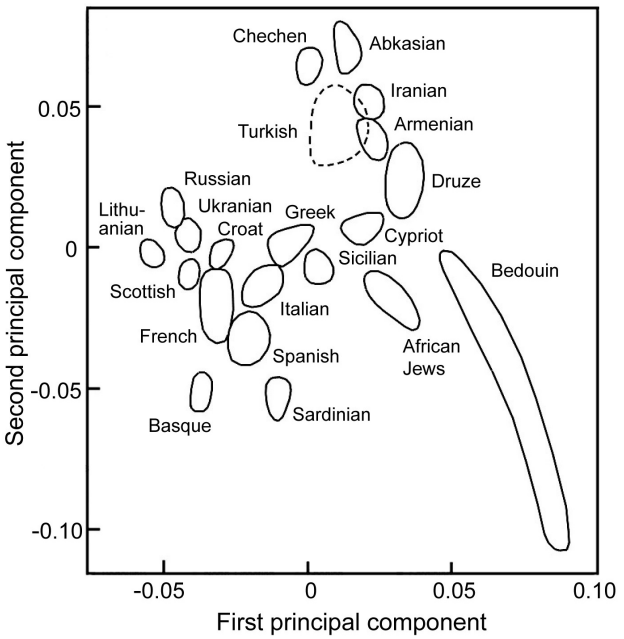

Figure 3. Genomic data for modern humans plotted to show two principal eigenvectors. Note that outliers have been omitted from the Turkish field. Modified after Lazaridis et al.[29]

Ancient DNA Analysis

Until recently, it was not possible to extract usable amounts of DNA from ancient burial sites and distinguish it from modern contamination. For this reason, the first genomic studies of ancient human DNA (*Homo sapiens*) were made on frozen bodies. For example, DNA analysis of hair from a 4,000-year-old Paleo-Eskimo from western Greenland yielded an autosomal DNA signature similar to eastern Siberians, and also showed that mitochondrial and Y-chromosomal DNA were derived entirely from the same northeast Asia haplogroup.[30] Because mitochondrial and Y-chromosomal DNA are defined by inheritance through only one parent, they are not as useful as autosomal DNA to characterize complex population mixing histories. However, they are very useful for testing modern contamination. For example, these data showed that no modern European contamination had been introduced during laboratory processing in Denmark.

Since DNA undergoes much more rapid deterioration as temperatures increase, it is much more difficult to recover usable amounts of DNA from (nonfrozen) skeletal remains. These samples typically contain only 1% of ancient human (endogenic)

DNA, the remaining 99% being largely bacterial and fungal DNA.[31] Therefore, the first successful genome-wide study of ancient human migration patterns was based on 5,000 year-old bones and teeth from Sweden[32] where DNA preservation was enhanced by the cold climate. As an additional precaution, samples were leached before DNA extraction with 0.5% bleach, which preferentially removes modern contamination.[33]

The techniques of DNA analysis in the Swedish study[34] were typical of modern "next-generation" sequencing.[35] These began with DNA extraction using a proteinase buffer and purification by centrifugation through columns containing silica-gel membranes.[36] Marker sequences were then added to the ends of DNA fragments, creating "adaptor-ligated sequence libraries." The method is based on the parallel method of sequencing modern DNA by deliberately fragmenting the genome into short pieces.[37] Since ancient DNA is already fragmented in short pieces (20–100 base pairs),[38] adaptor ligation was applied directly to the extracted DNA.[39] All DNA in the sample was then amplified and sequenced (shotgun sequencing) on the *Illumina* platform, after which the nonhuman data were discarded.

Due to the relatively cold conditions in the Swedish burial sites, useable fractions of endogenic human DNA were recovered (2.4–6.35%). However, samples from temperate latitudes are much more demanding, since they contain a lower fraction of preserved ancient DNA. The best recovery of ancient DNA is achieved from the interiors of teeth[40] and dense regions of bone such as the limbs and the base of the skull near the inner ear.[41] In addition, DNA extraction and purification methods have been adapted to enhance the recovery of very short fragments (< 40 base pairs).[42] However, the fraction of endogenous DNA may still be too low for cost-effective sequencing. Therefore, a method was developed to selectively target and extract short segments of ancient human DNA by attaching "capture probes." For genome-wide DNA studies, capture probes are obtained from short pieces of modern DNA corresponding to SNPs right across the human genome.[43] This DNA is used to make a "bait library" of RNA which is then amplified and reacted with ancient human DNA in the sample. The RNA probes are made to bind chemically to magnetized microbeads, allowing the attached endogenic DNA to be extracted magnetically, after which it is amplified and sequenced in the normal way.

The final stage of data collection is to merge overlapping sequence reads (e.g., > 15 bp length with 95% agreement)[44] into longer sequences, and then map these onto a human reference genome in order to identify SNPs.[45] The resulting data set can then be analyzed statistically.

Mesolithic and Neolithic Human DNA

The analysis of dated ancient samples is critical in order to move from speculative theories of ancient human migration to well-constrained models. This is now possible for the first time due to the publication of genome-wide DNA data from over 500 ancient humans.

To study human migration after the Agricultural Revolution, it is critical to define the genetic signature of local hunter-gatherer populations before the Agricultural Revolution. In this way, any migration of agriculturalists from one region to another can be clearly demonstrated by changes in the DNA signature through time. Therefore, some of the most important samples are from Mesolithic (pre-Neolithic) human populations (also called Epipaleolithic). These samples include hunter-gatherers from southern Anatolia, which represent the ancient DNA sample closest to the site of the Agricultural Revolution. These data are compared with other ancient and modern DNA signatures in figure 4.

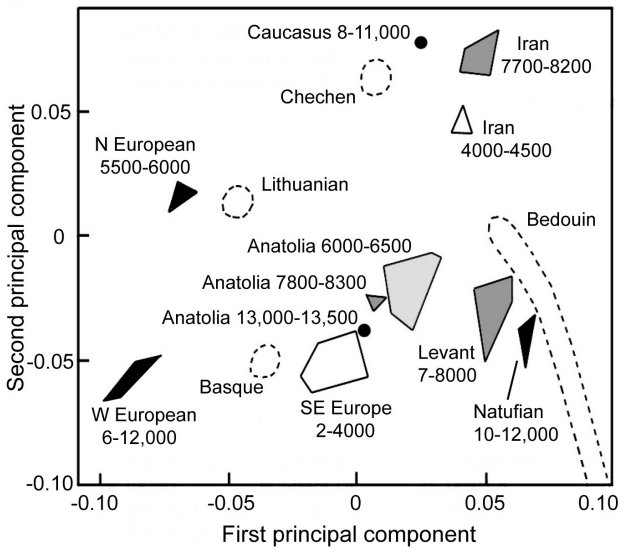

Figure 4. Principal component analysis of genomic data from the Middle East and Europe, with ages in years BC. Black = Mesolithic hunter-gatherers; dark grey = Pre-pottery Neolithic; pale grey = Pottery Neolithic; white = Chalcolithic; dashed = Modern. Data from Feldman et al.,[46] with age information and approximate SE Europe field from Lazaridis et al.[47]

The ancient genomic data in figure 4 are projected onto the two principal eigenvectors of SNP variation derived from modern human populations. Because these eigenvectors are defined by large modern populations (ca. 2,700 individuals), this allows small suites of ancient DNA data obtained by different research groups to be objectively compared. Also, for comparison with the ancient data distribution, four of the modern outlier population groups are shown as dashed envelopes in figure 4.

The DNA data in figure 4 show that Mesolithic hunter-gatherer populations (black points and fields) had very distinctive regional genomic signatures. Although these populations vary somewhat in age (labeled in years BC), they are shown by their archaeological context to be pre-agricultural.[48] Critically, the later Neolithic Anatolian populations have genetic signatures close to the Mesolithic Anatolian point (dated to 13,000 BC), showing that the genetic makeup of Anatolians remained relatively fixed for several thousand years during the Agricultural Revolution, with only minor inputs of genetic material from the Levant, the Caucasus, or Iran. Furthermore, archaeological evidence shows that the Anatolians adopted agriculture from the adjacent Northern Mesopotamian population soon after the Agricultural Revolution.[49]

Agriculture evidently gave these people a huge advantage in survivorship. As a result, they started to spread out in almost every geographical direction, intermixing with local hunter-gatherer populations in each area. Progressive migration over a period of several thousand years is demonstrated by the genetic make-up of human remains dating to the pre-pottery Neolithic, the pottery Neolithic and the Chalcolithic periods (dark grey, pale grey and white fields respectively in fig. 4). In most cases, the Neolithic and Chalcolithic fields are intermediate between the southeast Anatolian Mesolithic sample and local hunter-gatherer populations in the Levant (south), Europe (west), and the Caucasus and Iran (northeast).

Agricultural Migration and the Table of Nations

In the Genesis account, Noah represents a "new Adam," and the Table of Nations describes the outward spread of people groups after the Flood. This idea shows a strong correspondence with the genomic evidence for outward movement of people from SE Anatolia/Northern Mesopotamia beginning in the pre-pottery Neolithic (ca. 9–7000 BC) and gaining full force in the late (pottery) Neolithic (ca. 7–5000 BC).

If the Flood occurred in Southern Mesopotamia around 5700 BC, the genomic evidence suggests that the outward migration of people actually began up to two millennia before the Flood. However, such an outward migration would have had important consequences for the experience of those who survived the Flood on Noah's Ark. After the Flood, it is almost inevitable that the Ark would have become a holy site where human worship was strongly centred. The Genesis account supports this view, quoting the descendants of Noah in Mesopotamia as saying that they did not want to be scattered (Gen. 11:4). However, when these people did start to travel outwards from the new center of civilization in Southern Mesopotamia, they would have encountered a depopulated landscape. Their immediate surroundings on the plain had been depopulated by the Flood, which in the words of the Gilgamesh Epic "was flat as a roof" on which "all mankind had returned to clay."[50] But beyond the limits of the Flood, the descendants of Noah would probably have encountered a landscape depopulated by the outward Neolithic population migration. In fact, evidence from paleo-archaeology suggests that several villages in northern Mesopotamia were abandoned before the Flood and never resettled.[51]

The very factors that first led to the Agricultural Revolution in Northern Mesopotamia probably encouraged this abandonment. As suggested above, it was probably climatic pressure that first led people to adopt agriculture. Having done so, they would probably have discovered that the wetter, more consistent climate in the Levant, the Caucasus, and especially Europe, was more conducive to sustained agricultural production than Mesopotamia. Thus, the first waves of settlers would doubtless have reported back favorably to their home villages that conditions were better elsewhere.

The wave of agriculturalist migration is shown particularly clearly in the west.[52] Here, across Anatolia, the Balkans, and the Aegean, age-peaks of radiocarbon dates show that this was truly a westward wave of mass migration. Data from the Aegean (fig. 5) suggest that the peak of the westward-moving wave

passed through just before 6000 BC, a few hundred years before the most likely date of Noah's Flood. This westward migration is described in some detail in the Table of Nations, which identifies the maritime peoples of the Mediterranean as being descended from Javan (a son of Japheth), who is identified in the book of Daniel with the Greeks. However, it is impossible that ancient peoples could have known the precise historical timing of this migration. Writing was not invented until thousands of years later, and did not comprise a system of recording dating information until at least 2750 BC.[53] Therefore, it is logical that the ancient biblical author assumed the westward migration to have occurred after Noah's Flood.

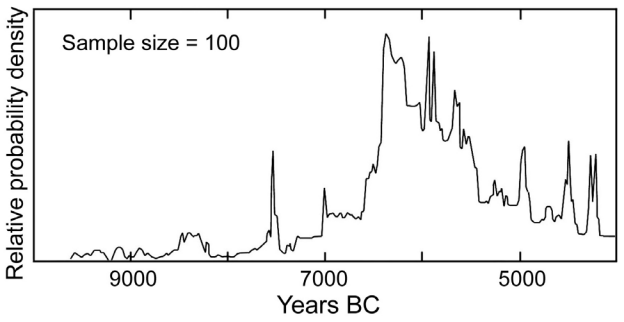

Figure 5. Probability density plot summarizing the relative number of radiocarbon ages as a function of time in the Aegean region. Modified after Silva and Vander Linden.[54]

The sons of Ham are even more important in the Table of Nations than the sons of Japheth, because they include the Egyptians and Canaanites, the principle enemies of Israel in later history. Linguistically, the Canaanites are part of the same Semitic language group as the Israelites themselves. However, this would not have concerned the ancient author, who was more interested in broad geographical and political identities.

Significantly, the southward migration of the sons of Ham into the Levant is supported by the principal component analysis in figure 4, which shows the pre-pottery Neolithic population of the Levant as having a DNA signature intermediate between Anatolia and the Mesolithic Natufians of the Levant. However, because the eigenvectors in figure 4 summarize genomic variation in the data set as a whole, they cannot provide a quantitative analysis of the relatedness of individual groups across a large number of SNPs. Therefore, some of these relationships were tested by Lazaridis et al. using *f*4 statistics (fig. 6).[55] This analysis will be used here to test the proposed southward migration from Anatolia to the Levant.

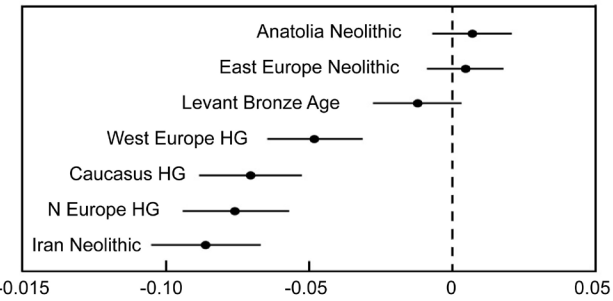

Figure 6. Results of the f_4 statistic (test-group, Natufian; Levant-Neolithic, chimp) to see if the Levant Neolithic population shares more alleles with a test population than the Levant Mesolithic. HG = hunter-gatherer. Error bars are +/- 3 standard errors. Modified after Lazaridis et al.[56]

Figure 6 shows results of the f_4 statistical test (test-group, Natufian; Levant-Neolithic, chimp). This test compares the relatedness of the Levantine Neolithic population to different test populations relative to the Mesolithic Natufians of the Levant, using the chimp genome as a yardstick for comparison. The positive result at the top of the chart shows that Levant Neolithic farmers shared a greater number of alleles with Anatolian farmers than with Natufian hunter-gatherers, whereas most other Mesolithic or Neolithic populations are more remotely related. This provides evidence for a migration of Anatolian farmers to the Levant. However, since the second closest population to the Levant Neolithic comprises Eastern European farmers, this suggests that the source of the migrants was not Anatolia specifically, but a general pool of Neolithic farmers from the whole region of the Agricultural Revolution.

Mitochondrial and Y-Chromosomal Evidence

Before the development of genome-wide (autosomal) DNA population studies, early work on the genetic relationships between human and primate lineages was based largely on the study of mitochondrial and Y-chromosomal (haploid) genetic inheritance.[57] Since these techniques reflect inheritance solely through the female and male lines respectively, this means that mitochondrial and Y-chromosomal DNA yield less-reliable evidence about the mixing of ancient people groups. However, because haploid DNA is more susceptible to local extinction events, it is very sensitive to population bottlenecks. It is also useful for dating these bottlenecks, because the simpler lines of descent make it easier to provide age calibrations based on haploid DNA mutation rates.

One of the most important of these bottlenecks is the "out-of-Africa" migration that occurred when small bands of modern humans left Africa.[58] Mitochondrial and Y-chromosomal evidence support the thesis that this bottleneck of human evolution occurred around 55,000 years ago, and was followed by an evolutionary diversification event (fig. 7) as the small bands of migrants spread out over the rest of the world.

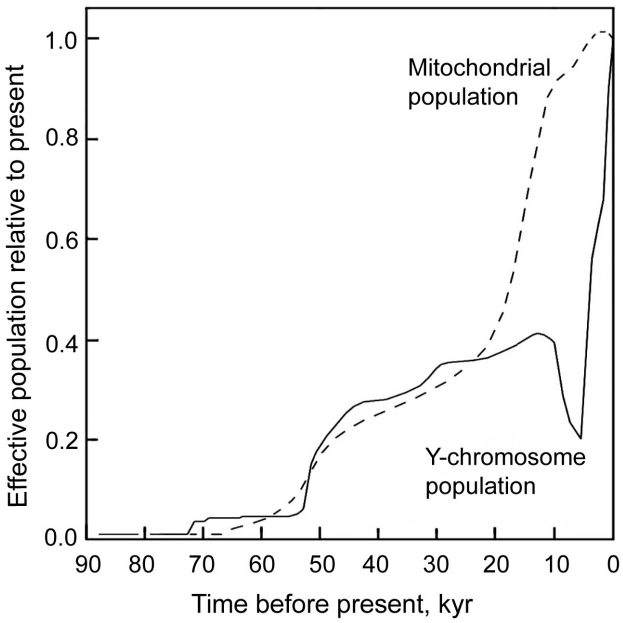

Figure 7. Variations in effective mitochondrial and Y-chromosomal population diversity, relative to the present day. Modified after Karmin et al.[59]

Y-chromosomal population diversification was more dramatic than the growth of mitochondrial population diversity after the 55,000 year dispersal event (fig. 7), and Y-chromosomal evidence also gives a signal for an earlier "out-of Africa" migration around 75,000 years ago (consistent with the date of human fossil remains in India[60]). On the other hand, mitochondrial population diversity increased more rapidly in the interval from 20 to 10 kyr before present. This mitochondrial diversification event began earlier in the Middle East than in Europe,[61] suggesting that it reflects migration into newly available landscapes as glaciers retreated at the end of the Ice Age. In contrast, there is only one case in the last 50 kyr in which haplogroup population diversity was markedly reduced, and this occurred less than 10,000 years ago, after the Agricultural Revolution.

The effective Y-chromosomal population diversity crashed at the beginning of the Neolithic Period and did not recover for several thousand years, whereas the mitochondrial population diversity shows no such decrease (fig. 7). Zeng et al. suggested that this difference reflects the different social structure of male and female kinship groups.[62] For example, if male kinship groups were in strong competition, there would be a high likelihood of small Y-chromosomal populations going extinct, so that during periods of intense competition, Y-chromosomal population diversity could crash. In contrast, females move more freely between kinship groups, keeping larger mitochondrial populations extant.

A dramatic demonstration of a kinship selection event of this type is given in the biblical Flood story. According to the biblical account, all of the survivors on the Ark were from one male kinship group (Noah and his three sons). On the other hand, we can infer that the four women on the Ark were probably less closely related. Therefore, if the account of human annihilation in the biblical and Mesopotamian Flood stories is based on a real event, we can see that this event would have caused an intense bottleneck in Middle Eastern Y-chromosomal populations, but less so for mitochondrial populations.

Modeling the history of effective male population diversity for different geographical regions provides evidence for this type of bottleneck. For example, the proposed Late Neolithic date of the Flood corresponds with a Y-chromosomal population minimum in the Middle East (fig. 8). However, we can see that the decline in Y-chromosomal population diversity actually began before the Flood, starting immediately after the Agricultural Revolution.

We can infer that the enhanced survivorship of male kinship groups practicing agriculture was so greatly enhanced that most hunter-gatherer kinship groups went extinct during the early spread of agriculture in the Middle East. These agriculturalists spread out over the known world, establishing the first complex civilizations. Within these civilizations, competition between male kinship groups was probably reduced, allowing a strong diversification of Y-chromosomal populations.[63] This model is dramatically confirmed by the behavior of European Y-chromosomal populations around 4000 BC (fig. 8). This is the approximate time when Steppe populations practicing agriculture swept across Western Europe, essentially annihilating native male kinship groups.[64] In contrast, the Steppe immigrants were highly successful, leading

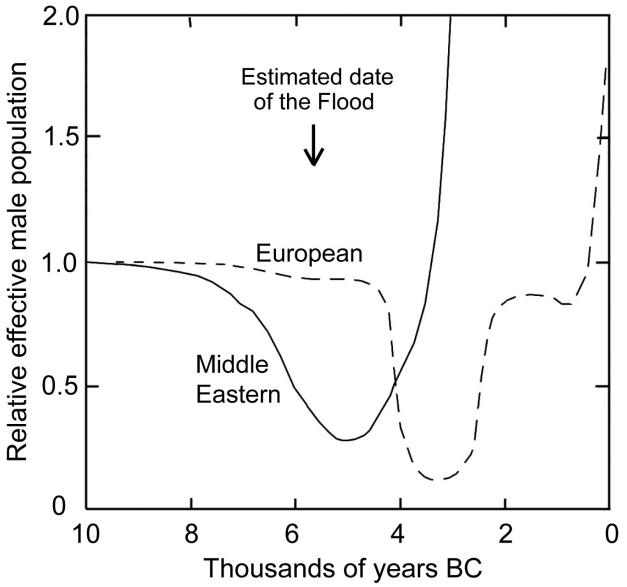

Figure 8. Effective Y-chromosome population diversity for the Middle East and Europe, normalized to their value before the Agricultural Revolution. Modified after Karmin et al.[65]

to massive Y-population diversification shortly afterwards.

It is significant that the autosomal and haploid DNA evidence gives a consistent picture of the timing of Neolithic migration events, despite their different sources of chronological information. Thus, the ages of the samples in figure 4 are "real time" ages of actual individuals derived from radiocarbon dating or archaeological contexts. In contrast, the ages of population bottlenecks in figure 7 are model ages based on the application of mutation rates to divergent modern haplogroup signatures. The fact that these two completely different sources of chronological information agree provides powerful evidence in support of the accuracy of the agriculturalist migration and diversification model.

Conclusions

In attempts to reconcile the Genesis account of human origins with scientific evidence, two different approaches have been taken. One approach has been to identify Adam as a Neolithic agriculturalist based on the occupations of his sons, one of whom is also described as the first city builder. This view locates Adam in Mesopotamia, reflecting his placement by God in the Garden of Eden, where the Tigris and Euphrates rivers met. In this view, Adam was the priestly father of humanity, and, through his descendant Noah, he played a formative role in the origin and development of Middle Eastern civilization.

The other approach locates Adam in Africa 100–200 thousand years ago, where he is the biological father of the human race. This model requires tens of thousands of years of lost human experience, during which time Adam's descendants must have migrated out of Africa and spread over the rest of the earth. Genesis contains no hint of such a migration event, but it does claim that all Middle Eastern people groups were descended from the survivors of a catastrophic Flood in the Mesopotamian region.

If Noah's Flood occurred in the Neolithic Period, the spread of humanity across the Middle East ties in closely with genomic evidence for a massive outward migration from Northern Mesopotamia/southeast Anatolia after the Agricultural Revolution. Therefore, the overall portrait of Middle Eastern origins painted in Genesis is consistent with scientific evidence for the origins of human religion and civilization in the Neolithic Period in Mesopotamia. ♥

Notes

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Semper fidelis: The Power of Friendship in Suffering

Beth Madison

Beth Madison

No one, especially those of us in academia, wants to be seen as weak, incapable, or "less than" in any aspect of our lives. Weakness is a sharp contrast to the drive and tenacity requisite for entrance and success in academia. Most academics pride themselves on being "gritty," as Duckworth would say. As academics, we are expected to be in control of our research, students, schedules, thoughts, and personal lives simultaneously. Perception is everything to us. We do most everything we can to hide any sign of weakness … until we cannot.

I was diagnosed with rheumatoid arthritis (RA) in 2012 in my twelfth year as an academic. RA changed my life then and continues to do so every day. Since RA is an autoimmune disease, my immune system sees my body's tissues as unwanted invaders. My immune system's attack on my tissues causes inflammation resulting in swelling, pain, stiffness, and possible permanent damage from cartilage destruction.[1] The synovial tissues lining the joints of the fingers and toes are usually the first to succumb to attack, but other joints and organs can quickly become involved with subsequent progression of the disease. Widespread damage in seemingly unrelated organs and tissues such as the heart, lungs, kidneys, and eyes can also occur because the activation codons for RA reside in the DNA of every cell of an RA patient's body. Thus, nearly 40% of patients like me have other symptoms such as fever, fatigue, appetite loss, and weakness along with co-morbidities including osteoporosis, migraines, heart, kidney, eye, and/or lung disease, diabetes, and other diseases.[2]

Rheumatoid arthritis and other chronic illnesses do not respect gender, age, ethnicity, socioeconomic class, location, faith, or profession. The statistics speak for themselves—almost 50% of Americans suffer from at least one chronic illness; 40% have two or more chronic illnesses; nearly 75% of annual aggregate healthcare costs are for treatment of chronic illnesses; and 70% of deaths in the USA annually are from complications of chronic illness.[3]

With many chronic illnesses, there is not a pill, shot, surgery, or "app for that" since they are usually incurable and often inhabit our DNA. Such illnesses include (but are not limited to) diabetes, heart disease, mental illness, multiple sclerosis, chronic obstructive pulmonary disease, muscular dystrophy, and rheumatoid arthritis. Goodwin and Morgan indicate that at least 20% of Americans with chronic illness report a major negative and/or debilitating influence from the illness on their daily life functions.[4] Wherever someone falls on the severity of symptoms, chronic illness is life changing.

Every. Single. Day.

Life with chronic illness is more than just a diagnosis and symptom management—

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it is a reframing of expectations of what I thought my life would be. Morgan says it well: "Sickness is more than physical discomfort. It is dis-ease, jarring our whole person."[5] Nearly 96% of chronic illnesses are perceived as invisible as a consequence of symptoms often hidden because of embarrassment (diarrhea, rash) or exacerbation of common symptoms (fatigue, muscle pain).[6] Hence, there is the commonly unspoken notion of incompetence with chronic illness patients. The afflicted individual is considered incapable of just "getting everything under control" and thus labeled as weak, when actually, he or she is sick. Disregard for illness increases the patient's isolation, which can also exacerbate symptoms. Hiding is what is expected and respected by society, especially academia. A cancer survivor clearly expressed what I feel almost every day—"I keep my voice firm and strong, but inside I feel fragile as glass."[7]

I feel fragile from the weight of constantly dealing with physical symptoms, the grief and frustration of progressive loss of strength and abilities, and an often overwhelming list of responsibilities as wife, mother, and professor. Yet I know that I am not alone; just one forum question about chronic illness in *The Chronicle of Higher Education* garnered nearly 2,200 responses and 57,000 readings.[8] Fear of replacement, removal, and/or rejection because of the stigma of chronic illness is a strong motivator for many academics to simply put their heads down, keep silent, and hide (or leave).

But my colleagues would not let me hide or leave. Their support and help are what keeps me going in academia, especially on the hard days which seem to stretch past the horizon into next semester. Before diagnosis, I knew I was not an island unto myself (as the seventeenth-century poet and cleric John Donne might say), but I never realized that I was an important component in my university's ecosystem. I have learned that I am far more than the number of papers published and/or students taught per year. In fact, I think as I grow physically weaker, my contribution to the university grows stronger as I learn to depend on what is truly important: faith in the God who sees me and gave his only son for my sin and my redemption. And as my faith grows, I know more of the importance of dependence, vulnerability, and prayer.

Every. Single. Day.

Having to depend daily on God for physical strength, energy, and functionality is teaching me that he alone is my strength and portion as my heart and flesh fail (Ps. 73:26); I can trust him to provide what is needed for whatever he puts in my day (2 Cor. 12:9); his presence truly is sweeter and more satisfying than any other (Ps. 34:8); and he is good to those who look to him for help (Lam. 3:25). God sends me help every day through my colleagues. Some of the tangible helps I receive from colleagues include stopping by my lab room to see whether I need someone to sub for me that day, or help in moving lab equipment and gathering supplies; volunteering to help in calibrating lab equipment; sending her student worker across campus to pick up copies and/or library books for me; sitting next to me at lunch meetings to carry my plate from the buffet and then cut my food, if needed; bringing a meal to my family; and texts telling me she is praying for me today (while she is in the drive-through for lunch, and would I like something to eat?).

Every offer, call, text, and email speaks courage to my heart. C. S. Lewis expresses this well: "When pain is to be borne, a little courage helps more than much knowledge, a little human sympathy more than much courage, and the least tincture of the love of God more than all."[9] The courage I gain from my colleagues helps me to persevere and to keep working. In turn, my colleagues tell me that my perseverance helps them to endure in their challenges, be it at the university or in their homes. Also, students see the importance of caring, through my colleagues stopping, listening, and helping, and through my receiving their help. We model for our students the way Christ intended for us to live together as Christians (Luke 6:31). This model is a pointed contrast to our normal lessons in narcissism in academia and the tendency to keep to ourselves.

Vulnerability is another pointed contrast to the easier and expected choice of pride in the response of "thanks, but I got this." When I choose vulnerability, without complaining, I acknowledge my need for help while empowering others to reach past themselves to help me. Even though I often say "I'm fine" in response to "How are you doing today?," some colleagues press in and say, "Are you sure?" and "How can I help you today?," because they care for Christ and thus care for me (Matt. 10:42). Their persistence allows me to reply "Not great"; this

translates to "I wish I were in the hospital or at least at home in bed with an IV." Honestly, I like hiding, but I have learned that my vulnerability can help my colleagues. Vulnerability allows my colleagues to talk about wayward children, financial difficulties, struggling spouses, depression, and other needs not easily expressed in normal conversation with people who seem to have everything in life under control. I have become "a safe space" for many because they know that I understand the reality of suffering and the power of prayer.

Recognition of the true power and essential nature of prayer is another lesson God is teaching me. It is as if God had to strip me of what I could do for myself to let me glimpse what he longed to do for others through me via prayer. As a scientist, it is mind-boggling to evaluate the correlation of answered prayers with the occasions when I have prayed with and for colleagues. Many times these answered prayers are beyond explanation, expectation, or imagination (Eph. 3:20–21). (How incredible to think that God desires for me to participate in his workings!) The evidence of answered prayers helps both my colleagues and me to grow in faith and gives us the desire to pray even more, both individually and together. Even the seemingly strongest and most "got it together" colleague amongst us has deep aching needs that only God can answer. I did not realize before RA just how many people have no one praying for them, much less someone who prays for them every day. And logically, when we pray for each other, we strengthen each other, independent of our confidences, challenges, and circumstances.

Every. Single. Day.

Some people say I have lost a lot of myself in the past seven years to RA. I see this as a much-needed improvement. In the losses, I have found an unexpected and growing freedom in trading self-reliance for trusting God, and self-centeredness for gratefulness. Life now has more joy and contentment than ever before from having been "pushed, and at times shoved, against the breast of your Savior," and there, finding him as my living hope (1 Tim. 4:10).[10] It is as if the joy and contentment is sweeter because it is hard-won and costly. I would not trade RA for anything, because of what God has taught and is teaching me through it.

Only God could use a cane, arm braces, and an electric scooter as doors for the Gospel with students who do not believe God exists and cannot understand or explain away how I choose faith in suffering. They have heard all the conventional answers for faith and have rejected them. Yet my reality counteracts their logic and naturally, they want to know more. They seek Truth and I am delighted to share with them the hope that I have found in Christ. Equally important, I pray for them and ask my colleagues to pray for them too. And then my colleagues and I rejoice to see traditional and nontraditional undergraduate students alike come to Jesus for salvation and then bring their friends and family members to Christ as well.

Only God can take chronic illness and use it to teach me (and hopefully, my colleagues) the incomparable satisfaction found in helping others and receiving help from them. My colleagues and I help each other to be strong in our life-challenges, be they chronic illness or something else. And thus, we build community since "suffering together builds togetherness."[11]

This togetherness is essential for our lives as Christ followers. This togetherness serves to model the love of Christ for others in our lives who are not yet Christ followers, including our students, colleagues, friends, and family.

Every. Single. Day.

When my colleagues help me, they remind me that I am seen by God and my niche is important to academia, even and especially as my health declines. I treasure the gift of being seen in compassion, not pity, by my colleagues. In turn, when I help my colleagues, it reminds them that they are not alone and that their faith will grow when they choose to trust God. Together we display to our students that "caring is a yearning for the good," as my colleagues supply their strengths to complete what is missing in mine.[12] We all yearn to be seen, to be cared for, to be helped. We all have opportunity to see, to care, to help, and in turn, we can be made stronger together.

Every. Single. Day.

♥

Notes

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[7]Kate Bowler, *Everything Happens for a Reason and Other Lies I've Loved* (New York: Random House, 2018), 114.

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Environment

HOPE IN THE AGE OF CLIMATE CHANGE: Creation Care This Side of the Resurrection by Chris Doran. Eugene, OR: Cascade Books, 2017. 247 pages. Paperback; $31.00. ISBN: 9781498297028.

Chris Doran is Associate Professor of Religion at Pepperdine University in Malibu, California. His research and teaching have focused on a variety of areas related to the interaction between theology and science. His current work centers upon developing theological responses to climate change and its effects on the totality of God's creation. His main argument in this book is that it is easy to become hopeless when contemplating the destruction that climate change will bring to humans, nonhuman creatures, and the rest of creation. However, he argues that hopelessness "should not appear plausible or even reasonable to Christians who believe in the resurrection of Jesus" (p. 15). According to Doran, resurrection hope provides the foundation for creation care, and the third chapter of the book is devoted to an explanation and justification of this linkage.

A large portion of the book focuses on two particular issues of concern: the idol of economic growth, and the American association with food. In chapter six, Doran describes the "neoclassical economic model" which is based upon the assumption that persistent economic growth will provide everyone with the opportunity to achieve prosperity. He presents a number of reasons why Americans continue to consume in spite of the fact that they are not happier than other peoples in the world. One reason, simply stated, is that we define prosperity solely by our ability to consume goods and services. Another reason we consume so much is that the "priests" of the neoclassical worldview rely on a sophisticated group of advertisers and marketers who effectively shape consumer desire. This priesthood also maintains the idol's prominent position in our society by claiming that economics does not depend upon ethical presuppositions and can therefore be considered an objective science. In addition, this worldview presupposes that humans are individuals who make rational decisions based on self-interest and that the economy prospers when this so-called rational decision-making process is allowed to flourish. The neoclassical economic model is also based on the idea that scarcity is pervasive, which naturally leads to competition between humans and corporations. Finally, this worldview presumes that economic growth always generates useful technology and that technology will always be able to solve any problems that it might create.

Doran concludes chapter six by arguing that the neoclassical model of economic growth is founded upon faulty presuppositions and that it is a system stricken by hopelessness. He asserts that economics is not just about money, but it is also a justice issue. It is about sharing resources among all who need them, rather than encouraging developed-world citizens to live luxurious lives that fail to discern the real difference between wants and needs. Chapter seven then summarizes the characteristics of an economy of hope that includes the goals of justice, sustainability, ecological health, and climate change mitigation. Most of the chapter is devoted to the practice of one specific virtue that can help us live more hopefully. That virtue is frugality, a "subversive" virtue, which "strikes at the core of the idol of economic growth as it impugns our cultural belief in the idol's innate goodness and capacity to deliver on its many promises" (p. 136). Doran quotes a number of the church fathers who, while not using the term "frugality" explicitly, do spend a considerable amount of time explaining the relationship between humans and their possessions from a Christian perspective. For all of these church fathers, the purpose of human life is not to consume or accumulate but to do justice. Frugality, then, is the Christian expression of hope in a God whose abundance is sufficient if we are willing to live in such a way that distinguishes needs from wants and that creates the space to share with others, including the nonhuman creatures that inhabit our planet.

The second major issue of concern raised in the book is the American association with food, the subject of chapter eight. Doran delineates a number of problems that are associated with food production and consumption in the United States. Consumption issues include the massive amount of food that is wasted, the staggering amount of meat that Americans eat, and the fact that this country is one of the most obese nations on the planet. Food production concerns include the massive use of artificial fertilizers, soil erosion, pesticide runoff, and water pollution, all of which are closely associated with monoculture agriculture. Doran quotes Norman Wirzba who contends "that we have given food production and consumption over to the modern idols of control, efficiency, and convenience" (p. 151). The main targets of Doran's critique are the nation's many confined animal feeding operations (CAFOs) which treat animals inhumanely, and the entire meat-processing industry that pays human workers low wages while exposing them to numerous health hazards. The chapter concludes with a timely reminder from the church fathers that gluttony was once known as one of the seven deadly sins.

In the chapter that follows, Doran lays out a number of reasons why eating should be an act of Christian hope. While he does not conclude that eating meat is immoral, as some vegetarians often presuppose, he does argue that American Christians should reduce their meat consumption significantly and should completely refrain from eating meat that comes from CAFOs. In order to eat hopefully, Christians should be aware of two important considerations: the care of the animal to be eaten, and the welfare of the humans that raised and slaughtered it. If Christians choose to eat meat, they must be willing to pay more for it by demanding that they will eat only meat "that makes dignity possible for the least of these" (p. 189). Reconnecting to the moral and theological aspects of eating through participation in the Eucharist should cause us to remember how eating connects us to our neighbors, to other creatures, and ultimately to God.

While the issues of economic growth and the American association with food are the main topics of this book, other aspects of creation care are also addressed. The biblical basis for describing God as Creator and Redeemer is presented in the first two chapters. God's care for nonhuman creatures, the Incarnation's affirmation of the goodness of the entire creation, and the concept of cosmic redemption are all discussed. In chapter four, Doran critiques the idea that humans are to be stewards of God's creation. After surveying other options, he examines a single virtue in chapter five that may help us be Christians "who better witness to the creation-care work the resurrection inspires us to perform" (p. 90). This virtue is humility, the recognition of one's proper place in God's plan for the universe. The book concludes with two chapters that describe several ways the church can be a beacon of hope in this age of climate change.

While all Christians need to be confronted with the central themes that are raised in this book, it appears to be written primarily for use in college-level courses that address the subject of sustainability from a Christian perspective. The book includes an extensive bibliography, and footnotes appear on nearly every page. The author draws on the Bible, the church fathers, and modern theologians to develop a thoughtful and practical ethic of creation care. The main message of the book, as stated on the back cover, is that "Christians should think, purchase, eat, and act in novel and courageous ways because they are motivated daily by the resurrection of Jesus." Unfortunately, far too many Christians fail to connect their belief in the resurrection with the daily witness of their faith, particularly as it relates to issues of creation care. Hopefully, reading this book will encourage many to make the connection and then to respond with action.

Reviewed by J. David Holland, Clinical Instructor, Department of Biology, University of Illinois at Springfield, Springfield, IL 62703.

History of Science

DREAMERS, VISIONARIES, AND REVOLUTIONARIES IN THE LIFE SCIENCES by Oren Harman and Michael R. Dietrich, eds. Chicago, IL: University of Chicago Press, 2018. 324 pages. Paperback; $40.00. ISBN: 9780226569901.

I have always been intrigued by scientists who were able to think outside established paradigms to advance scientific knowledge, and I have always wondered what gives them this ability to think outside the box. For example, what convinced Barbara McClintock that chromosomes could be broken and rejoined, whereas the rest of the scientific community believed that intact chromosomes were critical for passing on genetic information properly? What gave Judah Folkman the stubborn persistence to pursue anti-angiogenic molecules when they eluded him for so long, and the rest of the scientific community thought he was pursuing a phantom? Questions like these piqued my interest in *Dreamers, Visionaries, and Revolutionaries in the Life Sciences*, which explores scientists whose work, theories, or methods made them stand out from their peers as something other than "run of the mill." This is the third book in a series of three, the first of which focused on scientists whom editors Oren Harman and Michael R. Dietrich describe as rebels, mavericks, and heretics. The second focused on innovative, outsider scientists. This book highlights eighteen individuals the volume's editors deem scientific dreamers, visionaries, and/or revolutionaries. The eighteen people are divided into six subdisciplines: evolutionists, medicalists, molecularists, ecologists, ethologists, and systematizers, placing three in each subdiscipline, although many could well be placed in more than one of these groupings.

The eighteen individuals highlighted range from historically important scientists (Jean-Baptiste Lamarck) to scientists whose contributions are quite recent (David Sloan Wilson). They include scientists who followed a typical educational and professional pathway, such as Ilana and Eugene Rosenberg, to those whose pathway was quite atypical, such as Jane Goodall who skipped a bachelor's degree altogether. The dreamers, visionaries, and revolutionaries even include Mary Lasker, who was not a scientist at all but an important health advocate.

Among my favorite chapters is "Jonas Salk: American Hero, Scientific Outcast" (chap. 5), whose hero was Louis Pasteur because Pasteur conquered disease using creativity, perseverance, and concern for humanity (p. 85). Salk's life was shaped, in large part, by stories of pogroms, witnessing the 1918 flu pandemic, and his Jewish faith, which taught him that people are defined by the good works they do. He was ambitious, meticulous, tenacious, persistent, and took calculated risks. He had the audacity to challenge the science of the day. He questioned dogma. He was able to envision a world in which diseases such as polio were not a threat.

Other favorites include the chapter describing Mina Bissel's work on extracellular matrix and signaling molecules, which compelled scientists to consider both genes and cellular environment to explain cell behavior. I learned that Ilana and Eugene Rosenberg's work led to the explosion in our understanding and interest in microbiomes, and that it was the vision of Margaret Dayhoff that laid the groundwork for the sequence databases many of us depend on today. Visionaries Rachel Carson, Jane Goodall, John Todd, and James Lovelock still have important lessons to teach us as we face increasingly alarming global environmental crises.

I appreciated the number of women included—six if you include Ilana Rosenberg (the subject of chapter 18, along with her husband). The authors often pointed out that these women worked around family obligations and that these outside responsibilities did not hamper their scientific contributions. Rather, in many cases, being mothers gave these women eyes to see what others missed. I noted that many of the subjects benefited from interdisciplinary or cross-disciplinary work—something those of us at liberal arts institutions should advertise! The visionaries were creative, thoughtful, and passionate. They welcomed competing/alternative viewpoints and collaboration. As outcasts themselves, many of the dreamers in this book were extraordinarily inclusive.

The book ends with an epilogue in which Joan Roughgarden insightfully identifies seven distinct features of scientific dreaming and dreamers. The first feature is that "scientific dreamers sense that something is wrong, dreadfully wrong, with contemporary science" (p. 305). Her claim reminded me of a sermon series my pastors recently led at our church. They dedicated their 2019 Lenten sermons to lament. In one sermon focusing on Lamentations 2, our pastor argued that to be a visionary, a person must practice lament because in lament, we envision a world more like the one God desires, and we are compelled to act in such a way as to bring our current reality more in line with that vision—with God's vision. A Christian in the Reformed theological tradition, I see common grace at work in the lives of the subjects of the eighteen chapters of this book. Whether these scientists were people of faith or not, they saw something that was dreadfully wrong with how we interpret the world, with the human condition, or with how we interact with the natural world. Then, they used science as a tool to right the wrong they identified. Perhaps this is a lesson for Christians who want to integrate faith and science meaningfully. Practice lament, identify places in our world that do not match God's intent, and use science to work to make reality more closely match God's vision.

I will recommend this book to graduate students and undergraduate students with an eye on graduate school as an incentive to embrace the features of scientific dreamers, visionaries, and revolutionaries.

Reviewed by Sara Sybesma Tolsma, Professor of Biology, Northwestern College, Orange City, IA 51041.

UNBELIEVABLE: 7 Myths about the History and Future of Science and Religion by Michael Newton Keas. Wilmington, DE: ISI Books, 2019. 256 pages. Hardcover; $27.95. ISBN: 9781610171533.

Several years ago, while in Singapore on sabbatical, I needed to hitch a ride to a lecture at one of the local universities; I jumped into the back seat of a car driven by a rather well-known MIT physicist. As we sped off, somehow the conversation in the front seat turned to the "Dark Ages" and how foolish it was that people could believe that "the earth was flat," according to the driver. At the time, I knew that the presumption was off the mark, but I did not have the facts at my fingertips to enter into the conversation. Had I possessed this book, I would have had plenty to say. The truth, of course, is that, as elaborated in chapter 3, it has been pretty universally held from the time of the ancient Greeks that the earth is round. I remember thinking, how can there be such ignorance in the context of criticizing ignorance? In a sense, that is what the book is all about.

Unbelievable, by Michael Newton Keas, is part of a genre which has grown over the past few decades to debunk a number of misconceptions about science and history, not least of which is the claim that science and religion are at "war." (Indeed, in the last chapter, Ron Numbers is quoted as saying, "The greatest myth in the history of science and religion holds that they have been in a state of constant conflict.") All the myths in the book somehow serve this conflict image, and though they may be propagated in ignorance, the beliefs are often held by those who have an agenda. In contrast to some other books in

this genre that have multiple authors, this book has only one, and this gives it a coherence not always achieved elsewhere. The content contains a mixture of original research (e.g., studying historical textbooks going back more than two centuries, with some reference to original texts) and reliance on the work of other historians. In addition to the main historical story, an interesting feature is the side story of how misconceptions have been reported in textbooks over the years, even continuing to the present.

In Part 1, the book focuses on seven "myths" concerning history, science, and Christianity. In order, the myths treated are (1) the medievals thought of the universe as small and that somehow small was inferior; (2) the medieval period is justifiably considered "dark" with regard to knowledge; (3) medievals believed the earth to be flat; (4) Giordano Bruno should be considered a martyr for science; (5) Galileo was imprisoned for his science; (6) a Copernican view constitutes a demotion and humbling of the medieval view because it removes us from the center; and (7) when we meet extraterrestrial beings (ET), the meeting will bring about a kind of scientific enlightenment.

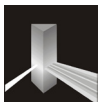
When I first encountered the book, I was not sure why these particular myths were chosen, and why they were ordered in this way. However, upon reading, I found that the myths and their ordering constitute a natural progression, from one to the next. And in a certain sense, these seven myths constitute a suitable representative sample to stand in for the many that could be discussed. As stated later in the book, the first three myths belong to the medieval period, whereas the next three are associated with the early modern period. The last relates to a yet future hypothetical event, one that is talked about with a kind of secular religiosity in passages quoted. In many cases, you can see a progression; once a myth is created, it gets picked up and propagated by those who would like to promote a particular cause. Most of these myths are myths in the usual sense of a false story. But the last falls into another category, as an "imaginative archetypal story that shapes a culture's identity and dominant worldview" (p. 5).

Following Part 1, the second part of the book is devoted, in part, to the question of why the myths continue to be propagated, and, in part, to an elaboration of the misconceptions in order to place them within a fuller context. Much of this second part adds to and enhances the arguments in the first part. For example, in the first chapter, the theme of ET is revisited and tied to a science fiction theme, and the next chapter discusses how science television shows such as *Cosmos* (both the Sagan version and the Tyson version) propagate the theme that science represents progress, putting it in opposition to the "outmoded" religion of the past. A later chapter reveals one of the more interesting facts. In considering a large number of textbooks used in American education, from the seventeenth century to the present, virtually none of the myths appeared until around the early nineteenth century, suspiciously closely following the so-called "Enlightenment" period. One of the earliest texts discussed is one written by Kepler, which is portrayed as a splendid example of compatibility between science and Christianity.

I have read other books in this general genre, yet I still learned much from this one. Aside from the usual stories of Bruno and Galileo, there are also lesser known stories such as Sagan's use of Hypatia to justify an imagined war between science and Christianity, and Tyson's telling of false historical stories to justify his position, a practice surprisingly endorsed by historian Joseph D. Martin for the "greater good" (p. 152).

Who might be interested in reading the book? I would recommend it to anyone who is interested in the history of science and Christianity in general. In particular, Christians in science can benefit from the broader theme of knowing what the myths are that continue to be propagated, with an eye toward revealing them to others when the subjects come up. If you have not read much on this subject, this book would be a good place to start.

Reviewed by Donald N. Petcher, Professor of Physics, Covenant College, Lookout Mountain, GA 30750.



Physics

THE PHYSICS OF EMERGENCE by Robert Bishop. San Rafael, CA: Morgan & Claypool, 2019. 112 pages. Paperback; $50.00. ISBN: 9781643271538.

What options are available when thinking about the physical and material universe? Are all phenomena and behaviors reducible to the fundamental laws of nature, perhaps in a single comprehensive materialist "theory of everything"? Or must any comprehensive account of the material universe be necessarily dualist, perhaps even one in which physical theory needs to be supplemented by some type of non-material essence or possibly by divine intervention? Or is there a middle way, one in which reductionism is inadequate and dualism unnecessary? In this book Robert Bishop affirms the latter by arguing that the structure of physics itself indicates that the universe displays contextual emergence, a type of emergence in which lower-level structure is insufficient to account for higher-level properties and behavior,

owing to the role contextual and contingent factors play in shaping higher-level structure.

Bishop, currently John and Madeleine McIntyre Endowed Professor of Philosophy and History of Science at Wheaton College, is well positioned to address such a challenge. He earned a BS and MS degree in physics and a PhD in philosophy, all from the University of Texas at Austin. He specializes in the foundations of the physical and social sciences, particularly on determinism and free will, irreversibility, and theories of mind and consciousness. Bishop codeveloped the concept of contextual emergence along with Harald Atmanspacher (Robert C. Bishop, "Patching Physics and Chemistry Together," *Philosophy of Science* 72, no. 5 (2005): 710–22; Robert C. Bishop and Harald Atmanspacher, "Contextual Emergence in the Description of Properties," *Foundations of Physics* 36, no. 12 (2006): 1753–77). In *The Physics of Emergence*, Bishop further explains the concept and argues that it is grounded in physics.

Given the checkered history of the concept of emergence with a spectrum of diverse meanings, any work on emergence is well served by explaining its use of the term. Bishop does so clearly and succinctly in the introduction and first chapter. He notes the common belief among the scientific community in reductionism, whereas emergence denies these reductionist views without resorting to dualism. Essentially, reductionists believe "that everything else in the Universe reduces to the play of elementary particles under elementary forces (or the action of quantum fields)" (p. xii). In contrast, emergentists believe that fields such as condensed-matter physics, biology, or psychology study phenomena that "aren't explainable or derivable from elementary particles/forces …" (p. xii).

In the first chapter, Bishop provides a brief but helpful history of emergence. He cites key comments from luminaries such as Einstein, Pauli, Schrödinger, Anderson, and Laughlin that indicate an openness to emergence while the scientific community tended to hold firmly to reductionism.

In the second chapter, Bishop wastes no time in addressing the primary objection usually raised against emergence, namely "the belief in the *causal closure of fundamental physics* (CCFP)." In other words, knowing only the elementary laws of nature and the initial conditions, the subsequent evolution of any system over time can be determined. No contextual or external factors are needed. The universe is thought to be fully explained by "bottom-up" factors. Bishop points out that there are two basic assumptions in this objection:

> **Atomism**: *Law-like regularities of macrostates are fully determined by the law-like regularities and micro features of microstates in all cases regardless of context.*
>
> **Context freedom**: *All features of macro contexts are fully determined by context-free features of the underlying law-like features of microstates.* (chapter–page, 2–5)

The rest of the book is a thorough refutation of the CCFP and related objections to emergence. Chapter three is devoted to showing specifically how factors that cannot be derived solely from fundamental laws are necessary for understanding complex phenomena. Chapter four presents several case studies illustrating the need for higher level contexts in physics. One of the examples he describes is the very concept of temperature which depends on stability conditions that are not often articulated in statistical mechanics.

In chapter five, Bishop returns to the objections to contextual emergence he earlier listed in chapter two and convincingly dispenses with them, arguing that, without contextual information, the fundamental laws are inadequate for explaining the world around us. Finally, Bishop concludes with chapter six, in which he discusses the broader implications of contextual emergence. In biology, for example, collective interactions of large ensembles of microbes, cells, or biomolecules set the contextual conditions for novel structures to emerge.

Though the book is short, it is decidedly not a casual fireside read. A solid grounding in theoretical physics and philosophy is helpful in following the key arguments and examples. Nevertheless, going beyond the details of his argument to the big picture, Bishop has provided us with a powerful, seminal work. He has given us a compelling refutation of the reigning perspective of reductionism, together with a rich new paradigm of contextual emergence for a path forward in understanding our universe.

As he explains, the laws of nature provide a necessary but not sufficient set of conditions for behavior and properties at a larger scale. The specific context of an application of those laws provides additional necessary and sufficient conditions for the behavior of that system. That is, the characteristics we observe at a larger scale emerge from the laws of nature operating in a specific context that is related to but not derivable from the fundamental laws.

Another important implication relates to the understanding of determinism and free will. Bishop shows how the laws of nature in and of themselves are neither deterministic nor indeterministic. Rather, "… contextual emergence makes explicit that determinism and indeterminism are contextually-emergent

features of our world as opposed to an absolute feature of the Universe" (chapter–page, 6–17). In some contexts, the laws of nature, such as the Newtonian laws of motion, lead to systems that are deterministic while in other contexts they do not. Thus, "determinism is a contextual feature of reality" (chapter–page, 6–11).

Finally, dualism is not required to explain complex phenomena that cannot be derived solely from fundamental laws. Rather, the conditions that emerge from the interaction of an ensemble of components provide the contexts in which the lawful behavior of nature produces those phenomena. Contextual emergence recognizes the top-down conditions that influence the bottom-up work of the laws of nature. Those conditions are not independent of but are related to the fundamental laws and particles of which the system is composed.

Bishop has laid the philosophical foundation in physics for the rich concept of contextual emergence. It is likely to bear much fruit in the future as it is applied to all the domains such as biology and sociology in which we describe our universe.

Reviewed by Randy Isaac, ASA Executive Director Emeritus, Topsfield, MA 01983. ♥

Letters

Doubting Miller's Doubt

Keith Miller's article "Doubt and Faith in Science and Religion" (*PSCF* 70, no. 2 [2018]: 90–100) is informative, well written, and realistic. The author is well versed in the subject of science and religion. Unfortunately, I do have a problem with the basic concept of his article which is that "scientific inquiry and religion are founded on the acceptance of fundamentally unprovable assumptions." However, many actual observations and actual experiences are not based on assumptions at all.

The following simple scientific inquiry is a typical example: I hold an object in my hand. I want to know if it floats in water. In order to find out I have to perform an experiment. I place the item in a pail filled with water. I observe that it sinks. My knowledge of the universe has been increased by performing this experiment. I now know that the item sinks in water. There is no doubt in the result of this experiment. This scientific inquiry was not founded on basic assumptions because it did not use any assumptions at all.

Scientific knowledge and religious knowledge based on actual observation and/or experience are not founded on assumptions and are therefore not subject to correction and change. Their explanations may be founded on unprovable assumptions and may be subject to correction and change.

Martin Huizinga
ASA Member

Miller Replies

In his letter responding to my article "Doubt and Faith in Science and Religion" (*PSCF* 70, no. 2 [2018]: 90–100), Martin Huizinga argues that many actual observations and experiences are not contingent on any assumptions. However, this comment illustrates one of the primary points that I made in the article. That is, there are fundamental unprovable assumptions that underlie all knowledge. These assumptions are often held without any conscious awareness. In using observations to construct our understanding of the natural world, we depend on the assumption that our senses provide true information about an external physical reality. In fact, we must assume that an objective physical reality that is accessible to us even exists. This is not trivial.

The equivalent in the pursuit of religious truth, is the assumption that there is a "supernatural" reality. For Christians, that assumption includes the existence of a personal transcendent creator God who is also immanent in the natural world. All our subsequent knowledge must start there.

Keith B. Miller
ASA Fellow ♥

Perspectives on Science and Christian Faith Three-Year Index

The three-year *PSCF* index will no longer be published in the journal. The last one was published in the December 2016 issue. An index for each issue is available online by clicking on "Dynamic directory of *PSCF* articles and tables of contents" found at https://network.asa3.org/page/PSCF?.

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Canadian Scientific and Christian Affiliation, PO Box 63082, University Plaza, Dundas, ON L9H 4H0. Website: www.csca.ca.

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