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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Listening Together

James C. Peterson

With the title *Perspectives on Science and Christian Faith*, this academic journal takes into account that, from the beginning, churches have carried forward the Hebrew scriptures (the Old Testament), and added texts that were connected to the apostles and that were recognized by all the churches as anointed by God for instruction and reproof.[1] These additional writings were eventually bound together as the New Testament. The texts embody the interest and language of their human authors, and tradition says that, by God's grace, they are trustworthy in all that they affirm. Some Christians describe this scripture with the specific term "inerrant," being without error. The guarantee of being without error has been described as important so that the reader does not have to pick and choose what is true. All that they teach is true.

The most widely cited statement of inerrancy was drafted in October of 1978 and is called "The Chicago Statement on Biblical Inerrancy." The writers of the declaration wanted to be quite clear that what they saw in the Bible as without error, is what the Bible affirms—not what first comes to mind to someone reading it in Chicago two thousand years later. There are things that a modern reader might expect the text to mean that are not what the text is actually saying.

One might read that God sends his rain on the just and the unjust,[2] and think that the text is teaching that God afflicts the just and the unjust. "Don't rain on my parade," is an old American saying. Anticipated baseball games can be rained out. So the plain, straightforward meaning of rain is a downer, right? Actually, since this was written to people in something of a desert, where they desperately needed the infrequent rain, rain would be perceived as a great blessing: water from the sky, free to drink and to raise food! What that particular text is teaching is that God generously blesses the just and the unjust too. What is without error, true, trustworthy, and so, authoritative, is what the text means, not what any one particular reader reads into it.

People often confuse the authority of scripture with the authority of how they in particular read it. Inerrant scripture does not guarantee that readers are always inerrant. One person's plain meaning of a text, may not be the plain meaning evident to someone else. A heartbreaking example of such an error can be seen in the following excerpt from an exegetical sermon in 1860. The preacher E. N. Elliott proclaimed that Genesis 9:25 teaches that God established slavery through Noah's curse on Ham for all people of African descent.[3]

> May it not be said in truth, that God decreed this institution (slavery) before it existed; and has he not connected its existence with prophetic tokens of special favor, to those who should be slave owners or masters? He is the same God now, that he was when he gave these views of his moral character to the world.[4]

Was Elliott right that Genesis 9:25 teaches that people of African descent should be slaves three thousand years later in South Carolina? To reach this conclusion, he had to read into the text much that was not in the text:

1. That Ham's actions could be punished in all his descendants for future generations forever.
2. That Noah had the authority to pronounce this punishment of enslavement for all of Canaan's descendants.
3. That Canaan's descendants were all black Africans.

Are any of these assumptions present in the text, or even defensible?[5] The warning here is that we, too, might sometimes see in scripture what we want, rather than what is actually there. It takes careful study to hear what is being taught by the text. That is what is true and trustworthy.

If our reading of the Bible and the sciences appears to disagree at some point, it is an opportunity to make sure we are getting right our reading of the science and our reading of the Bible, because God's Works and God's Words will not clash if we understand them rightly. All truth is God's truth.

Scientists know that they make mistakes in understanding the data. One of the most powerful aspects of the scientific method is delighting in finding and correcting incomplete theories. Christians know as well that we are mistake prone. We need due modesty in claiming to relay the message of scripture. Indeed James 3:1 warns that teachers of scripture will be judged with greater strictness. If one is convinced that the Bible is without error in what it teaches, it is imperative to listen carefully for what it is teaching, and not to proclaim something as its voice which is not.

So how do we do get this right? We have to listen carefully to the original context, as it is written for us, not to us. We also gain much from community as we check and learn from each other in the sciences, and in Christian faith, and here in this issue. ∞

Notes

[1]2 Timothy 3:16–17.
[2]Matthew 5:45.
[3]Craig S. Keener, *Paul, Women, and Wives* (Grand Rapids, MI: Baker Academic, 1992).
[4]E. N. Elliott, "The Bible Argument: Or, Slavery in the Light of Divine Revelation," in *Cotton Is King, and Pro-Slavery Arguments*, ed. E. N. Elliott (Augusta, GA: Pritchard, Abbott & Loomis, 1860), 463.
[5]Elizabeth Fox-Genovese and Eugene D. Genovese, *The Mind of the Master Class: History and Faith in the Southern Slaveholders' Worldview* (New York: Cambridge University Press, 2005); Eugene D. Genovese, *Roll Jordan Roll: The World the Slaves Made* (New York: Vintage, 1976); and Mark A. Noll, *The Civil War as a Theological Crisis* (Chapel Hill, NC: The University of North Carolina Press, 2006).

James C. Peterson
Editor-in-Chief

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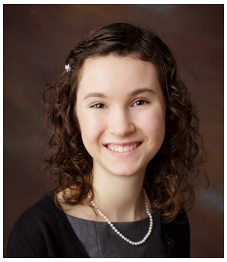

Rachel M. Roller

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Galileo and Global Warming: Parallels between the Geocentrism Debate and Current Evangelical Skepticism about Anthropogenic Climate Change

Rachel M. Roller and Louise Ko Huang

In the face of scientific evidence that the environment is in crisis, studies consistently reveal evangelicals' reluctance to address environmental issues. This tension between science and the church bears surprising resemblances to the Galileo affair of 1633, when the Roman Catholic Church forced Galileo to repudiate his Copernican teachings as heretical. Both conflicts stem from a perceived dearth of evidence, biblical literalism, and complex political factors. This article discusses these parallels between evangelicals' environmental skepticism and the church's condemnation of Galileo and explores what evangelicals can learn from the Galileo affair about how to avoid the mistakes of the past and care for the earth.

Greenhouse gas concentrations are rising.[1] The planet is warming.[2] The ocean is rising and acidifying.[3] Pollution is marring the air we breathe and the water we drink.[4] Species are going extinct.[5] God's creation is in crisis.

For many evangelicals, the preceding statements would be classified as scientifically ungrounded alarmism, neo-pagan Earth worship, or simply liberal tree-hugger propaganda.[6] Despite mounting scientific evidence that human activity is negatively impacting the planet, many evangelical Christians remain apathetic about environmental concerns and resistant to seriously engaging in creation care.[7] In particular, the idea of anthropogenic, or human-caused, climate change continues to be ignored or invalidated by many evangelical Christians.[8] Of course, evangelicals are a wide and varied group, so it would be unfair and inaccurate to imply that this trend applies to every evangelical. We do not intend to discount influential voices such as Francis Schaeffer, Calvin DeWitt, Michael Northcott, and others who have taken strides to challenge the evangelical community to care for God's creation. In general, however, the research indicates that conservative evangelicals in the United States are less likely to accept the evidence for climate change or support environmental action.[9]

This is not the first time that the church has been reluctant to accept the implications of new scientific evidence—a look at

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history reveals significant parallels between modern American evangelicals' skepticism about anthropogenic climate change and the Roman Catholic Church's refusal to accept Galileo's claims that Earth revolved around the sun.[10] Both in Galileo's time and today, much of the tension between the church and the new science was caused by three main factors: a perceived lack of scientific evidence, an insistence on biblical literalism, and complex political divisions. In the remainder of this article, we explore these three parallels and consider what the Galileo affair can teach the church about how it should be responding to climate change.

Telescopes and Thermometers: The Problem of Evidence

The first major parallel between the historical opposition to Galileo's Copernicanism and the current resistance to anthropogenic climate change is the combination of a perceived lack of reliable evidence and a denial of the evidence that exists. Galileo had a preponderance of evidence for the heliocentric, or sun-centered, Copernican model, but his evidence was not entirely incontrovertible.[11] To make matters more complicated, Tycho Brahe had proposed a third cosmology that retained an unmoving Earth in the center of the universe but allowed all the other planets to orbit the sun.[12] The Tychonic system was an ideal compromise because it was mathematically equivalent to the Copernican model; it allowed all the benefits of accurate prediction without the troublesome side effects of contradicting a literal interpretation of scripture or breaking with Aristotelian tradition.[13] Galileo's telescopic observations of the phases of Venus effectively discredited the geocentric, or Earth-centered, Ptolemaic system, but could not distinguish between the Copernican and Tychonic models.[14] In fact, the Copernican system was not conclusively established until the nineteenth century, when precise instrumentation finally allowed observation and measurement of a stellar parallax.[15] In sum, while Galileo had enough evidence to make a strong case for heliocentrism, he could not verify Copernican cosmology beyond reasonable doubt.

The case for anthropogenic climate change lies in a somewhat similar position. There is a strong, even overwhelming, scientific consensus that human activity is increasing greenhouse gas concentrations in the troposphere and driving climate change, but the evidence leaves at least some room for skepticism. One difficulty is that just as the Copernican model was not incredibly intuitive—it certainly does not feel as if Earth is hurtling through space to orbit the sun—climate change may not be immediately obvious to the casual observer. According to a 2014 study by Jones, Cox, and Navarro-Rivera, when climate change skeptics in the United States were asked why they did not believe in global climate change, 33% replied that it was still cold outside.[16]

Another obstacle to the acceptance of anthropogenic climate change comes from alternate theories of what is causing the observed rise in temperature. For example, in the same study, 12% of climate change skeptics cited conflicting or insufficient scientific evidence, 18% claimed that temperature varies naturally, and 4% advanced some alternate scientific explanation.[17] These claims of natural explanations for warming trends are reminiscent of the compromise of the Tychonic model. Just as Tycho's theory accounted for telescopic observations without removing Earth from the center of the cosmos, the current attempts to naturally explain climate change acknowledge the observed warming trend without accepting that human activity is the underlying cause.[18]

Perhaps the most troublesome obstacle—and the biggest parallel to the Galileo case—is the extent to which nonscientific factors cause skeptics to ignore or downplay the evidence that is available. In Galileo's case, two of his more unreasonable opponents—natural philosophers Cremonini and Libri—refused even to look through the telescope because they claimed God did not intend for humans to have telescopic vision.[19] While most modern denials of climate science are not so flagrant or absurd, it is fairly common for people's nonscientific beliefs to shape the way they view the scientific evidence for climate change. For example, Jones, Cox, and Navarro-Rivera found that 61% of Democrats thought that the majority of scientists believe in anthropogenic climate change, while only 34% of Republicans agreed.[20] Different groups of people theoretically have access to the same scientific information, but, as discussed in the remainder of this article, their preconceived notions about scriptural interpretation and politics can affect how they perceive the evidence of climate change.

People of the Book: Biblical Literalism

One of the most obvious parallels between the Galileo affair and the climate change debate is the connection to a literal view of scripture. On the surface, the Roman Catholic Church's resistance to Copernicanism was rooted in literal scriptural interpretation. Passages such as Joshua 10:12–13 and Psalm 96:10, when taken at face value, portray a stationary Earth and a moving sun. Thus, in 1616, several years before the Galileo affair, the Congregation of the Index issued a declaration condemning Copernican cosmology as "false and completely contrary to the Holy Scriptures."[21] Copernicus's writings were suspended until corrected, and Galileo was forbidden to "hold, defend, or teach" heliocentrism.[22] Galileo, however, continued to present evidence for Copernicanism and attempted to reinterpret scripture to remove the conflict between the Bible and the Copernican model.[23]

Under normal circumstances, Galileo's attempts at hermeneutics may not have caused much of a stir, but in the aftermath of the Protestant Reformation, the Roman Catholic Church took a very conservative stance on biblical interpretation, prohibiting any reading that was "contrary to the unanimous agreement of the Fathers."[24] Thus, when Galileo dared to reinterpret scripture to fit his scientific observations, he was arrested on the charge of "vehement suspicion of heresy," forced to repudiate his heliocentric teachings, and sentenced to house arrest for the remainder of his life.[25] Clearly, a literal reading of scripture posed a major obstacle to Copernican cosmology.

Although (to the authors' knowledge) no church has officially declared belief in anthropogenic climate change to be heretical, some of evangelicals' resistance to accepting and acting on climate science appears to be linked to a literal reading of scripture. In 1989, Eckberg and Blocker conducted random phone interviews of adults in Tulsa, Oklahoma, and found that a more literal view of the Bible predicted lower concern for the environment, independent of any background variables or other measures of religious involvement.[26] Schwadel and Johnson's analysis of General Social Survey data from 1984 to 2012 indicated that a literal interpretation of the Bible was the most significant factor in evangelical Protestants' reluctance to support environmental spending.[27] Arbuckle and Konisky evaluated data from the 2012 Cooperative Congressional Election Study and found that evangelical Protestants from denominations with a commitment to biblical literalism expressed lower levels of environmental concern.[28] Perhaps most tellingly, Kilburn's analysis of the 2008 American National Election Survey revealed that biblical literalism correlated with both lower environmental concern and skepticism over anthropogenic causes of climate change.[29] In sum, a literal view of scripture seems to incline evangelical Protestants to be less concerned about the environment, less likely to support spending on environmental initiatives, and more skeptical about anthropogenic climate change.

In the case of Galileo, it is easy to see how a literal reading of passages such as Joshua 10 influenced the church to condemn Copernicanism as heretical, but in the present environmental debate, the connection between biblical literalism and climate change skepticism is not quite as direct or obvious. Granted, it is possible to interpret scripture in a way that precludes climate change. For example, skeptics claiming to provide biblical perspective on the issue of climate change often cite Genesis 8:22 ("As long as the earth endures, seedtime and harvest, cold and heat, summer and winter, day and night will never cease") to support the claim that humans could not possibly upset the God-ordained rhythms of cold and heat.[30] Primarily, however, the connections between a literal view of scripture and a lack of environmental concern appear to flow from three main sectors: dominion theology, premillennial dispensationalist eschatology, and young-earth creationism.

Fill the Earth and Subdue It: Dominion Theology

Some of evangelicals' reluctance to care for the environment appears to flow from a theology of dominion. In the Genesis creation narrative, God creates humans to rule over all the living creatures, tells them to "fill the earth and subdue it," and grants them every seed-bearing plant for food.[31] Advocates of creation care view this passage as a powerful call to environmental stewardship, arguing that we have a responsibility to care for and protect the gift of God's creation, but the dominion mandate has been interpreted in many ways throughout the centuries.[32] Medieval interpretation of this passage "promotes an anthropocentric conception of nature, but it is a conception that takes a passive, interpretive view of the world, rather than one that actively seeks its material exploitation."[33] During the thirteenth century, "a new source of knowledge of the natural world arrived in the West," bringing an increased emphasis on "the intellectual mastery of knowledge of living things."[34] At that time, therefore, the purpose of creation care was "to serve spiritual and moral requirements" and not merely to promote utility.[35] Later, however, the introduction of innovative agricultural machinery in Europe "revolutionized the relationship between human beings and the land that they inhabited."[36] By the seventeenth century, the literal interpretation of "dominion over the earth" became "the exercise of control not in the mind but in the natural world."[37] Such literal interpretation of Genesis was further supported by the emerging Protestant work ethic, influenced by the Calvinist notions of election.[38] Hence, in recent centuries, this passage has too often been used to argue that humans have a nearly unlimited right to domination over the earth and its resources.

In 1967, Lynn White gave a landmark address entitled "The Historical Roots of Our Current Ecologic Crisis," in which he essentially blamed this theology of dominion for precipitating the current ecological crisis.[39] White claims that "Christianity is the most anthropocentric religion the world has seen," in other words, that Christianity puts humans at the center of the universe, making Christians believe that "nature has no reason for existence save to serve man."[40] This anthropocentric mindset, as White argues, permits Christians to feel "superior to nature, contemptuous of it, willing to use it for our slightest whim."[41]

In the years since 1967, many researchers have attempted to test White's hypothesis. When Taylor, Van Weiren, and Zaleha conducted a comprehensive literature review of studies on religion and environmentalism between 1967 and 2015, they found support for White's hypothesis through the early 1990s, mixed results in the late 1990s through the early 2000s, and some movement toward environmentalism in recent years.[42] Other studies show a potential link between biblical literalism and the dominion theology that White criticized. In 2000, Schultz, Zelezny, and Dalrymple surveyed undergraduate social science students in North, Central, and South America and Spain, finding that a literal interpretation of scripture correlated with a more anthropocentric and less ecocentric stance on environmental issues.[43] In other words, the biblical literalists in the study were somewhat concerned about the environment, but mainly because of potential effects on humans.

Meanwhile, Village's 2015 study of churchgoers in the United Kingdom revealed that those with a symbolic view of scripture tended to view nature as a sacrament and were accordingly more concerned about the environment, while those with a literal view of scripture tended to focus on humankind's dominion over the earth and were therefore less concerned about environmental issues.[44] Studies like these indicate that while White's claim that Christians are directly responsible for environmental degradation may be a bit overblown, there is some evidence that a literal view of the Bible can lead to an overemphasis on dominion and a lack of concern about the earth, and hence, the dismissal of anthropogenic climate change and its consequences.

It's All Gonna Burn Anyway: Premillennial Dispensational Eschatology

Another possible reason for the relationship between biblical literalism and apathy toward environmental issues, including climate change, is found in premillennial dispensationalist eschatology, or the belief that God will suddenly take believers to heaven before the dramatic destruction of the earth. This eschatology flows from a literal interpretation of apocalyptic scriptural passages and often leads to environmental apathy. Spence and Brown explain that a literal interpretation of apocalyptic scriptural passages such as 2 Peter 3:10–11, which predicts the destruction of the earth by fire, easily leads to "environmental fatalism" and a lack of concern for the environment.[45] According to Truesdale, if the earth is indeed under a "divinely imposed death sentence," it can be difficult to find a reason to care for the environment.[46] Bouma-Prediger summarizes, "If the earth will be 'burned up to nothing,' why care about it? Why care for something that will be destroyed?"[47]

This connection in people's minds between eschatology and apathy about anthropogenic climate change is supported by empirical research. For example, Barker and Bearce's examination of the 2007 Cooperative Congressional Election Study found that belief in Christ's imminent second coming correlated with lower support for government action to fight climate change, even when controlling for political party, frequency of church attendance, denomination, other measures of general biblical literalism, media distrust, and other demographic variables.[48] Barker and Bearce explained this result by positing that believers in a second coming cannot justify large short-term expenditures to avoid long-term catastrophe because they do not believe the earth will be around long enough for climate change to become a major issue.[49] It seems, then, that biblical literalism counteracts concern for climate change partly because of the literalist eschatological belief that the earth is too short-lived to be worth preserving.

In the Beginning: Creationism and Mistrust of Science

Perhaps the subtlest reason for the connection between a literal reading of scripture and a lack of concern over the environment comes in the form of creationism, especially young-earth creationism. Since many evangelicals take the Genesis creation account literally, they tend to distrust anything—including climate science—that smacks of evolution.[50] Take, for example, an article entitled "A Proposed Bible-Science Perspective on Global Warming" published in the journal of *Answers in Genesis*, a prominent young-earth creationist group. The author calls the idea of anthropogenic global warming "an offshoot of evolutionary thinking"[51] and reminds his readers that "it must be kept in mind that global warming advocates are predominantly evolutionists."[52] In case Martin's audience missed his point, he reiterates that "global warming is an arena where the battle between biblical truth and evolutionary untruths is currently raging," firmly cementing the idea that climate change is some sort of unbiblical hoax by atheistic evolutionists.[53]

While it would be a mischaracterization to imply that all evangelicals, all biblical literalists, or even all creationists would agree with the stance of this *Answers in Genesis* article, this article does not represent an isolated phenomenon. In fact, the correlation between creationism and climate change skepticism is fairly widespread. Using data from the 2007 Pew Research Center survey, Rosenau found a significant correlation between origin beliefs and support for environmental action—proponents of evolution supported stricter environmental legislation, while creationists opposed environmental action.[54] A third basis for the correlation between biblical literalism and climate change skepticism, then, appears to be a mistrust of science, a lack of trust that flows from an insistence on creationism.

We the Evangelicals: Political Division

The third major parallel between the Galileo affair and the current environmental debate is the extent to which the scientific and scriptural debate is blurred by political division. While popular thought often portrays the Galileo affair as a straightforward conflict between science and the church, significant evidence suggests that Galileo's arrest was highly influenced by the social and political climate of the time and had more to do with "political intrigue" than "doctrinal necessity."[55] Galileo had unwittingly made enemies of several powerful Aristotelian natural philosophers who resented his new, observation-based methods of science, and some scholars believe that these natural philosophers played a crucial role in Galileo's arrest.[56]

Even disregarding personal feuds, the Galileo affair was strongly affected by the aftermath of the Protestant Reformation and the Thirty Years' War. Galileo and Pope Urban VIII had been personal friends, and the Pope had even granted Galileo protection against a charge of atomistic heresy in 1624–1625, so it was completely unexpected and out of character for Pope Urban to suddenly abandon Galileo in 1633.[57] In the aftermath of the Catholic defeat at Breitenfeld in the Thirty Years' War, however, the Pope's pro-France leanings were coming under serious scrutiny, and Urban found himself in a precarious political position.[58] Pope Urban needed to save face and show that he was "a conservative and authoritative defender of the faith," and the best way he could do this was to "make an example of someone."[59] The fact that the trial was carried out with unprecedented publicity and threats of torture, whereas Galileo was in reality treated very leniently—to the point that an anonymous enemy complained to the Inquisition—supports the theory that Pope Urban was using Galileo as a "pawn in a political game" to keep his own tenuous position secure.[60] In light of this evidence, it is clear that the Galileo affair was not a simple conflict between science and the church but rather a thorny imbroglio fraught with political intrigue.

Just like the Galileo affair, the current issue of climate change skepticism cannot be reduced to a simple conflict between science and a literal reading of the Bible. Studies consistently show that political affiliation is a significant and sometimes decisive factor in attitudes toward the environment. Schwadel and Johnson's examination of the General Social Survey from 1984 to 2012 revealed that environmental concern is becoming an increasingly political issue.[61] A 2014 study by Kilburn showed that environmental concern in the United States is now highly politicized, with a majority of Republicans tending to believe that climate change is not caused by humans and is not a cause for concern, and a majority of Democrats tending to believe the opposite.[62] Similarly, Arbuckle and Konisky's analysis of 2010 Cooperative Congressional Election Study data showed that political affiliation, not theology nor religious practices, was the most significant direct predictor of attitudes toward the environment.[63]

This increasing political polarization partly explains why evangelicals hesitate to take action to address anthropogenic climate change. At the risk of oversimplifying, in general, evangelicals in the United States tend to identify as political conservatives, and political conservatives do not generally support environmental initiatives. Accordingly, many evangelicals in the United States "view environmentalism as a liberal issue, at best, and anti-Christian at worst" and therefore shy away from environmentalism because they do not want to get drawn into political liberalism.[64] In their analysis of data from the 1993 General Social Survey, Sherkat and Ellison found that respondents with a commitment to biblical literalism believed in a responsibility to steward the earth, but since they also tended to identify as political conservatives, they expressed lower levels of concern for the environment.[65] In other words, even though Christians with a literal view of scripture might have been inclined to steward God's creation, they followed the example of their fellow political conservatives and shied away from environmental issues. Greeley, observing this type of phenomenon, goes so far as to say that this connection between biblical literalism and political conservatism explains why biblical literalists tend not to be concerned about the environment.[66] In addition, conservatives in general tend not to support governmental intervention. Since many proposed solutions regarding climate change may involve national and international governmental regulations, people therefore have an ideological reason to discredit the science behind climate change due to motivated disbelief.[67]

However, this has not always been the case. Danielsen traces the politicization of environmental concern within the church by analyzing articles that address environmental issues from three Christian periodicals—*Sojourners, Christianity Today,* and *World*—from 1984 to 2010.[68] Danielsen discovered that the three magazines began to diverge in 1995–2004 when the Christian right began to view environmentalism as a "liberal" issue.[69] By the years between 2004 and 2010, the three magazines were completely polarized, with *Sojourners* and *Christianity Today* calling for concrete political action to fight climate change, and *World* rejecting the evidence for climate change and calling for Christians to refocus on other moral issues such as human sexuality and abortion.[70] Just as in the Galileo affair, the political issues of today serve to complicate the relationship between the church and science.

Lessons from the Past: A Call to Action

So far, we have discussed several parallels between the Roman Catholic Church's resistance to Copernicanism and many American evangelicals' reluctance to accept climate change science. In both cases, the scientific evidence is compelling but not incontrovertible, much of the church's resistance appears to be rooted in biblical literalism, and the issues are highly politicized. However, a critical aspect in which the two situations differ is the need for action. Copernicanism makes no practical or ethical demands of us—for all intents and purposes, it makes no difference in day-to-day life whether Earth orbits the sun or the other way around. If, however, anthropogenic climate change is an urgent, global issue, then we must take action. As one scholar said when comparing the Galileo affair and the current resistance to accepting the evidence for climate change, we cannot afford to wait another two hundred years for a paradigm shift—we must take action now.[71] In the remainder of this article, we will discuss practical steps evangelicals can glean from the Galileo affair in order to overcome barriers that deter evangelicals from caring for the environment.

Just the Facts: Promoting Enquiry and Conversation

The first lesson evangelicals can learn from Galileo's story is the importance of objectively considering the evidence rather than behaving like the two men who refused to look through Galileo's telescope. Accordingly, one of the first steps in winning skeptical evangelicals over to creation care is simply presenting the scientific evidence regarding climate change, and fostering a spirit of open enquiry. At present, discussions of the environment are notably absent from many churches: a 2008 study found that 64% of churchgoers had never heard a sermon on environmental stewardship.[72] This is understandable, given the common view that environmental discourse is, at best, a distraction from more familiar American evangelical concerns such as sexual morality and the integrity of marriage, and, at worst, a false religion that Christians should avoid at all costs.[73] Yet some voices in the church cogently communicate the urgency of the need for environmental stewardship. Pope Francis's 2015 encyclical, *Laudato Si,* reiterated the importance of "respect for life" and the need for "faithful stewardship."[74] Similarly, the late British evangelical leader John Stott called climate change the most serious global threat facing our planet.[75] Evangelicals Katharine Hayhoe, Steven Bouma-Prediger, and organizations such as Young Evangelicals for Climate Action are making a significant impact by communicating with and mobilizing others to understand the imminent danger of anthropogenic climate change.[76]

It is clear that churches have a unique opportunity to foster discussion about how to care for God's earth. Christian higher education, too, provides a natural venue for conversations about creation care. It is important that science courses discuss the chemistry of rising CO_2 levels and the complexities of ecology, that business courses study the economics of climate change, that political science courses brainstorm practical policy measures to reduce CO_2 emissions and pollution in ways that minimize unintended consequences, and that theology courses explore what the Bible says about caring for God's creation. Much progress has already been made in these areas. For instance, Hope College is a pioneer in creation care, implementing sustainable practices campus-wide through course offerings, faculty research, undergraduate internship opportunities, student-led efforts, food services, and office supplies.[77] These practices are influencing sustainability initiatives in the college's local community in Holland, Michigan. Similarly, Central College is "a leader in environmental stewardship in Iowa."[78] The first to receive Leadership in Energy and Environmental Design (LEED) rating in Iowa, Central utilizes green energy practices, provides food and education for the community through its campus garden, and requires every student to take a course in global sustainability.[79] In California, Santa Clara University created a culture of sustainability with the commitment of the entire campus community.[80] As churches and colleges expand opportunities for investigation and dialogue surrounding environmental care, these actions will go a long way toward healing the historical rift between many American evangelicals and the environment.

Hermeneutic of Charity: Practicing Intellectual Hospitality in Scriptural Interpretation

Another significant lesson evangelicals can learn from the Galileo affair is the importance of careful scriptural interpretation. According to Galileo, when his opponents dogmatically insisted on their own particular reading of scripture even when it contradicted science, they inevitably undermined the authority of God's word.[81] For this reason, Galileo strongly cautions against entangling scientific debates with scriptural controversies. Does Galileo's advice mean that Christians should keep scripture and science completely separate, or that the Bible has no bearing on scientific issues? Of course not. When Galileo famously quoted Cardinal Baronio's sentiment that the intent of scripture is "to teach us how one goes to heaven, not how the heaven goes," he was not barring the Bible from scientific discourse, but rather issuing a call to remember that the true purpose of scripture is not to give detailed scientific information, but to draw people to God.[82]

When Galileo reminded his readers to focus on the main message of God's word rather than getting embroiled in arguments over scientific details, he drew on Saint Augustine's concept of the hermeneutic of charity. Augustine believed that the "twin commandments of charity"—that is, love of God and love of neighbor—ought to be the guiding principles of scriptural interpretation.[83] Because of this hermeneutic of charity, Augustine argued that we should love and respect those who disagree with our interpretations. In his words, "if we engage in hurtful strife as we attempt to expound [Moses's] words, we offend the very charity for the sake of which he said all those things."[84] In other words, if debates over the meaning of scripture degenerate into dissension and conflict, they miss the entire point of scripture—that is, love of God and love of neighbor.

What would Galileo's caution in scriptural interpretation and Augustine's hermeneutic of charity look like when applied to the current evangelical debate over the validity of anthropogenic climate change? First, it would mean American evangelicals having the humility to admit that some readings of passages such as the dominion mandate in Genesis 1 or the eschatological vision in 2 Peter 3 may be flawed or in need of additional nuance. As Steven Bouma-Prediger's book *For the Beauty of the Earth* points out, it is possible to read these texts in a way that supports an ethic of care for God's earth. If the conservative, American evangelical community is willing to consider alternate interpretations of such passages, they may find that biblical literalism does not preclude creation care.

Second, a hermeneutic of charity would invite evangelicals to be willing to overlook differences with those who interpret texts such as the creation account in Genesis nonliterally. This may not mean rejecting a literal reading of the Genesis narrative, but it would require abandoning the harsh, divisive rhetoric that views with suspicion anything remotely related to evolution. This would entail letting go of some of the deeply held mistrust of science for long enough to objectively consider the evidence for climate change, and it would also involve overcoming disagreements with non-evangelical Christians and even people of other faiths to partner with them in regard to care for God's creation.

Out of Many, One: Crossing the Aisle to Care for the Planet

This discussion of overcoming differences leads naturally to the topic of political division. If the role of the Thirty Years' War in the Galileo affair teaches us anything, it is the danger of allowing our political affiliation to cloud our scientific and theological judgment. Yet many conservative evangelicals in the United States shy away from creation care not because they have solid scientific evidence against climate change or because they think environmental care is contrary to scripture, but simply because they view the environment as one of the "liberal" issues, among other matters such as governmental intervention and international treaties. If evangelicals are to rise to the task of caring for God's good earth, they will need to transcend party lines and become willing to partner with those across the aisle to care for our common home. This does not mean that evangelicals must switch parties any more than treating Galileo fairly would have required the Pope to become a Protestant, but it does mean that evangelicals ought to consider environmental initiatives on their own merit, regardless of whether they were proposed by Republicans or by Democrats. If evangelicals can free environmental concern from its association with one end of the political spectrum and be nonpartisan, they will go a long way toward caring for God's earth and for those who are most vulnerable to the consequences of global climate change.

Concluding Thoughts: A Theocentric Approach to Creation Care

A glance at church history reveals many parallels between the Roman Catholic Church's resistance to Galileo's Copernican cosmology and many modern American evangelicals' reluctance to engage with anthropogenic climate change. In both cases, the tension between the church and science stems from a perceived lack of evidence, a literal view of scripture, and complex political division. The Galileo affair shows that evangelicals who are not supportive of climate change should thoughtfully promote inquiry regarding the scientific evidence, interpret scripture with a hermeneutic of charity, and transcend political divisions in order to avoid the mistakes of the past. Meaningful and effective solutions to global climate change may remain elusive until the church unites to care for God's creation.

One final word remains to be said about the connection between Galileo and the present climate change debate, and that concerns the proper place of humanity in the universe. Prior to the Copernican Revolution, Earth was thought to be the center of the cosmos, with the sun, moon, and heavenly bodies orbiting our globe. Thus, there is a common misconception that when Copernicus and Galileo proposed that Earth orbits the sun, they dethroned humanity from the place of honor in the center of the cosmos. In other words, modernity thinks that the shift away from the Ptolemaic model demoted Earth to one insignificant planet among many.

A deeper look at the Medieval understanding of the geocentric cosmos, however, reveals that nothing could be further from the truth. In the Medieval mindset, the center of the universe was not a place of honor, but something akin to a cosmic dump. Everything beyond the moon's orbit was part of the Heavens—shining, light, and unchanging.[85] Earth, however, was dark, heavy, and subject to corruption, forever excluded from the heavenly spheres.[86] In Dante's *Divine Comedy*, the exact center of the universe—the ninth circle of the Inferno—was reserved for Satan himself and the vilest of traitors.[87] Clearly, in the Medieval understanding, the center of the cosmos was no place of honor.

Thus, when Copernicus and Galileo showed that Earth orbits the sun, they were not removing humanity from the throne of the universe, but rather elevating Earth to the status of one of the heavenly bodies.[88] Yes, we were one planet among many, but we were finally granted a place among the stars. When the Copernican revolution put Earth in its proper place, it was not a demotion, but a promotion.

The Galileo affair has much to teach us about who or what is the metaphorical center of the universe today. Terms such as anthropocentrism (human concerns have priority over other forms of life), biocentrism (all of life is at the center), ecocentrism (the interconnected ecosystem takes precedence), and a multitude of other "-centrisms" abound in climate change debates, indicating that one of the primary questions of creation care is who occupies the center of the universe. As discussed earlier, an anthropocentric approach is potentially problematic, because it tends to interpret humanity's God-given dominion as a right to domination and overlooks the fact that humans are fellow creatures with all of creation.[89] Anthropocentrism puts humans at the center of the universe, essentially usurping God's throne. A biocentric or ecocentric approach, on the other hand, tends to be a nonstarter for many evangelicals in the United States, because it too often places human life on the same level as animal and plant life and forgets that humans occupy a special place in creation as God's image bearers.[90] In the eyes of many evangelicals, ecocentrism and biocentrism put nature itself at the center, dethroning both humanity and God. Perhaps, to address the misconception that caring for the environment is a liberal or pantheistic notion, a theocentric approach—putting God in the center—is necessary as the ultimate motivation for creation care.

Among evangelicals, there appears to be significant concern that if we abandon an anthropocentric stance on the environment, we humans will lose our central place of honor in the community of life and become just one organism among many. But could it be that just as in the Copernican Revolution, a shift away from humanity being the center of the cosmos is not a demotion but a promotion? Could it be that putting God at the center, making God the sun around which our debates orbit, would make everything else fall into its proper place?

As many of the frontrunners of the creation care movement have proclaimed, evangelicals must pursue a theocentric approach to creation care, an approach that puts God—not humans or animals or ecosystems—at the center of our environmental discourse. This shift away from narrowly focused anthropocentrism is actually a promotion to humans' intended place as God's cocreators. As cocreators, humanity is called to cultivate a flourishing future for this earth.[91] The Apostle Paul describes in Romans 8:9–22 that all creation groans as it waits for God's children to rise to their ultimate calling to participate in the redemption of the created world.[92] As cocreators, humans are intended to partake in the redemptive work of God—first, as creatures who stand in need of redemption, and then, as coredeemers who share the conviction and ability to modify, domesticate, and reshape the environment.[93] Such a holistic approach harmonizes interactions of life forms—humans, animals, and plants—into a thriving community of life.[94] But most importantly, it recalls that the true reason Christians should care for creation is out of love for God and neighbor. As Francis Schaeffer, one of the pioneers of the creation care movement, so beautifully wrote, "Loving the Lover who has made it, I have respect for the thing He has made."[95] Nearly four centuries after the Galileo affair, will evangelicals who dismiss anthropogenic climate change heed the lessons of the past, transcend their divisions, and put God in the center in order to care for creation?

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Notes

[1]Intergovernmental Panel on Climate Change, *Climate Change 2013: The Physical Science Basis,* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, ed. T. F. Stocker et al. (Cambridge, UK and New York: Cambridge University Press, 2013).

[2]U.S. Global Change Research Program, *Climate Science Special Report: Fourth National Climate Assessment, Volume I,* ed. D. J. Wuebbles et al. (Washington, DC: U.S. Global Change Research Program, 2017), https://doi.org/10.7930/J0J964J6.

[3]S. Levitus et al., "World Ocean Heat Content and Thermosteric Sea Level Change (0–2000 m), 1955–2010," *Geophysical Research Letters* 39, no. 10 (May 28, 2012), https://doi.org/10.1029/2012GL051106; P. M. Haugan and H. Drange, "Effects of CO_2 on the Ocean Environment," *Energy Conversion and Management* 37, no. 6–8 (1996): 1019–22, https://doi.org/10.1016/0196-8904(95)00292-8; and S. C. Doney et al., "Ocean Acidification: The Other CO_2 Problem," *Annual Review of Marine Science,* vol. 1 (2009): 169–92, https://doi.org/10.1146/annurev.marine.010908.163834.

[4]T. Kjellstrom et al., "Air and Water Pollution: Burden and Strategies for Control," in *Disease Control Priorities in Developing Countries*, 2nd ed., ed. D. T. Jamison et al. (Washington, DC: The International Bank for Reconstruction and Development, The World Bank, 2006), chapter 43, https://www.ncbi.nlm.nih.gov/books/NBK11769/.

[5]David B. Wake and Vance T. Vredenburg, "Are We in the Midst of the Sixth Mass Extinction? A View from the World of Amphibians," *Proceedings of the National Academy of Sciences* 105, Supplement 1 (August 12, 2008): 11466–73, https://doi.org/10.1073/pnas.0801921105.

[6]For a discussion of these stereotypes, see E. Calvin Beisner, "Why One Conservative, Evangelical Republican's Case for Climate Alarm Fails—Part 2," Cornwall Alliance for the Stewardship of Creation (May 30, 2015), https://cornwallalliance.org/2015/05/why-one-conservative-evangelical-republicans-case-for-climate-alarm-fails-part-2/.

[7]M. B. Arbuckle and D. M. Konisky, "The Role of Religion in Environmental Attitudes," *Social Science Quarterly* 96, no. 5 (November 2015): 1244–63, https://doi.org/10.1111/ssqu.12213; P. Schwadel and E. Johnson, "The Religious and Political Origins of Evangelical Protestants' Opposition to Environmental Spending," *Journal for the Scientific Study of Religion* 56, no. 1 (March 2017): 179–98, https://doi.org/10.1111/jssr.12322; and D. M. Konisky, "The Greening of Christianity? A Study of Environmental Attitudes over Time," *Environmental Politics* 27, no. 2 (2018): 267–91, https://doi.org/10.1080/09644016.2017.1416903.

[8]A. Leiserowitz et al., *Climate Change in the American Christian Mind* (New Haven, CT: Yale Project on Climate Change Communication, and Fairfax, VA: George Mason University Center for Climate Change Communication, March 2015), 4–25, https://environment.yale.edu/climate-communication-OFF/files/Global-Warming-Religion-March-2015.pdf; and N. Smith and Anthony Leiserowitz, "American Evangelicals and Global Warming," *Global Environmental Change* 23, no. 5 (2013): 1009–17, https://doi.org/10.1016/j.gloenvcha.2013.04.001.

[9]Leiserowitz et al., *Climate Change*; and Smith and Leiserowitz, "American Evangelicals and Global Warming."

[10]Steven Sherwood, "Science Controversies Past and Present," *Physics Today* 64, no. 10 (2011): 39–44, https://doi.org/10.1063/PT.3.1295; and Anne-Katrin Arnold, "Climate Change Science vs. Public Opinion: Closing the Gap," *Media Asia* 41, no. 1 (2014): 16–18, https://www.tandfonline.com/doi/abs/10.1080/01296612.2014.11689993.

[11]Stillman Drake, *Galileo: A Very Short Introduction* (New York: Oxford University Press, 2001), 66–67.

[12]Thomas S. Kuhn, *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought* (Cambridge, MA: Harvard University Press, 1957, 1966), 201–2.

[13]Drake, *Galileo,* 29; and Kuhn, *Copernican Revolution*, 202–5.

[14]Richard J. Blackwell and Michael H. Shank, "Galileo Galilei," in *Science and Religion: A Historical Introduction,* ed. Gary Ferngren (Baltimore, MD: Johns Hopkins University Press, 2002), 109.

[15]Drake, *Galileo,* 66–67.

[16]Robert P. Jones, Daniel Cox, and Juhem Navarro-Rivera, *Believers, Sympathizers, and Skeptics: Why Americans Are Conflicted about Climate Change, Environmental Policy, and Science* (Washington, DC: Public Religion Research Institute, 2014), http://www.prri.org/research/believers-sympathizers-skeptics-americans-conflicted-climate-change-environmental-policy-science/.

[17]Jones, Cox, and Navarro-Rivera, "Believers, Sympathizers, and Skeptics."

[18]Sherwood, "Science Controversies," 39–44.

[19]Drake, *Galileo,* 51–52; Kuhn, *Copernican Revolution*, 226.

[20]Jones, Cox, and Navarro-Rivera, "Believers, Sympathizers, and Skeptics."

[21]Blackwell and Shank, "Galileo Galilei," 112.

[22]Drake, *Galileo,* 79, 94; and Blackwell and Shank, "Galileo Galilei," 112.

[23]John Hedley Brooke, *Science and Religion: Some Historical Perspectives* (Cambridge, UK: Cambridge University Press, 1991, 2014), 105–6.

[24]Thomas Dixon, *Science and Religion: A Very Short Introduction* (New York: Oxford University Press, 2008), 27.

[25]Ibid., 1; and Maurice Finocchiaro, *Retrying Galileo, 1633–1992* (Berkeley, CA: University of California Press, 2005), 12.

[26]Douglas Lee Eckberg and T. Jean Blocker, "Varieties of Religious Involvement and Environmental Concerns: Testing the Lynn White Thesis," *Journal for the Scientific Study of Religion* 28, no. 4 (December 1989): 509.

[27]Schwadel and Johnson, "Religious and Political Origins," 179–98.

[28]Arbuckle and Konisky, "Role of Religion," 1244–63.

[29]H. Whitt Kilburn, "Religion and Foundations of American Public Opinion towards Global Climate Change," *Environmental Politics* 23, no. 3 (2014): 473–89, https://doi.org/10.1080/09644016.2013.859777.

[30]Science Faculty, "Climate Change," The Master's University (September 11, 2017), https://www.masters.edu/news/climatechange.html; and Implanted Word, "Global Warming: A Biblical View," Implanted Word (2019), http://implantedword.com/global-warming-a-biblical-view/.

[31]Genesis 1:27–29, NIV.

[32]Richard Bauckham, *Bible and Ecology: Rediscovering the Community of Creation* (London, UK: Darton, Longman and Todd, 2010), 19.

[33]Peter Harrison, "Subduing the Earth: Genesis 1, Early Modern Science, and the Exploitation of Nature," *The Journal of Religion* 79, no. 1 (1999): 92, https://www.jstor.org/stable/1207043?seq=1.

[34]Ibid., 92–93.

[35]Ibid.

[36]Ibid., 94–95.

[37]Ibid., 96–97.

[38]Ibid., 99.

[39]Lynn White Jr., "The Historical Roots of Our Ecologic Crisis," *Science* 155, no. 3767 (March 10, 1967): 1203–7, https://www.jstor.org/stable/1720120?seq=1.

[40]Ibid., 1205, 1207.

[41]Ibid., 1206.

[42]Bron Taylor, Gretel Van Wieren, and Bernard Zaleha, "The Greening of Religion Hypothesis (Part Two): Assessing the Data from Lynn White, Jr., to Pope Francis," *Journal for the Study of Religion, Nature, and Culture* 10, no. 3 (October 2016): 306–78.

[43]Paul Wesley Schultz, Lynnette Zelezny, and Nancy J. Dalrymple, "A Multinational Perspective on the Relation between Judeo-Christian Religious Beliefs and Attitudes of Environmental Concern," *Environment and Behavior* 32, no. 4 (2000): 576–91, https://doi.org/10.1177/00139160021972676.

[44]Andrew Village, "Was White Right? Biblical Interpretation, Theological Stance and Environmental Attitudes among a Sample of UK Churchgoers," *Journal of Empirical Theology* 28, no. 1 (2015): 23–48, https://doi.org/10.1163/15709256-12341321.

[45]Mark Benjamin Spence and Lee Warren Brown, "Theology and Corporate Environmental Responsibility: A Biblical Literalism Approach to Creation Care," *Journal of Biblical Integration in Business* 21, no. 1 (2018): 49.

[46]Al Truesdale, "Last Things First: The Impact of Eschatology on Ecology," *Perspectives on Science and Christian Faith* 46, no. 2 (1994): 117, https://www.asa3.org/ASA/PSCF/1994/PSCF6-94Truesdale.html.

[47]Steven Bouma-Prediger, *For the Beauty of the Earth: A Christian Vision for Creation Care* (Grand Rapids, MI: Baker Academic, 2001), 76.

[48]David C. Barker and David H. Bearce, "End-Times Theology, the Shadow of the Future, and Public Resistance to Addressing Global Climate Change," *Political Research Quarterly* 66, no. 2 (2013): 267–79, https://doi.org/10.1177/1065912912442243.

[49]Ibid.

[50]Brian McCammack, "Hot Damned America: Evangelicalism and the Climate Change Policy Debate," *American Quarterly* 59, no. 3 (2007): 645–68, https://doi.org/10.1353/aq.2007.0065.

[51]Rod Martin, "A Proposed Bible-Science Perspective on Global Warming," *Answers Research Journal* 3 (May 26, 2010): 104, https://answersingenesis.org/environmental-science/climate-change/a-proposed-bible-science-perspective-on-global-warming/.

[52]Ibid., 92–93.

[53]Ibid., 92.

[54]Josh Rosenau, "Evolution, the Environment, and Religion," *National Center for Science Education Blog* (May 15, 2015), https://ncse.com/blog/2015/05/evolution-environment-religion-0016359.

[55]Finocchiaro, *Retrying Galileo*, 33, 36; and Brooke, *Science and Religion,* 50.

[56]Drake, *Galileo,* 17, 35, 79, 94; Brooke, *Science and Religion,* 133; and Blackwell and Shank, "Galileo Galilei," 106.

[57]Brooke, *Science and Religion,* 49, 132; and David M. Miller, "The Thirty Years' War and the Galileo Affair," *History of Science* 46, no. 151 (2008): 58.

[58]Brooke, *Science and Religion,* 132; and Miller, "Thirty Years' War," 60–61.

[59]Brooke, *Science and Religion,* 133; Dixon, *Science and Religion: A Very Short Introduction*, 30; and Miller, "Thirty Years War," 62.

[60]Finocchiaro, *Retrying Galileo,* 11–13, 26–27, 56–57; ____, "That Galileo Was Imprisoned and Tortured for Advocating Copernicanism," in *Galileo Goes to Jail: And Other Myths about Science and Religion,* ed. Ron Numbers (Cambridge, MA: Harvard University Press, 2009), 73–78; and Miller, "Thirty Years' War," 63–64.

[61]Schwadel and Johnson, "Religious and Political Origins," 179–98.

[62]Kilburn, "Religion and Foundations," 473–89.

[63]Arbuckle and Konisky, "Role of Religion," 1244–63.

[64]Stephen Ellingson, Vernon A. Woodley, and Anthony Paik, "The Structure of Religious Environmentalism: Movement Organizations, Interorganizational Networks, and Collective Action," *Journal for the Scientific Study of Religion* 51, no. 2 (2012): 266–85, https://doi.org/10.1111/j.1468-5906.2012.01639.x; and J. Aaron Simmons, "Evangelical Environmentalism: Oxymoron or Opportunity?," *Worldviews: Global Religions, Culture, and Ecology* 13, no. 1 (2009): 40–71, https://doi.org/10.1163/156853508X394508.

[65]Darren E. Sherkat and Christopher G. Ellison, "Structuring the Religion-Environment Connection: Identifying Religious Influences on Environmental Concern and Activism," *Journal for the Scientific Study of Religion* 46, no. 1 (2007): 71–85, https://www.jstor.org/stable/4621953?seq=1.

[66]Andrew Greeley, "Religion and Attitudes toward the Environment," *Journal for the Scientific Study of Religion* 32, no. 1 (1993): 19–28, https://www.jstor.org/stable/1386911?seq=1.

[67]Troy H. Campbell and Aaron C. Kay, "Solution Aversion: On the Relation between Ideology and Motivated Disbelief," *Journal of Personality and Social Psychology* 107, no. 5 (2014): 809–24.

[68]Sabrina Danielsen, "Fracturing over Creation Care? Shifting Environmental Beliefs among Evangelicals, 1984–2010," *Journal for the Scientific Study of Religion* 52, no. 1 (2013): 198–215, https://doi.org/10.1111/jssr.12017.

[69]Ibid., 198–215.

[70]Ibid.

[71]Arnold, "Climate Change Science vs. Public Opinion," 16–18.
[72]Barna Group, "Evangelicals Go 'Green' with Caution," *Research Releases in Culture and Media* (September 22, 2008), https://www.barna.com/research/evangelicals-go-green-with-caution/.
[73]Richard Slimbach, "Evangelicals and the Environment," *Sustainable Societies Coursepack* (Azusa, CA: Azusa Pacific University, 2013).
[74]Pope Francis, *Encyclical Letter, Laudato Si: On Care for Our Common Home* (Rome, Italy: Libreria Editrice Vaticana, 2015).
[75]John Stott, *The Radical Disciple: Some Neglected Aspects of Our Calling* (Downers Grove, IL: InterVarsity Press, 2010).
[76]Katharine Hayhoe and Andrew Farley, *A Climate for Change: Global Warming Facts for Faith-Based Decisions* (New York: FaithWords, 2009); Bouma-Prediger, *For the Beauty of the Earth;* Young Evangelicals for Climate Action, https://www.yecaction.org/; and Rachel L. Lamb, Benjamin S. Lowe, and Kyle J. Meyaard-Schapp, "Renewing Evangelical Engagement on Climate Change," *Perspectives on Science and Christian Faith* 71, no. 1 (2019): 50–54, https://www.asa3.org/ASA/PSCF/2019/PSCF3-19Lamb.pdf.
[77]Hope College, "Sustainable Hope: Working Together for a Sustainable Campus and Community," Office of Sustainability (2019), https://hope.edu/offices/sustainability/.
[78]Central College, "Global Sustainability Education" (2019), https://central.edu/academics/programs/global-sustainability-education/.
[79]Ibid.
[80]Sherry Booth et al., "Weaving a Culture of Sustainability: Santa Clara University's Evolving Story," in *Sustainability in Higher Education: Stories and Strategies for Transformation*, ed. Peggy F. Barlett and Geoffrey W. Chase (Cambridge, MA: The MIT Press, 2013), 163–74.
[81]Galileo Galilei, "Letter to the Grand Duchess," in *Selected Writings,* trans. William R. Shea and M. Davie (New York: Oxford University Press, 2012), 88.
[82]Ibid., 70.
[83]Augustine, *The Confessions*, trans. M. Boulding (San Francisco, CA: Ignatius Press, 2012), XII.25.35.
[84]Ibid.
[85]Galileo Galilei, "Dialogue on the Two Chief World Systems," in *Selected Writings,* trans. William R. Shea and M. Davie (New York: Oxford University Press, 2012), 133, 168, 208.
[86]Ibid., 168.
[87]Dante Alighieri, *The Divine Comedy*, trans. John Ciardi (New York: New American Library, 2003), Canto XXXIV.
[88]Galilei, "Dialogue on the Two Chief World Systems," 157, 167.
[89]Richard A. Young, *Healing the Earth: A Theocentric Perspective on Environmental Problems and their Solutions* (Nashville, TN: Broadman and Holman, 1994), 116–23.
[90]Ibid., 127.
[91]Philip Hefner, *The Human Factor: Evolution, Culture, and Religion* (Minneapolis, MN: Fortress Press, 1993), 264.
[92]Christopher Southgate, "Creation as 'Very Good' and 'Groaning in Travail,'" in *The Evolution of Evil*, ed. Gaymon Bennett et al. (Göttingen, Germany: Vandenhoeck & Ruprecht, 2008), 80–81.
[93]Ronald Cole-Turner, *The New Genesis: Theology and the Genetic Revolution* (Louisville, KY: Westminster/John Knox Press, 1993), 96.
[94]Jürgen Moltmann, *God in Creation: An Ecological Doctrine of Creation* (London, UK: SCM Press, 1985), 100; and Michael S. Northcott, *The Environment and Christian Ethics* (Cambridge, UK: Cambridge University Press, 1996), 142.
[95]Francis A. Schaeffer and Udo W. Middelmann, *Pollution and the Death of Man* (Wheaton, IL: Crossway Books, 1970), 57.

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On the ASA and CSCA websites, Robert Kaita has written an essay that informs us about what is currently available in fission and fusion, and raises a gamut of questions. He is well prepared to lead us on this topic after nearly forty years in nuclear fusion research at the Plasma Physics Laboratory at Princeton University. Kaita's research interests include plasma heating techniques and plasma instabilities, and he developed diagnostic instrumentation and structural materials for fusion research devices. He also supervised the doctoral research of numerous students in the Plasma Physics Program in Princeton's Department of Astrophysical Sciences, and has served as the president of the American Scientific Affiliation, and is a member of our *PSCF* editorial board.

Readers are encouraged to take up one of the insights or questions, or maybe a related one that was not mentioned, and draft an article (typically about 5,000–8,000 words) that contributes to the conversation. These can be sent to Dr. Kaita at kaita9094@gmail.com. He will send the best essays on to peer review and then we will select from those for publication in a theme issue of *Perspectives on Science and Christian Faith.*

The lead editorial in the December 2013 issue of *PSCF* outlines what the journal looks for in article contributions. For best consideration for inclusion in the theme issue, manuscripts should be received electronically before **July 30, 2020**.

Looking forward to your contributions,

James C. Peterson, *Editor-in-Chief*

J. B. Stump

Did God Guide Our Evolution?

J. B. Stump

There are several broad strategies for responding to the question, "Did God guide our evolution?" which attempt to uphold both the science of evolution and Christian theology. I survey some of the most promising of these, and then present a longer defense of the strategy I find most plausible—the epistemological strategy which recognizes that science and theology are different ways we have developed for thinking about reality. Both have their own traditions, vocabularies, and explanatory principles, and both give a true perspective on our origins. But neither tells the whole story, and their accounts should not be fused into one.

If forced to give a short and simple answer to the question in my title, I would have to say "yes." But I am afraid that the question is not simple, so my answer would not be short. I do think that the question is a fair one, as it gives voice to what many people ask when it comes to evolution. Sociologist Elaine Ecklund found that one of the two most important questions people have about science and religion is, "What does science mean for the existence and activity of God?"[1] But ultimately, I will claim that the simple-yes-or-no-gotcha question is loaded and ill conceived, along the lines of "Have you stopped gambling with your rent money?"

The question "Did God guide our evolution?" seemingly puts us Christians who accept the science of evolution on the horns of a dilemma. If we answer "no," it sounds as if we must be deists who think that God started things up and then just watched them go; if we answer "yes," it sounds as if we have conceded to intelligent design because, as its supporters claim, neo-Darwinism is not the kind of process that could be guided.

Is there a logical problem with accepting the overwhelmingly dominant explanation of evolution for how life (including humans) developed on Earth, while, at the same time, affirming the kind of providence typically associated with Christian theism? Critics from both sides seem to think so. For example, Stephen Meyer wrote,

> Thus, any proponent of theistic evolution who affirms that God is directing the evolutionary mechanism, and who also rejects intelligent design, implicitly contradicts himself.[2]

Several of the words in his claim might be interpreted in various ways, but the clear sense of the charge is that if an individual is going to accept anything like a traditional view of God, he or she will need to adopt the intelligent design version of science which inserts God's action into the workings of science in obvious and detectable ways.

A complementary charge comes from the other side. Richard Dawkins said,

> Humanity's best estimate of the probability of divine creation dropped steeply in 1859 when *The Origin of Species* was published, and it has declined steadily during the subsequent decades, as evolution consolidated itself from plausible theory in the nineteenth century to established fact today.[3]

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Again, we might quibble with various words and concepts from this specific quote, but the clear charge from Dawkins is that evolutionary science has shown the beliefs of traditional Christian theism to be wrong and silly (and harmful, according to other things he has written).

These are the extreme cases. There are more subtle and sophisticated versions that may impulsively reject the conflict narratives, but their authors are often unsure how the peace is to be maintained between evolution and Christian theism, or what concessions will have to be made. There is an often-unresolved tension for many of us who have these twin intuitions:

- As science-minded people, the more we examine the development of life, the more we are persuaded of the efficacy and integrity of natural mechanisms.
- As Christians, the more we learn of God and his ways, the more we are persuaded that God loves us and has partnered with us to achieve God's purposes for the world.

The first of these intuitions leads us to think that science, while not infallible, has shown itself to be a reliable, truth-discovering enterprise, and that, therefore, the science describing our evolution is at least largely correct. The second leads us to believe that God had (and has) a plan for us as image bearers, and therefore God did all that was necessary to provide for our appearance on Earth. So we have a tension, because it seems as if the answer to "Did God guide evolution?" must be "no" based on the first intuition, and "yes" based on the second.

It is my aim in this article to consider a range of defensible ways of responding to this question, arguing more specifically for the one I find most persuasive. First, to give greater definition to the question, I will formalize the intuitions mentioned above into these two claims:

C1. Evolution is the best scientific explanation for the origin of *Homo sapiens*.

C2. God intentionally created human beings in God's image.

My challenge, then, is to show how I (and many other evolutionary creationists) can consistently hold to both claims. How can we reconcile our belief that evolution is at least largely correct in its explanation of our origins, with our commitment that we are not accidents—that God intentionally created us to be divine image bearers to the rest of creation?

Following are four strategies for effecting this reconciliation. There is no attempt at exhaustiveness here, and you may be able to make variations, and even hybrids, of these strategies, but I think that these at least point toward the most plausible responses we can make to the perceived dilemma.

The Semantic Strategy

In the semantic strategy, avoiding contradiction between the two claims is simply a matter of language. For two propositions to contradict, the relevant terms in each must refer to the same thing. The two claims, "The Red Sox won the World Series" and "The Boston baseball team lost the World Series" contradict each other if "Boston baseball team" refers to the Red Sox, and if "World Series" in both statements refers to the 2018 World Series. Both statements cannot be true in that sense. However, if, in the first statement, it was the "Red Sox" who won the "2018 World Series" and if, in the second statement, it was the "Boston Braves" who lost the "1948 World Series," then both statements are true and do not contradict each other. The relevant terms in each statement refer to different things. Similarly, if it can reasonably be claimed that the referents for "*Homo sapiens*" and "human beings" are different in my C1 and C2, the contradiction would be avoided.

So, do "*Homo sapiens*" and "human beings" pick out the same set of individuals? Who gets to decide? Language is fascinating and tricky, and its governance is not at all straightforward. If you look up "*Homo sapiens*" in a dictionary, you will find the definition, "the species of bipedal primates to which modern humans belong."[4] That implies that all modern humans are *Homo sapiens*, but the definition is noncommittal on the converse: are all *Homo sapiens* modern humans?

The semantic strategy might say, "No, not all *Homo sapiens* are modern humans; there is something else added to *Homo sapiens* that makes them into the true humans we see today." That could be the breath of God, a soul, the image of God, or a special relationship (the way, for example, adopted children have a special relationship to their adopted parents that they do not have with other adults). Then we could claim that it is only modern humans who were intentionally created in God's image, whereas *Homo sapiens* did indeed evolve the way science describes them. We might imagine that at some point God entered into a special relationship with some *Homo sapiens*, thereby conferring God's image on them and making them truly human. Denis Alexander's *Homo divinus* model might be leveraged into some such scenario (it should be noted, though, that Alexander himself does not confine the image of God or humanity to this restricted set of persons, but says that they are the only ones who are "spiritually alive").[5]

Depending on theological convictions, you might say that this creation event occurred around the time of the events depicted in Genesis 2–4, and you might even say that this initial creation event of humans was restricted to two individuals—Adam and Eve. But then there is some further explanatory work to do on the status of the other living *Homo sapiens* (which had spread around the world by then). For this model of reconciling my two claims to work, those other *Homo sapiens* cannot be humans. Are they merely animals? And presumably all of us *Homo sapiens* today are modern humans, so how does being human spread? From parents to children? That might occur through a kind of traducianism, according to which souls are propagated naturally as a result of intercourse. But then God would intentionally create only the first two, and that starts to make my C2 problematic. We could also argue that God creates all souls directly, or even opt for a relational view. But then it is not clear why ancestry would be so important, as God could enter into such a relationship with any *Homo sapiens*, not just those descended from Adam and Eve. Furthermore, one should consider that this strategy involves postulating beings who are behaviorally similar and sexually compatible, but who are not deemed human.

Such concerns could encourage us to push the creation event back further in time and make it applicable to all *Homo sapiens*. Perhaps there was a time when all *Homo sapiens* were confined to one community before the exodus from Africa, and God entered into a special relationship with all of them at once, thus conferring the divine image and humanity onto all extant *Homo sapiens* and their descendants. The science has become increasingly clear that the population of *Homo sapiens* has never dipped below about 10,000, so it is difficult to imagine what that event would have been like. And we are still left with the question of other beings which were closely enough related to us that we could successfully mate with them; this almost certainly includes Neanderthals and Denisovans, but possibly other species too.

I have concerns about solving problems like this by definitional fiat, as I think ambiguity in language is often a reflection of genuine ambiguity in reality, and definitional fiat only masks that ambiguity, rather than resolving it. The biological classification system we have inherited from Linnaeus works only by imposing artificial boundaries between species. And while "human" might be used in a theological sense, it also definitely has a nontheological usage that is widespread among English speakers, and the trend seems to be to extend this to all species in the *Homo* genus. On the Smithsonian's Hall of Human Origins website, "human" is treated as the larger category: all *Homo sapiens* are humans, but not all humans are *Homo sapiens*.[6] This seems to be the more common usage in popular science, recognizing other *Homo* species as human too.[7] We might try to change the way in which culture uses language by stipulating exactly what we mean by a term, but unless that usage catches on we cannot claim to have the true meaning of the term.

So, while there are some possibilities for reconciling my two claims through the semantic strategy, there also seem to be considerable difficulties in doing so through this strategy alone. Perhaps those difficulties are not insurmountable, but I turn here to a second strategy.

The Nomological Strategy

The next two strategies I will discuss involve rethinking or reinterpreting the science. They both affirm C1 (Evolution is the best scientific description for the origin of *Homo sapiens*), but I think that there are other ways of understanding the science than as unguidable.

First is the nomological strategy. According to it, there are laws (hence, "nomological") applicable to the process of evolution which have not yet been fully uncovered and understood. Once they are, we will see that evolution is much more predictable than has been previously characterized. Stephen Jay Gould famously claimed, "Replay the tape a million times from a Burgess beginning, and I doubt that anything like *Homo sapiens* would ever evolve again."[8] But challenging this view is Simon Conway Morris who says, "Contrary to received wisdom, the emergence of human intelligence is a near-inevitability."[9]

If Conway Morris is correct, then the nomological strategy has promise. Indeed, it appears that we will end up with something like a fine-tuning argument from biology. Just as we have discovered physical constants that were highly improbable and yet necessary for our existence, so too the process of evolution seems to be designed so that creatures like us are guaranteed to emerge. Of course, there is some debate about just how similar these creatures would have to be to us. Did we need to have five fingers on each hand? Probably not. Did we need to have the capacity for moral responsibility? Definitely. In between those extremes, there might be disagreements over how much similarity a creature must have to us in order to fulfill God's intention of creating organisms to bear God's image. Did we have to be warm-blooded? Walk upright? Have opposable thumbs? These characteristics are part and parcel of the kind of creatures we are now, but perhaps the capacities required for image bearing could have been realized in very different kinds of beings.

So, does this strategy succeed in reconciling the two claims? For the scientific claim C1, it gives a fascinating interpretation of the evidence. Convergence is now a well-attested phenomenon in evolution, whereby very similar traits have evolved multiple times on different parts of the evolutionary tree—things such as eyeballs, and wings, and even REM sleep. But it seems to me too soon to claim that these convergences imply that human beings (whether *Homo sapiens* or something sufficiently like us) were inevitable. It is definitely worth paying attention to the ongoing research in this area.

For the theological claim C2, the nomological strategy front-loads God's intention to create us: God did not intervene along the way, but instead set up physical laws at the beginning of the process guaranteeing that creatures like us would develop. That, in itself, is not necessarily a problem; I think it is a legitimate understanding of how "intentions" might be carried out. But it does seem to suggest a deistic view that most of us evolutionary creationists think should be avoided for theological reasons. Did God just start things up and then sit back and watch it all unfold? That is the view attributed to "theistic evolution" in the book by that title recently produced by proponents of intelligent design.[10] But I do not know anyone who identifies as an evolutionary creationist who would accept that as an accurate description of their beliefs. So I join with the contributors to that book in rejecting views of evolution that make God a spectator to what matter can do on its own.

A recent defense of a nomological view that comes close to making God a spectator was presented by philosopher Chris Barrigar in these pages.[11] He calls his view a "front-loaded" strategy in contrast to the "punctuated" strategies he rejects. I am sympathetic to Barrigar's critique of the punctuated strategies, as I will discuss in the next section, but I also have concerns with his front-loaded strategy. His first step in avoiding the conflict between C1 and C2 is a semantic move that rejects *Homo sapiens* as synonymous with humans. It need not have been *Homo sapiens* that developed on Earth, so long as something with the capacity for *agape* emerged.

Then he employs the front-loading, or what I have called the nomological strategy, to ensure that the right kinds of beings will develop. As long as the initial conditions of the created world are right, and if there are sufficiently large numbers of opportunities, then there is a very high probability that the right kinds of beings will eventually emerge somewhere without God's intervention in the process. Barrigar says, "God allows the created order to evolve on its own, to 'make itself' (to use Polkinghorne's phrase) from initial conditions which lead to the probabilistic emergence of *agape*-capable beings."[12]

Barrigar's account is sophisticated and subtle, and definitely worth further consideration. However, I find myself leaning away from it because of the implications for God's distance from the created order. Barrigar is committed to Trinitarian orthodoxy and thus does not want to accept the deist label. To counter this charge he claims, "God is at all times actively engaged with creation by sustaining the continuing existence of creation (presumably by sustaining the physical fields and forces undergirding the universe)."[13] To my mind, it is with this bald assertion (nothing further is said about how we might understand God's sustaining activity) that the view becomes problematic. Using the same logic that led Barrigar to reject the punctuated views, we must ask, "Why would God not make the created order such that it can sustain itself? And how are we supposed to understand the nature of God's activity in sustaining the physical fields and forces?" Evidently

God just does it. And if that kind of response is open to us (which it would have to be eventually in order to stave off an infinite regress), I think that there are better ways of understanding God's activity.

The Causal Joint Strategy

I am calling this next approach the causal joint strategy, because it looks for some point of interaction that allows for the seamless integration of God's action into the natural order of causes, yet without intervening in the sense of overriding natural law. This is not intended as an explanation for miraculous interventions by God, for which there would be no scientific description, but for the regular ongoing providence by which God governs the created order. More specifically for our topic, this noninterventionist mode of divine action is an attempt to show how God could guide the process of evolution without that action showing up as anomalous scientific data.

For this to work, nature itself must be such that it can provide necessary, but not sufficient, conditions for some events. That is to say, the causal structure of nature must not be determinate. So, from the perspective of science, a complete description of the initial conditions of a system along with a comprehensive knowledge of the natural laws would still be insufficient for predicting the later states of the system with 100% accuracy.

The most promising version of this strategy is Robert J. Russell's, which he calls non-interventionist objective divine action (NIODA).[14] He identifies quantum indeterminacy as the causal joint in nature, because from the perspective of science (at least within the Copenhagen interpretation), quantum events are not determined by the prior state of the system, and are genuinely random. The equations we have for describing quantum states give only a range of possibilities or potentials for the future of that quantum system. But perhaps God can determine one of these potential outcomes by causing the quantum wave to collapse in a manner that would bring about a desired end. In this way, God would work within the natural system, achieving results that are within the parameters of what could possibly have been expected from the perspective of science alone.

A question to be asked of this strategy is whether determining the outcomes of some quantum level events is scalable to bring about macroscopic outcomes. Typically, we understand that the many, many random quantum events going on "even out," so that macroscopic behavior is predictable. But there may be an opening for quantum influence in the evolution of a particular species. One of the factors (not the only one) driving the evolution of new species is the random errors, or mutations, that can occur in copying the genetic code. Many of these mutations involve quantum processes such as the breaking of a hydrogen bond in the DNA molecule. It is there, according to Russell, that God can act outside the view of science, actualizing one of the potential outcomes and thereby guiding the evolution of species.

So, based on this strategy, we can reconcile C1 and C2 by understanding that the science does indeed describe the evolution of *Homo sapiens* accurately, while also affirming that God works within the cracks in nature to ensure that we humans emerge from the process. This is an elegant way of incorporating God's intentional action into the course of nature, and it will be attractive to many.

I am not sure, though, that it is correct to call it "noninterventionist." Science may not be able to detect God's action in individual mutation events, but the strategy does assert that things turn out differently than if God had not acted.[15] That sounds like an intervention. Perhaps we are just fussing with words here, and the label "intervention" does not need to be avoided at all costs. But, for the integrity of science, Russell wants to avoid the detection of divine intervention. I wonder, though, whether such detection is inescapable in the long run. That depends on the number of interventions required for God to keep evolution on track to produce us. If evolution turns out to be more predictable along the lines the nomological strategy suggests, then there might be very few of these interventions required, and they would blend into the overall possibilities and not look remarkable. But if there are many interventions required in this process, then it might start to look suspiciously as if there were an intelligence tinkering with the process to bring about a desired end (and, of course, playing into the strategy of intelligent design), because the outcome is too improbable for how we understand the science itself. That would mean we are not really affirming C1, namely, that evolution accurately describes our origin.

We could insist, then, that there are relatively few interventions required. The problem with occasional intervention is that it does not help much with removing the charge of deism. As Aubrey Moore noted more than a century ago, "a theory of occasional intervention implies as its correlative a theory of ordinary absence."[16] So, just as with Barrigar's nomological strategy, there still remains the need to supplement this with another approach that does not confine God's action to very rare occasions.

I have one more concern with the causal joint strategy that echoes my concern with Barrigar's description of God's sustaining action, and I think that, for this approach, it is the most challenging. In claiming to find a causal joint as the locus of interaction between two different kinds of activity, I am reminded of the most famous of these in the history of science and philosophy: Descartes's proposal that the pineal gland serves as the place where the immaterial mind interacts with the material body. That just seems like a category mistake, and I cannot help wondering if something similar is going on here.

It appears to me that the causal joint strategy pushes for a scientific explanation of how God affects the course of nature, thus reducing God's action to one of the physical causes. Russell resists that charge against his view, but I wonder if that undercuts the strategy and ultimately leaves it unsatisfying. To the question, "How does God guide evolution?" it gives the scientific-sounding answer, "by causing mutations during DNA replication." Then we ask, "How does God cause mutations?" and we get the equally scientific-sounding "by collapsing the quantum wave in just the right way." But can we not then ask, "So how does God cause the quantum wave to collapse that way?" I do not think there is a scientific-sounding answer to such a question. Instead, we are reduced to saying something like, "Well, God just does it." But if we can opt out of the scientific discourse in answering the question about quantum events, why can we not just go there immediately when asked, "How does God guide evolution?" and answer, "God just does it"? How does it help to break down the natural process into smaller bits and say of them, "God just does it"?

My critique of this strategy depends substantially on the coherence of my preferred strategy, so I turn to it now.

The Epistemological Strategy

I have called this strategy "epistemological" because it develops the claim that science and theology are different ways of knowing. Some people like to say that there are different "levels of explanation"; I have become partial to calling them different "discourses." All of these descriptors point toward what the British philosopher Roger Scruton has called "cognitive dualism."[17] That is not to say that reality is dualistic, but rather that we humans have developed two different broad ways (with lots of sub-ways) of thinking about reality, and these two ways have their own traditions and vocabularies. I prefer to call these two broad ways of knowing the scientific and the personal.[18]

On this strategy, the method of reconciling C1 and C2 comes down to recognizing that they come from different discourses. There are similarities here with the semantic strategy in attempting to dissolve the apparent conflict. But instead of simply claiming that the words "human" and "*Homo sapiens*" mean something different, I am claiming that C1 and C2 are embedded in traditions that have come to describe different aspects of reality. More specifically, the scientific claim C1 tells the story of human origins one way, and the theological claim C2 (which is part of the personal discourse, since it describes the actions of a personal agent) tells that same story in a different way. Each abstracts from reality different features that are appropriate to its discourse, and communicates through its particular lens on the world. As such, these are not competing descriptions but complementary, and neither tells the whole story.

Some history of the idea

This idea of two discourses is not a new one that I have invented, but rather draws on a tradition that has recognized the need for different ways of describing our experience of persons in a world that is increasingly explained with science. Immanuel Kant claimed that when we look at the world through our understanding, we see chains of causal connections that subject everything to necessary laws, leaving no room for freedom. But persons must be viewed through a different lens, that of practical reason, which sees us as responsible and beholden to the laws of reason.

C. Lloyd Morgan was a British psychologist and administrator, who gave the Gifford Lectures in St. Andrews in 1922. In 1904 he gave the Lowell

Lectures in Boston and developed them in his book, *The Interpretation of Nature*, which gives an elegant defense of the claim that we understand the world through two different modes of interpretation.[19]

The Jewish philosopher Martin Buber said, "The world is two-fold for man in accordance with his two-fold attitude."[20] He called these images the "You-world" and the "It-world" depending on whether we treat our experiences as originating from a subject (a You) or an object (an It). Applying this specifically to our experience of other human beings, he describes our two-fold experience as follows:

> When I confront a human being as my You and speak the basic I-You to him, then he is no thing among things nor does he consist of things … Even as a melody is not composed of tones, nor a verse of words, nor a statue of lines—one must pull and tear to turn a unity into a multiplicity—so it is with the human being to whom I say You. I can abstract from him the color of his hair or the color of his speech or the color of his graciousness; I have to do this again and again; but immediately he is no longer You.[21]

Mid-twentieth century philosopher Wilfred Sellars observed,

> The philosopher is confronted not by one complex many-dimensional picture, the unity of which, such as it is, he must come to appreciate; but by *two* pictures of essentially the same order of complexity, each of which purports to be a complete picture of man-in-the-world, and which, after separate scrutiny, he must fuse into one vision.[22]

What I have called the personal discourse or image, conceptualizes and organizes our experience in such a way that we can see a human being "as" a personal agent who acts intentionally, has free will, and is morally responsible. We see her as a subject and explain what she does by appeal to the reasons she had for her behavior. But then we can take the same human being and put her under the microscope, recognizing that she is a complex material organism made of particles of matter that obey physical laws. This way of conceptualizing and organizing our experience of her is represented as the scientific image, and when we see her as an object, we explain her actions by appealing to the kinds of causes recognized in the various sciences.

The epistemological strategy can apply this two-fold way of organizing and interpreting our experience to the problem of divine action.[23] God is a personal agent (or tri-personal, according to the Christian Trinitarianism I espouse), and God's actions are thus most properly described and explained using terms from the personal discourse. That is, we ascribe reasons to God for acting in certain ways; we say God has intentions and will. Such terms are not scientific and are not reducible to scientific terminology. Indeed, the success of the scientific revolution came at least in part because of the narrowing of the aims of science to provide natural explanations in terms of what Aristotle called efficient and material causes. But personal action is explained by final causes—reasons—which are part of the personal discourse. Charles Taylor says, "The great achievement of the seventeenth-century scientific revolution was to develop a language for nature that was purged of human meanings."[24]

It has been the tendency to treat the scientific discourse as the real description of things and to treat whatever does not fit within that discourse (e.g., free will, morality, meaning) as folk psychology and fictions. But that is to succumb to scientism. Philosopher of science Mary Midgley discusses the technical language of science compared to the "language of everyday life," saying,

> There is still no reason to expect that one of their messages will turn out to be real and the other illusory. These two languages are not rivals, competitors for a prize marked "reality." They merely do different work. Their differences simply show that when we talk about the same topic, we are considering it from different angles and asking different questions.[25]

So the epistemological strategy sees the evolutionary account of the origin of *Homo sapiens* as a description of our origins from the perspective of science. It gives us an accurate picture insofar as the concerns of science are involved, but it is not a complete picture. Theology gives a description of our origins from the perspective of the personal discourse, appealing to God's reasons and intentions. It too is accurate, but also incomplete in itself.

Some illustrations of cognitive dualism

To further explain what I mean by cognitive dualism and the two discourses, I point to a few illustrations. A familiar one is John Polkinghorne's example of explaining why the kettle is boiling:[26] we can explain and describe the event scientifically by talking about closed electrical circuits, excited molecules, and vapor pressure; or we might explain the boiling kettle by saying that I wanted a cup of tea. The first explanation appeals to physical or material causes—parts of the scientific discourse; the second is a personal explanation which appeals to reasons to explain the event. Unless we are going to claim that reasons are ultimately and completely reducible to material causes (e.g., they are just certain neurons firing), then there will remain two different levels of explanation—neither of which tells the whole story of the event. They do not conflict with each other so long as we recognize that they are describing different aspects of reality. Similarly, evolution is a scientific theory appealing to physical causes; talking of God's intentions and design is a theological account of the history of life that appeals to personal reasons as explanations.

Another way of thinking about these two discourses is that they are like different maps of reality.[27] A map abstracts various features of reality (and ignores others) and presents them in a way that highlights what is important for a particular purpose. A political map shows the boundaries of different levels of political organization. A topographical map shows the elevation and other features of the landscape. And, of course, we might have maps of streets, population concentrations, or underground plumbing for a particular area. None of these is a comprehensive presentation of all aspects of reality—indeed, that would be useless to us. Instead, each map is a tool for depicting one aspect of reality. My claim, then, is that science and theology are like different maps, drawing our attention to different aspects of reality.

Slightly different is to compare cognitive dualism to different styles of art. Think of two paintings by Picasso: *The Old Guitarist* and *Guitariste*.[28] These are both pictures of someone playing a guitar, but they are of very different styles, abstracting from the actual thing, and re-presenting some aspects to us. In *The Old Guitarist*, the colors used and even the angular and exaggerated lines of the body highlight a mood that is captured in the picture. *Guitariste* comes from Picasso's cubist period, which to the untrained eye does not look at all like someone playing a guitar. But the goal of cubism was to develop a new way of seeing the most fundamental shapes of a more complex object: therefore, we have the figure represented in squares and triangles and circles. So too with science and theology. They are abstractions of different aspects of reality.

Distinguishing from NOMA

One of the criticisms often raised against this strategy is that it is just like Stephen Jay Gould's non-overlapping magisteria (NOMA) approach to science and religion. I do not think that is right. Gould hoped he could bring peace to science and religion conflicts by restricting science to facts, and religion to values. He said,

> To summarize, with a tad of repetition, the net, or magisterium, of science covers the empirical realm: what the universe is made of (fact) and why does it work this way (theory). The magisterium of religion extends over questions of ultimate meaning and moral value. These two magisteria do not overlap.[29]

It always seems to me that religion gets the short end of the stick in that way of thinking: science gets to tell us the truth of things, while religion is just feelings and values. Now, that is a simplification of NOMA, but the key difference is that in the view I am proposing, both science and theology are making factual truth claims. When I say I believe that God intentionally created human beings in God's image, I am claiming that to be a fact, and it is true or false depending on whether it is an accurate description of reality.

I have to admit that the epistemological strategy sometimes acts like an independence model according to Ian Barbour's four-fold typology (of which NOMA is an extreme example),[30] but not absolutely so. For most of the objects of inquiry, one of the discourses (or levels of explanation, or ways of knowing) will prove to be a more appropriate guide to learning about it. Science does not have much of relevance to say about the atonement or the *Filioque* clause added to the Nicene Creed; theology does not have much to contribute to understanding tectonic plates and germ theory. But if we are asking the questions "What does it mean to be human?" or "When in natural history did sin begin?" then both science and theology have something relevant to say, and if we attempt to answer these questions with just one of them, we are going to get an incomplete answer.

So, evolution is the best scientific explanation for the origin of *Homo sapiens*. This is scientific language, and evolution appeals to physical causes, and within that domain it does a very good job of explaining where we came from. But it does not tell the whole story. Theology offers a personal explanation: we believe God to be a person, and therefore it is appropriate to use verbs from the personal universe of discourse, which are not reducible to scientific causes. We can truly affirm that God guides, God designs, God creates.

Conclusion

Did God guide evolution? If my analysis is correct, the framing of the question leads to problems by combining terms from the scientific discourse with terms from the personal discourse. This might be all right in more colloquial contexts, but when we probe deeper, we find there are problems with combining these terms. Instead, when seeking greater clarity, we should ask about the origin of ourselves, and then realize that we have to answer with two different stories: one that gives the scientific details of the evolution of *Homo sapiens*, the other that gives the personal story of God's loving intentions for human beings. We hold those two stories up for inspection like two different paintings of the same thing. We learn more about the object by considering both—even allowing for dialogue between the artists—but not by fusing them into one hybrid picture.

Some people appear to think that unless you combine these stories or discourses into one, you have not really given a proper account of an issue.[31] Of course, wherever possible, we want to present unified and coherent accounts of our experience. But ultimately, we are perspectival beings and perhaps should not expect to see all aspects of reality in one unified view.

There is precedent for this in the disciplines of science and theology themselves. In science, we ask: "Is light a particle or a wave?" When we conduct one kind of experiment, it gives us one answer; and when we carry out another, we get a different answer. We could say the same thing about general relativity and quantum theory: they both seem to be true, but we cannot figure out how to put them together. These examples show that the concepts we have at our disposal do not allow us to describe reality completely; instead, these are true but incomplete perspectives on reality.

The same is true in theology for the doctrine of the Incarnation: Is Jesus human or divine? How appropriate that the very center of our faith is one of those subjects of inquiry that cannot be described comprehensively by just one set of concepts. Instead, we describe one aspect as well as we can, and then we have to "change registers" and speak differently.[32]

We might think of these examples as putting on different eyeglasses through which we look. Depending on which glasses we put on, we will see light either "as" a particle or "as" a wave; compare this with doctrines of Jesus "as" human or "as" divine. Note, this does not mean that these are false descriptions but, rather, that our observations are theory laden because of the "glasses" we look through. And we do not have specific conceptual glasses that let us see both perspectives at the same time.

I claim that this is the same situation for the question of whether God guides evolution. When I look at the evidence through my scientific glasses, I see the data that conform to scientific practice and principles. They are impressive, and there is every expectation that the problems or anomalies that are brought up by the scientific investigations and explanations will have scientific solutions. As Christians, we should loudly proclaim the success of this scientific story, in the same way we proclaim the marvels of the conception, gestation, and birth of a baby. But we must also proclaim clearly that science does not tell the whole story. When I look at the same natural world through my theology glasses, I see another aspect of reality—one that shows God's care, providence, and yes, even God's guidance of the grand story of creation.

Therefore, back to my two claims:

C1. Evolution is the best scientific explanation for the origin of *Homo sapiens*.

C2. God intentionally created human beings in God's image.

I do not think that we contradict ourselves by affirming both, as long as we recognize that they come from different discourses, presenting unique perspectives on our origins, and that neither tells the whole story.

∞

Notes

[1]Elaine Howard Ecklund and Christopher P. Scheitle, *Religion vs. Science: What Religious People Really Think* (New York: Oxford University Press, 2018), 2.

[2]Stephen C. Meyer, "Scientific and Philosophical Introduction: Defining Theistic Evolution," in *Theistic Evolution:*

A Scientific, Philosophical, and Theological Critique, ed. J. P. Moreland, Stephen C. Meyer, Christopher Shaw, Ann K. Gauger, and Wayne Grudem (Wheaton, IL: Crossway, 2017), 43–44.

[3]Richard Dawkins, "Why There Almost Certainly Is No God," *Edge:* Conversations, October 25, 2006, https://stage.edge.org/conversation/richard_dawkins-why-there-almost-certainly-is-no-god.

[4]"*Homo sapiens*," *Dictionary.com*, accessed March 12, 2019, https://www.dictionary.com/browse/homo-sapiens.

[5]Denis Alexander, *Creation or Evolution: Do We Have to Choose?* (Grand Rapids, MI: Monarch, 2014), 290.

[6]"What does it mean to be human? Species," Smithsonian Institution, accessed March 11, 2019, http://humanorigins.si.edu/evidence/human-fossils/species.

[7]For example, David Reich speaks of "ancient human genomes" which include Neanderthals and Denisovans, in addition to *Homo sapiens* (*Who We Are and How We Got Here: Ancient DNA and the New Science of the Human Past* (New York: Vintage Books, 2018), xvi); as does Yuval Noah Harari who claims there are at least six human species (*Sapiens: A Brief History of Humankind* [New York: Harper, 2015], 5). But there is a minority report, as typified by Alexander H. Harcourt, who says, "I use the word 'human' for only *Homo sapiens*" (*Humankind: How Biology and Geography Shape Human Destiny* [New York: Pegasus Books, 2015], 10).

[8]Stephen Jay Gould, *Wonderful Life: The Burgess Shale and the Nature of History* (New York: W.W. Norton & Company, 1989), 289.

[9]Simon Conway Morris, *Life's Solution: Inevitable Humans in a Lonely Universe* (New York: Cambridge University Press, 2003), xii.

[10]"In brief summary form, then, the form of theistic evolution that we are respectfully taking issue with is this belief: God created matter and after that did not guide or intervene or act directly to cause any empirically detectable change in the natural behavior of matter until all living things had evolved by purely natural processes." Wayne Grudem, "Biblical and Theological Introduction: The Incompatibility of Theistic Evolution with the Biblical Account of Creation and with Important Christian Doctrines," in *Theistic Evolution: A Scientific, Philosophical, and Theological Critique*, ed. Moreland, Meyer, Shaw, Gauger, and Grudem (Wheaton, IL: Crossway, 2017), 67.

[11]Chris Barrigar, "God's *Agape*/Probability Design for the Universe," *Perspectives on Science and Christian Faith* 70, no. 3 (2018): 161–75.

[12]Ibid., 165.

[13]Ibid., 171.

[14]Robert J. Russell, "Quantum Physics and the Theology of Non-Interventionist Objective Divine Action," in *The Oxford Handbook of Religion and Science*, ed. Philip Clayton and Zachary Simpson (New York: Oxford University Press, 2008).

[15]Technically, for any particular event, things could have turned out that way if God had not acted, but in order to ensure that things happen that way, God needs to act.

[16]Aubrey Moore, *Science and the Faith: Essays on Apologetic Subjects*, 6th edition (London: Kegan Paul, Trench, Trübner & Co., 1905), 184.

[17]Roger Scruton, *The Soul of the World* (Princeton, NJ: Princeton University Press, 2014).

[18]I should note that the philosopher Wilfred Sellars called these the "scientific" and the "manifest" images in his classic paper, "Philosophy and the Scientific Image of Man," in *Empiricism and the Philosophy of Mind,* Wilfred Sellars (London: Routledge & Kegan Paul, 1963). 1–40.

[19]C. Lloyd Morgan, *The Interpretation of Nature* (London: Macmillan & Co., 1905).

[20]Martin Buber, *I and Thou*, trans. Walter Kaufmann (New York: Touchstone Books, 1970), 82.

[21]Ibid., 59.

[22]Wilfred Sellars, "Philosophy and the Scientific Image of Man," in *Empiricism and the Philosophy of Mind*, 4–5.

[23]I think the strategy might also be fruitfully applied to the question of mind-body dualism, to free will, and to other issues in which persons are deemed to be effectual agents.

[24]Charles Taylor, "Gadamer on the Human Sciences," in *The Cambridge Companion to Gadamer*, ed. Robert J. Dostal (New York: Cambridge University Press, 2002), 130.

[25]Mary Midgley, *Are You an Illusion?* (New York: Routledge, 2014), 27–28.

[26]The example was probably not original to Polkinghorne, but he popularized and used it to great effect, beginning (so far as I can tell) with "Is Science Enough?," *Sewanee Theological Review* 39 (1995): 11–26.

[27]For an elaboration of this metaphor, see Bethany Sollereder, "Lost in a World of Maps: Relations between Science and Theology," *BioLogos*, published October 17, 2015, https://biologos.org/articles/lost-in-a-world-of-maps-relations-between-science-and-theology.

[28]An image of *The Old Guitarist* can be found at: https://en.wikipedia.org/w/index.php?curid=31832131; *Guitariste* can be found at: https://en.wikipedia.org/w/index.php?curid=39013881.

[29]Stephen Jay Gould, *Rocks of Ages: Science and Religion in the Fullness of Life* (New York: Ballantine Books, 1999), 6.

[30]Barbour's four categories are conflict, independence, dialogue, and integration. See his *Religion in an Age of Science* (San Francisco, CA: HarperSanFrancisco, 1990). For critique and refinement of this view see Ted Peters, "Theology and Science: Where Are We?," *Zygon* 31, no. 2 (1996): 323–43; Christian Berg, "Barbour's Way(s) of Relating Science and Theology," in *Fifty Years in Science and Religion: Ian G. Barbour and His Legacy*, ed. Robert J. Russell (Aldershot, UK: Ashgate, 2004): 61–75; and Mikael Stenmark, "How to Relate Christian Faith and Science," in *The Blackwell Companion to Science and Christianity*, ed. J. B. Stump and Alan G. Padgett (Malden, MA: Wiley-Blackwell, 2012), 63–73.

[31]The quote given above from Wilfred Sellars says explicitly that we must "fuse into one vision" the two pictures delivered by the scientific and personal discourses. Alister McGrath, whose account of these issues has much in common with my own, also seems to suggest that our goal should be to develop a "unified theoretical account" of the multiple perspectives. And, "Any attempt to achieve a broader vision of reality than that offered by a single discipline must, however, find some way of holding such insights together in the first place if a grander vision of reality is to emerge." McGrath, *The Territories of Human Reason: Science and Theology in an Age of Multiple Rationalities* (Oxford, UK: Oxford University Press, 2019), 60, 74.

[32]This metaphor comes from Rowan Williams, *The Edge of Words: God and the Habits of Language* (London, UK: Bloomsbury, 2014).

Rethinking Abiogenesis: Part 1, Continuity of Life through Time

Emily Boring, J. B. Stump, and Stephen Freeland

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Evolution teaches that any particular organism, population, or species is a point on a continuous lineage that extends back to life's origins. Apparent discontinuities (for example, species) often reflect subjective, human decisions as much or more than objective measurements. In the same way, no intrinsic, objective reason identifies any particular moment in the development of biochemical complexity as the origin of life other than the origin of the universe itself. There is no natural breakpoint presented by the physical universe. Focusing excessively on any other points robs science of important context and is detrimental to future progress—for example, by failing to extend our view one notch further back in order to understand how and why this particular point emerged. We advocate, instead, a view of abiogenesis that stresses continuity over particular "starting points." This way invites rich resonances with strands of historical and contemporary theology.

One of the standard objections to biological evolution is that there is no scientific explanation for how life could emerge from nonlife. A standard response to this objection is that the theory of evolution deals with only the diversification of life, not the origin of life.[1] Indeed, one form of this argument is that the emergence of "life" and "evolution" can usefully be distinguished from one another.[2] More broadly, a widespread assertion is that "abiogenesis," as the origin of life is sometimes called, is a different field of scientific inquiry, and one for which there is far less scientific consensus at present than there is for evolution.[3] But while this distinction may be made between evolution and abiogenesis, we believe that one of the chief impediments to closing this gap emerges from treating abiogenesis as a discrete event, a point in time, in stark contrast to the recognized continuity of evolution.

Instead, we would benefit from returning to an older and often maligned meaning of the word "evolution," one which encompasses the one continuous (and as-yet-incomplete) transition from the origin of time.[4] A different way to express this idea is that this perspective of continuity in abiogenesis opens up interesting questions on a number of different practical fronts for interdisciplinary research, both within science and beyond, including rich new pairings of theology with evolutionary science.

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Evolutionary Continuity in Biology

For most of Western intellectual history, objective lines of demarcation were perceived to separate individual organisms into natural groupings. Influential philosophical schools reasoned that these lines resulted from particular essences or forms that defined the species and placed them into hierarchical relationship.[5] The theory of biological evolution challenged this view by proposing continuity between species over time. But there is no nonarbitrary way to identify the first member of a species, and the arbitrary identification of such a point implies, for example, an organism that had parents of a different species (see Box 1).[6]

Box 1: A Brief Primer on the Ambiguities of Evolutionary Origins

Evolutionary biology indicates that around 400 million years ago, from within one subgroup of fish, successive generations of descendants evolved into amphibians, reptiles, birds, and mammals—including us.[7] This eventual outcome explains why we find a point of origin interesting (an important idea to which we will return below). But which generation or individual creature marks the origin of terrestrial animal life? Why not their parents or offspring? Or one generation further out from that?

We might hope to find the answer in the molecular basis of life. Genetic material, after all, comes in discrete (“digital”) states: sequences. Perhaps we might identify one such sequence as an unambiguous point of origin. But molecular genetics tells us that many slightly different gene sequences encode bodies and behaviors that are identical, and countless more that may or may not be functionally indistinguishable based on circumstance.[8]

Meanwhile, narrowing consideration to any specific characteristic paradoxically increases ambiguity in other ways. For example, fleshy fins that are starting to function as legs appear much later than swim bladders that are starting to function as lungs.[9] And refocusing on the point at which a suite of traits first coincides, merely relocates the ambiguity to the choice of which traits to include or exclude. Indeed, the more characteristics that are considered, the more recent a perceived point of origin becomes. The traits that define you, or any other specific human being, have probably never come together within a single, living organism until your lifetime (this is, after all, the basis of “DNA fingerprinting”).[10] In that sense, was the origin of you ... birth? Fertilization? Or some point in the development of the embryonic you?

That final option reminds us that anyone reading this does so with a physical body that is not done changing yet. We should probably consider an entire lifespan before deciding on which side of an origin it belongs. For an extreme example, tadpoles do not look much like land animals—the category in which we place amphibians, therefore, depends on the stage of life we observe. But this gives further pause for thought. The genetic instructions which encode you may well be travelling forward into the future, separated into different bodies alongside different travelling companions.[11] Considered like this, every population of living organisms comprises individuals whose descendants could be identified as significant by future biology in ways not yet known. Are these current individuals better understood as outcomes of a past origin, or as starting points of something new? Origins exist relative to outcomes only, and outcomes reflect the perspective of a particular moment in time.

All such reasoning applies to any scale at which we seek evolutionary origins (from “*homo sapiens*” to “animal”). We can choose to define breakpoints useful for various practical purposes, but biological evolution is fundamentally continuous. Every organism and every gene connect backward, in a direct and unbroken thread, to the origin of life. They likewise connect forward to futures that none of us have witnessed.

Furthermore, no single criterion identifies species objectively.[12] We might use morphology or reproductive behavior or genetics to group individuals, but—and this is the important point—different choices tend to identify different starting points in evolutionary history. Scientists who study speciation in our present-day world are among the best at explaining the limitations of the species concept.[13] It is not that the concept of species is meaningless. Rather, there are many ways to define the idea, and no one choice is inherently superior to the others. Each identifies something useful and is better or worse suited to a particular question and the context in which it is being asked. Conservation biology might identify one set of criteria in order to guide policy and thought about what exactly we are trying to conserve.[14] Paleontology might define another in order to understand when and under what conditions a particular fossil transition occurred.[15] Microbiology might define yet another for the purposes of medical diagnosis or quarantine.[16]

By analogy, think of the movie *Star Wars: Episode IV—A New Hope*. It seems perfectly legitimate to ask, at which point, in the original movie, did we meet the arch villain Darth Vader? And because the film consists of individual frames (over 174,000 of them), we ought to be able identify one specific frame as the point of meeting this character, right? But what exactly constitutes the "first meet" of this character?

During the opening scenes of the movie, the garrison of a small spaceship is quickly overrun by a much larger and better-equipped force of boarders. As the battle smoke clears, we hear an ominous heavy breathing and a figure steps forward wearing a dark cloak and mask. We will soon learn that this is Darth Vader who ordered this hostile boarding party. So when does Vader first appear? Is it the first frame in which any part of his clothing becomes visible through the smoke? Or the first frame in which his entire body is in view (with or without smoke obscuring our view, by the way)? Maybe it is the movie's opening sequence in which we see Vader's gigantic spaceship from afar; technically he was in that scene, right? Or perhaps we might choose a more traditional "face-to-face" option, except that we never get to see his face at any point in the movie! In another sense, were we not beginning to meet Vader through the violent actions of his troops, before his physical presence manifested? These are all visual evidences, but could we not first meet him through other senses? We hear Vader's distinctive breathing before we see any part of him. Should we just ignore that? Or maybe we should wait until the first time he is identified by name.

None of these are particularly bad choices. All of these points capture something of what we are interested in. But identifying any single frame reflects our choice, not an intrinsically meaningful measurement. There are clearly frames of the film that we could identify as before and after we meet Vader, according to any reasonable criterion. The specific point of this transition, however, is open to different interpretations.

So, too, with biological evolution. Given some concept of a species, clear before-and-after points exist within the evolutionary lineages of many species. No one suggests that the morphology we call *Homo sapiens* existed one million years ago; and clearly the morphology we label *Archaeopteryx* does not exist today. But the point of transition to either of these morphologies is a matter of subjective interpretation.

This logic is not limited to species. It also extends to any scale at which we choose to identify biological types. We might choose to perceive breakpoints at animals, tetrapods, hominids, or human beings. And different choices may be useful for a given aim (e.g., directing science funding, guiding conservation policy, or directing specific medical treatments). But any such point will gather useful context by extending the focus one notch backward or one notch forward, thus blurring that chosen line of demarcation. Therefore, one might think that the academic discipline of evolutionary biology can defend only one choice of origins as objective: living is a different category than nonliving, and abiogenesis—when chemistry became biology—is the point at which the continuity begins. Or is it?

Evolutionary Continuity Applied to Abiogenesis

In order to pinpoint a moment of transition from nonlife to life, we need a definition for what counts as life … and here the problems begin.

Cell theory

Elementary courses in biology often teach that cells are the most basic unit of life. This cell theory definition works reasonably well to lead us to useful inquiry such as, "What does it take for a cell to function?" But today, cell theory is taught as a useful simplification, not an accurate and sophisticated reflection of current science. In particular, a cell theory definition is not particularly helpful for thinking about abiogenesis because it is not intended for this purpose.

By analogy, elementary physics and chemistry teach that electrons orbit atomic nuclei rather like moon(s) orbit a planet. This is a useful foundation for beginning to learn about the ways in which energy and matter interact, such as in chemical reactions. But students who travel deeper into such science will have to overwrite this simple, conceptual model with something very different before they can come to grips with reaction dynamics or quantum mechanics. It would show poor reasoning—detrimental to scientific progress—if researchers had rejected the evidence for quantum physics because of its inconsistencies with the simple, introductory definition of atomic structure.

In the same way, subservience to the cell theory definition of life leads to misleading questions about abiogenesis: for instance, how did the first cell pop into existence from the primordial soup? Such a question reflects a failure to realize that our topic of interest, abiogenesis, has moved beyond the useful scope and purpose of the definition of life with which we are working.

There is nothing inappropriate about asking how and when the first recognizable cells were present on Earth (any more than it is inappropriate to ask about how and when the first morphology we call *Homo sapiens* emerged). But progress in answering such questions requires, at a minimum, a somewhat subjective definition of these terms, and, even then, progress can come only from researchers working to understand what came just prior to the first "modern" cell, what came just prior to that, and so on. No serious scientist of the twenty-first century would argue that the state immediately prior to a "modern" cell was chemical chaos. There is, quite simply, too much sophisticated molecular machinery within a cell for it to have emerged simultaneously.[17]

The central dogma and RNA

For students who begin with cell theory, the next step toward deeper understanding of the nature of life is the "Central Dogma of Molecular Biology." The central dogma asserts that within the boundaries of each cell's membrane, genetic information, encoded in DNA, is constantly translated into a suite of proteins. These genetically encoded proteins interact with one another to form the "business end" of life: metabolism, which includes the synthesis and replication of DNA (and, indeed, cell membranes).

The earliest "modern" cell is, in fact, rather similar to what the relevant research community has come to call LUCA—the Last Universal Common (shared) Ancestor of all living organisms.[18] Computer reconstructions of the genetic material of LUCA have led researchers to conclude that this material was "similar [in complexity and size] to … many extant [microbial] organisms." That means LUCA too was clearly the product of considerable biological evolution.[19] So what preceded it?

A compelling body of evidence has accumulated to suggest that somewhere prior to LUCA, the central role of DNA—genetic information and storage—was performed by RNA instead.[20] The atomic structure of RNA differs from DNA by a couple of minor chemical modifications which render DNA less chemically reactive and less prone to mutation. It seems that the evolutionary invention of DNA and its incorporation into life's biochemical foundations reflects an outcome of natural selection for a more stable information storage medium.[21] Where in this implied process of evolutionary upgrading should we locate the origin of life? We may stretch the question further. Exploratory research shows that the precise chemical structure shared in common by both RNA and DNA (types of ribonucleic acid) exhibits several subtle properties which seem slightly better suited to their role in living systems than slightly simpler chemical alternatives.[22] This implies that nucleic acids, as we know them, could be the outcome of natural selection for an optimal molecular representation of genetic information. If so, then would systems which encoded proteins using, say, **t**hreose **n**ucleic **a**cid (TNA) instead of **r**ibo**n**ucleic **a**cid (RNA) have crossed a boundary from the realm of biochemistry into that of nonliving chemistry?

Proteins, amino acids, lipids

So far, this argument has been developed in terms of one component of biology's central dogma: nucleic acids. But a similar situation holds for proteins and the amino acid building blocks from which they are constructed. The central dogma describes a system of genetically encoded proteins constructed from a molecular "alphabet" of 20 amino acids. Over the past several decades, multiple lines of evidence from diverse academic disciplines have converged on an unexpected finding: the system of genetic encoding probably began with just half of these amino acids.[23] Would a reproducing, evolving system that constructed its proteins using ten amino acids instead of twenty be objectively viewed as not alive? What if it built primitive enzymes from something chemically simpler than amino acids (a point to which we will return below)?

Yet another analogous story seems to be emerging for lipids, which form cell membranes. The precise molecular structure of lipids used in "modern" cell membranes is difficult to justify as a plausible product of prebiotic chemistry. But chemically simpler alternatives which could do the job adequately are plausible. We might infer that lipid membranes as we know them, like nucleic acids and amino acids, are an outcome of natural selection, an upgrade of something earlier.[24] So where in all this evolutionary "upgrading" of the molecular basis for life-as-we-know-it should an objective line be drawn for the origin of living systems?[25]

Simply expanding cell theory to go beyond the precise details of the central dogma that came to define life on our planet does nothing to pinpoint an event we might objectively call "abiogenesis." Perhaps we could regard the evolutionary growth of the amino acid alphabet, or chemical refinements to nucleic acid or to lipids, as changes of degree rather than type—but that distinction is the fundamental ambiguity of evolutionary processes. The thesis of this article has been all along to question whether objective changes of *type*, rather than changes of *degree*, are what we expect from evolution.

The RNA world

For example, we can take one further step backward from a world in which RNA genes may have encoded proteins using a reduced repertoire of amino acids. We can imagine a scenario that removes any act of translation from the central dogma. In 1989, two researchers won a Nobel Prize for demonstrating that RNA sequences can, under the right conditions, fold up spontaneously into three-dimensional shapes capable of catalyzing chemical reactions.[26] So perhaps, prior to the time of genetically encoded proteins, there was a time of reproducing, evolving organisms in which a single biopolymer, RNA, acted as both an information storage medium and the constituent unit of metabolic networks. Is that enough of a typological change to have crossed from nonliving to living?

In its most straightforward interpretation, this "RNA World" understanding of life's origins imagines that life began with a particular RNA sequence capable of folding into a ribozyme which catalyzes construction of another copy of itself. This self-replicating RNA ("RNA replicase") could, in principle, evolve increasing length for additional ribozymes which influence local conditions into a controlled chemical environment that facilitates copying—the first shadow of metabolism. Such a system could evolve onward to eventually cede the work of folding and catalyzing to genetically encoded proteins.[27]

A major challenge for this version of events comes from the inference that an RNA replicase sequence would probably have to comprise a couple of hundred nucleotides, chemically bound to one another in the correct sequence. For chance alone to form a specific sequence of that length would require a total mass of RNA exceeding the total mass of the entire universe. In other words, we have the same objection at this deeper level of understanding as we did when considering cell theory as a possible starting point for life: our "solution" seems utterly improbable without a simpler, preceding state.

We can press even deeper: An ingenious potential solution for RNA replicase comes from work demonstrating that many small RNA sequences can interact to produce the same overall effect as one large sequence.[28] This drastically improves the odds of the development of self-replicating RNA. But how far does it strain an intuitive definition of "life" to think of a network of smallish RNA fragments, potentially lacking any cell membrane(s), which interact to reproduce one another? Or perhaps our very description of these entities as "reproducing" and "evolving" causes us to identify them as living.

Chemical evolution

Now we have pushed far beyond most traditional definitions of what it means to be alive—at least those definitions informed by the world we experience today, some four billion years after the events under discussion. But we have found no obvious stopping point in the continuous process, and so we continue.

The process of natural selection is not limited to acting only on what we take to be alive.[29] The concept applies to anything that leaves behind copies of itself which vary in ways that are inherited from one generation to the next. The necessary outcome is, of course, that those variations, which for any reason leave behind more copies than their counterparts, are likely to form the basis for further variation as time flows forward. This process applies to chemicals in the absence of life, and exploration of chemical evolution seems increasingly important to investigate how life-as-we-know-it came into existence. Multiple ideas are still jostling to describe just how this may have happened.[30] Suffice it to say that somewhere between the RNA world and chemical evolution we have crossed over any clear divide between living and nonliving.[31]

Thinking in abstract terms about self-replication has led numerous researchers over the years to note a variety of well-known phenomena, from crystals to fire, which are quite different from what we intuitively consider alive but which could be said to harness energy so as to make copies of themselves. The existence of a class of nonliving phenomena, from among which at least one particular pathway leads seamlessly to life as we experience it, seems to us exactly what should be expected from a universe which produced life in a geologically rapid timeframe on a fairly ordinary planet in a fairly ordinary star system.

Viewed in this manner, abiogenesis becomes just one more subjectively chosen point on a continuum that now stretches back to the origin of the universe—which, according to current understanding, is also the origin of time. Maybe a cosmological physicist could, now or in the future, explain why it might be unhelpful to view the origin of the universe as a useful starting point, but for us this alignment between the origin of life and the origin of time is good enough.

Let us emphasize that, just as we claimed for the concept "species," we do not claim the concept of abiogenesis to be meaningless or unhelpful. Rather, there are many ways to define the idea, and no one choice is inherently superior to all the others. Each contributes something that is better or worse suited to a particular question and the context in which it is being asked.

Why Does the Perspective of Continuity Matter?

So far our argument might seem only to be advocating for a shift in perspective. Is there more at stake than perceptions? We claim so, on two different but overlapping fronts. One is the way in which scientific inquiry now proceeds regarding questions of "origins." The second is the way in which Christian theology connects with this scientific progress.

Practical implications for scientific progress

A typological or discontinuous view of abiogenesis is counterproductive to efficient progress on the topic. Put simply, patterns of thought that assume discontinuities and changes in type set us up to ask less-than-helpful questions and prevent us from asking the questions that may lead to new breakthroughs in understanding.

At an extreme, this discontinuous thinking leads to rejections of evolutionary science. For example, typological thinking about different species has repeatedly led some to question whether natural processes can account for the "jump" from one species to another.[32] Likewise, typological thinking about living versus nonliving entities causes some to perceive a gap so wide that it strains their credulity for any hope of a natural explanation.[33]

To all such reasoning, we would echo our brief critique of using cell theory as a guide to life's origins. Fully functioning cells are indeed implausible products of prebiotic chemistry in a single jump, but that was never the issue. We simply need to perceive fully functioning cells as a minor development of something earlier, which was a minor development of something earlier than that … and so on. It is the misplaced focus on one isolated point which leads to a wrong-headed question—or at least to a question that prevents us from asking more-productive, interesting questions.

Beyond debate about the veracity of evolutionary science, something subtly similar can occur between different scientific disciplines. We noted above that no serious, twenty-first-century scientist is attempting to research how prebiotic chemistry can lead directly to a fully functioning cell. But, instead, researchers may replace "fully functioning cell" with other isolated points, perpetuating the same unhelpful problem. The legacy of the Miller/Urey experiments serves to illustrate this point.

Miller and Urey in the 1950s succeeded in forming, within a matter of days, around half of the 20 genetically encoded amino acids from a simple chemistry representing prebiotic conditions.[34] This was enormously exciting and motivated a small army of chemists to attempt to produce the missing half. After three decades of work, 16 of the 20 amino acids had been accounted for by ingenious variations of reaction conditions (energy sources and gas mixtures).

Here, however, we see the footprint of a widespread mid-twentieth-century mindset about the proper relationship between scientific disciplines. Put crudely, when physics becomes sufficiently complicated it has moved into the domain of chemistry. When chemistry has become sufficiently complicated, it moves into the domain of biology. Under such thinking, the goal of organic chemists interested in life's origins can easily become "to account for the components of the central dogma as completely as possible" before handing over their results to biology and evolution. Another way of saying this is that chemists were motivated to form a "fully functioning amino acid alphabet" by any means necessary.

By the 1970s, other scientists were approaching the topic from a different disciplinary perspective: comparing the amino acids produced in spark tube experiments with those identified within meteorites. Meteorites are simply rocks that formed in space and underwent chemistry there before chancing to fall to Earth where they can be analyzed in laboratories. Considered as natural analogs for the spark tube experiments, meteorites revealed something interesting: they tend to contain more or less the same half of the "alphabet" of amino acids as the earlier spark tube experiments.[35]

It was left for scientists from yet another academic discipline, namely those studying the metabolic pathways by which amino acids are synthesized in contemporary biology, to notice an aligning pattern which led to a fundamentally different interpretation of the "missing half."[36] The half of the amino acid alphabet which forms plausibly under prebiotic conditions comprises molecules that are each found at the start of biosynthetic pathways. A series of sophisticated protein enzymes then act, one enzyme after another, to convert these prebiotically plausible amino acids into the missing half of the alphabet. A simple interpretation is to suggest that life's alphabet of genetically encoded amino acids began smaller—about half its current size. Then it was through biological evolution, not prebiotic chemistry, that the alphabet grew to incorporate amino acids absent from meteorites and difficult or impossible to produce through simulation experiments. The footprint of this ancient evolutionary history is seen, frozen through countless millennia, in present-day biochemical pathways—for much the same reason as a current version of Microsoft Windows contains fragments of code from 1980s MS-DOS. This idea of footprints of ancient evolution buried in modern metabolism resonates with one of the major directions of support for the RNA world hypothesis.[37]

Fast forwarding to the twenty-first century, this synthesis of different disciplinary insights has grown in strength and detail. Calculations of theoretical physics, empirical analysis of meteorites, simulations of organic chemistry, metabolic pathways of biochemistry, and computational reconstruction of ancient genomes all find unlooked-for alignment in the concept of a simpler, earlier stage of the genetic code which subsequently evolved a larger amino acid alphabet after protein enzymes were available to create useful, new amino acids. The problem of synthesizing missing amino acids in spark tube experiments has gone away. It is sobering, however, to remember the progress made by ingenious chemists in forcing "missing" amino acids into reluctant existence. The challenge, framed unhelpfully as it was, diverted time, skill, and resources away from the interdisciplinary breakthrough we now identify.

All ends well in the story of how we relate this history of science for the amino acids. But other potentially unhelpful points are alive and well within the origins community. "Fully functioning cell" and "complete amino acid alphabet" may have been left behind as targets for prebiotic chemistry, but "fully functioning RNA world," or "fully functioning RNA replicase molecule," or any other pinpoint can misdirect scientific efforts away from the fluid, openminded exchange of information between academic disciplines that yields progress.

In the past ten years, there has been a series of claims from one extraordinary research group about how prebiotic chemistry might have produced RNA. Those involved wrote openly in an early paper about motivations: "support [for] the 'RNA world' hypothesis … provide[s] a mandate for chemistry to explain how RNA might have been generated prebiotically on the early earth."[38] The resulting chemistry has been careful and ingenious, and has gathered considerable attention from scientific journalism. But oddities remain that seem to echo the amino acid history.

Neither RNA nor its constituent nucleotide building blocks have ever been identified in meteorites. RNA has likewise never been detected in spark tube experiments (or their ilk) unless these experiments were explicitly configured to detect RNA. (Indeed, the ingenuity lay in figuring out what configuration could possibly yield RNA!) The reaction pathway for plausibly prebiotic formation of RNA looks nothing like the pathway by which RNA is synthesized in contemporary biology. If we know that RNA once played the role of enzyme because the reaction pathways are still buried in modern metabolism, then why do we see nothing of the sort for RNA synthesis? Perhaps most intriguing, direct prebiotic synthesis of RNA does nothing to explain why RNA shows properties ideal for the role of genetic material in comparison with slightly different, simpler molecular analogs.

Voicing skepticism for the prebiotic synthesis of RNA, we are duty bound to admit, is the point at which our argument probably strays furthest from a mainstream view of current science. The RNA world hypothesis still reigns within the origins research community, and the spectacular series of claims for prebiotically plausible RNA was published in far more prestigious scientific journals by a group with far more funding and scientific authority than any of the authors of this manuscript can boast. But our purpose is less to make a judgment call than to ask the reader a question. Is a prebiotically plausible pathway for RNA synthesis really closing a gap between pieces of the puzzle for life's emergence? Or does it reflect the sort of problems that come from pinpointing abiogenesis? Put another way, does "support [for] the 'RNA world' hypothesis" really "provide a mandate for chemistry to explain how RNA might have been generated prebiotically on the early earth"? Or does it provide a mandate to ask what precursors might have been upgraded to RNA by natural selection for an optimal genetic molecule, and what precursors led to these RNA precursors, and so on, until we find answers that mesh with the chemistry that emerges easily and from a wide variety of spark tube experiments, meteorites, metabolic pathways, and other approaches?

Whatever you decide about RNA, one way to generalize our overarching point is to suggest that a discontinuous or typological view of abiogenesis can place different academic disciplines out of right relationship with one another. Right relationship in this sense means something like a humble open-mindedness and equality of disciplines which encourage objective integration of disparate knowledge. Preconceived hierarchies between disciplines or even preconceived notions of a discipline's legitimate domain stray from this notion of right relationship. For example, evidence in favor of a smaller, earlier amino acid alphabet would be hard to notice for any scientist who perceived only the chemical challenge ("How could the amino acid alphabet have been synthesized?"). However, this evidence would be easy to spot for a community of scientists comparing meteoritics, biochemical physiology, and chemistry with similar, shared questions in mind.

Expressed in this way, right relationship defines, to a large extent, the emerging interdiscipline of "astrobiology," which has encompassed and, in our view improved, the health of origins research.[39] In our direct experience, astrobiology is more a statement of community than it is an identity of an individual researcher. To the extent that individual scientists are astrobiologists, it seems to mean something like "open to the breadth of science telling me things I did not know" or "seeking unexpected connections between disparate dimensions of science." Happily, there are signs that the major funding sources increasingly favor this sort of approach for the study of life's origins.

For example, NASA and the National Science Foundation recently entered into a novel collaboration to jump-start fresh thinking within the origins community by putting thirty leading scientists from different disciplines through a commercial training process designed to break down preconceptions in order to form interdisciplinary teams.[40] Readers who are interested in exploring this unusual initiative in greater detail are warmly welcomed to browse a full description of outcomes, as gathered two years after the initial event.[41]

Interface of science and theology

On the surface, our framing of evolution and abiogenesis may appear to challenge some widespread interpretations of Christian doctrine. We have argued that all life stretches back in an unbroken continuum, and that any starting point is best understood in relation to all previous points. Christian ideas of creation, on the other hand, have often tended to emphasize discrete and discontinuous events: the special creation of humans, or each of the species according to their "kinds," for example.

But such notions of creation do not exhaust what is found in the Christian tradition. Indeed, to escape charges of deism (or at least a semi-deism or episodic deism), any Christian account of God's activity must acknowledge what God is doing between the moments of special creation.[42] Sometimes this is described merely as God's upholding or sustaining the world, but there is a rich tradition of referring to God's *creatio continua*, particularly in the writings of Maximus the Confessor, Gregory Palamas, and Hildegard von Bingen. On this view, God's creative work is ongoing and continual, and thus brings God into more direct relationship with all of the created order.

Emphasizing the continuous aspect of God's creative activity over the episodic does not diminish God's role but, rather, extends it.[43] Beyond a conception of intervention at narrowly defined starting points, God's role and presence expands to the continual, integrated, and coherent pattern of an unfolding universe. The relationship between such theological statements of *creatio continua* and the explanation of continuity in scientific language as presented above merits further exploration.[44] The theological challenge—and, we believe, the invitation—lies in a challenge to think about the origins of humanity, of life, or even of the universe itself as a *process*. We have described a framework of evolutionary thinking in which the primary themes are relationship, continuity, and pattern rather than linearity and discrete categories. What would it look like to extend these ideas to their theological application?

A good place to start might be with the thought of St. Bonaventure, a thirteenth-century theologian and contemporary of St. Thomas Aquinas. Bonaventure belonged to the Franciscan order, and just as St. Francis saw all creatures in the light of Christ, Bonaventure insisted that Christian thinkers must see the world through Christ—the creative Word through whom and for whom all was created. He claimed that Christ is the medium or Center of all the sciences.[45] As such, God is necessarily expressed through the created world, not at one or more points of origin but continually and continuously.

Bonaventure gave a series of proofs, in the sense recognized by medieval philosophy, that every individual creature proclaims the existence of God, and Bonaventure delighted (again like St. Francis) in what he saw as vestiges of the Trinitarian God manifested in the world. These vestiges were not limited to living creatures, though, as Bonaventure revived the idea first found in Augustine of *rationes seminales*. These are potentials with which God seeded the world, which would develop and unfold over time. For Bonaventure, matter itself is a kind of seed bed out of which later corporeal forms would bloom, not on their own accord, but precisely because God acts continuously at each moment.[46] This should not be understood as a scientific explanation in our modern sense, but it does resonate with the continuity of creation we have described here.

This view changes our priorities about the way we describe the created world. Investigating God through nature does not require or even benefit from rigid categorization with finite events such as a formal, and human-defined, origin of life. Instead, the study of ongoing and unbounded relationship—not only between different branches of life, but also between life and the universe within which it exists—is not only compatible but also helpful, and perhaps even necessary, in approaching questions about the nature of God. And our article provides one way to begin this investigation.

We suspect that this example is no more than one gesture to many specific ways in which a perspective of evolutionary continuity, far from threatening important theological tenets, instead invites a richer conversation between theology and science. In addition to uniting disciplines of physics, chemistry, and biology, we hope that the "right relationship" we have advocated will allow us to revisit traditional theological ideas with new scientific insight. ∞

Notes

[1]See, for example, Austin Cline, "Abiogenesis and Evolution," *Learn Religions*, updated June 25, 2019, https://www.learnreligions.com/abiogenesis-and-evolution-249875; and "Abiogensis," *RationalWiki*, https://rationalwiki.org/wiki/Abiogenesis.

[2]Sy Garte, "Teleology and the Origin of Evolution," *Perspectives on Science and Christian Faith* 69, no. 1 (2017): 42–50.

[3]Tom Siegfried, "Top 10 Scientific Mysteries for the 21st Century," *Science News,* January 28, 2015, https://www.sciencenews.org/blog/context/top-10-scientific-mysteries-21st-century; and Lauren Cahn, "15 Science Mysteries No One Has Figured Out," *RD.com >culture,* https://www.rd.com/culture/science-mysteries-no-one-has-figured-out/.

[4]Stephen J. Freeland, "Could an Intelligent Alien Predict Earth's Biochemistry?," in *Fitness of the Cosmos for Life*, ed. J. Barrow et al. (New York: Cambridge University Press, 2008), 289–91; and see Garte, "Teleology and the Origin of Evolution," for a discussion of the reasoning behind the semantics of "evolution" and what is meant by evolutionary change.

[5]This legacy is clear from the ancient Greeks (particularly Aristotle) through Linnaeus in the eighteenth century, and the intuitions remain today.

[6]We acknowledge that some people may have theological reasons for identifying a first member of the human species. We bracket this topic of discussion as irrelevant to the bigger point we are making in this article.

[7]Per E. Ahlberg, "Follow the Footprints and Mind the Gaps: A New Look at the Origin of Tetrapods," *Earth and Environmental Science Transactions of the Royal Society of Edinburgh* 109, no. 1-2 (2019): 115–37, https://doi.org/10.1017/S1755691018000695.

[8]Jack Lester King and Thomas H. Jukes, "Non-Darwinian Evolution," *Science* 164, no. 3881 (1969): 788–98, https://doi.org/10.1126/science.164.3881.788; Motoo Kimura, *The Neutral Theory of Evolution* (New York: Cambridge University Press, 1983); and Tomoko Ohta, "The Nearly Neutral Theory of Molecular Evolution," *Annual Review of Ecology and Systematics* 23 (1992): 263–86.

[9]P. L. Forey, B. G. Gardiner, and C. Patterson, "The Lungfish, the Coelacanth, and the Cow Revisited," in *Origins of the Higher Groups of Tetrapods: Controversy and Consensus*, ed. Hans-Peter Schultze and Linda Trueb (Ithaca, NY: Comstock Publishing Associates, 1991), 145–74; and Colleen Farmer, "Did Lungs and the Intracardiac Shunt Evolve to Oxygenate the Heart in Vertebrates?," *Paleobiology* 23, no. 3 (1997): 358–72, http://farmer.biology.utah.edu/manuscripts/1997%20Paleobiology23.pdf.

[10]The 1000 Genomes Project Consortium, "A Global Reference for Human Genetic Variation," *Nature* 526 (2015): 68–74, https://doi.org/10.1038/nature15393.

[11]Richard Dawkins, "Immortal Coils," in *The Selfish Gene* (New York: Oxford University Press, 1989), 21–45.

[12]Kevin De Queiroz, "Species Concepts and Species Delimitation," *Systematic Biology* 56, no. 6 (2007): 879–86, https://doi.org/10.1080/10635150701701083.

[13]Ramon Rosselló-Mora and Rudolf Amann, "The Species Concept for Prokaryotes," *FEMS Microbiology Reviews* 25, no. 1 (2001): 39–67, https://doi.org/10.1111/j.1574-6976.2001.tb00571.x; Ping Xie, "A Brief Review on the Historical Changes in the Concept of Species," *Biodiversity Science,* September 2016, http://en.cnki.com.cn/Article_en/CJFDTOTAL-SWDY201609006.htm; and Richard A. Richards, *The Species Problem: A Philosophical Analysis* (Cambridge, UK: Cambridge University Press, 2010).

[14]Tatiana Korshunova et al., "Multilevel Fine-Scale Diversity Challenges the 'Cryptic Species' Concept," *Scientific Reports* 9, no. 1 (2019): 6732, https://doi.org/10.1038/s41598-019-42297-5.

[15]Johanna Kovar-Eder et al., "Palaeontological and Biological Collections—Bridging the Gap," *Biodiversity Information Science and Standards* 3 (June 18, 2019), e37183, https://doi.org/10.3897/biss.3.37183.

[16]Konstantinos T. Konstantinidis, Alban Ramette, and James M. Tiedje, "The Bacterial Species Definition in the Genomic Era," *Philosophical Transactions of the Royal Society B, Biological Sciences* 361, no. 1475 (2006):1929–40, https://doi.org/10.1098/rstb.2006.1920.

[17]Patrick Forterre, Simonetta Gribaldo, and Celine Brochier, "LUCA: The Last Universal Common Ancestor," *Medical Sciences* 21, no. 10 (2005): 860–65.

[18]Patrick Forterre and Herve Philippe, "The Last Universal Common Ancestor (LUCA), Simple or Complex?," *The Biological Bulletin* 196, no. 3 (1999): 373–77, https://doi.org/10.2307/1542973.

[19]Tamir Tuller et al., "Reconstructing Ancestral Gene Content by Coevolution," *Genome Research* 20, no. 1 (2010): 122–32, https://doi.org/10.1101/gr.096115.109.

[20]Antonio Lazcano et al., "The Evolutionary Transition from RNA to DNA in Early Cells," *Journal of Molecular Evolution* 27 (August 1988): 283, https://doi.org/10.1007/BF02101189.

[21]In our argument thus far, we have assumed that the origin of life is closely linked to the origin of the process of evolution itself. In other words, studying the development of the process by which genetic information is encoded and passed on is equivalent (or at least a necessary step) to studying the development of life itself. Here we point the reader to an alternative view expressed in Garte, "Teleology and the Origin of Evolution." Garte argues that the origin of life and the origin of natural selection are best considered as two separate issues. He advocates that "evolution" as a process is a purely biological phenomenon, characterized by a linkage between genotype and phenotype. This distinction is important, in his view, when it comes to questions of teleology. The protein-synthesis/translation system that bridges the gap between genotype and phenotype allows us to conceive of a new definition of biological teleology—one in which meaning is found not in the action or outcome of evolution, but in the "fabric" of the process of evolution itself.

[22]Albert Eschenmoser, "Chemical Etiology of Nucleic Acid Structure," *Science* 284, no. 5423 (1999): 2118, https://doi.org/10.1126/science.284.5423.2118.

[23]Edward N. Trifonov, "Consensus Temporal Order of Amino Acids and Evolution of the Triplet Code," *Gene* 261, no. 1 (2000): 139–51, https://doi.org/10.1016/s0378-1119(00)00476-5; Paul G. Higgs and Ralph E. Pudritz, "A Thermodynamic Basis for Prebiotic Amino Acid Synthesis and the Nature of the First Genetic Code," *Astrobiology* 9, no. 5 (2009): 483–90, https://doi.org/10.1089/ast.2008.0280; and H. James Cleaves, "The Origin of the Biologically Coded Amino Acids," *Journal of Theo-*

retical Biology 263, no. 4 (2010): 490–98, https://doi.org/10.1016/j.jtbi.2009.12.014.

[24]David Deamer, "The Role of Lipid Membranes in Life's Origin," *Life* 7, no. 1 (2017): 5, https://doi.org/10.3390/life7010005.

[25]In his article, "Biological Information, Molecular Structure, and the Origins Debate" (*Perspectives on Science and Christian Faith* 63, no. 4 [2011]: 231–40), Jonathan Watts expands on the mechanisms of this "upgrading": how new information can be added to biological molecules via natural processes. He describes the modern laboratory technique SELEX (Systematic Evolution of Ligands through Exponential Enrichment) to show how the physical properties of nucleotide sequences can be exploited to artificially develop molecules with desired properties from a random pool of starting material. In Watts's view, new information can be incorporated into life-forms purely from the interaction of molecules with their environment, without a necessity for direct intelligent design. This capacity arises from the tight relationship between the information of a molecule and its physical structure, which in turn makes it difficult to separate the information in a biomolecule from the information in the rest of the environment. As we do, Watts explores how this relational and situated view of evolution expands rather than threatens theological conceptions of God's role in the development of life.

[26]"The Nobel Prize in Chemistry 1989," *NobelPrize.org*, accessed September 13, 2019, https://www.nobelprize.org/prizes/chemistry/1989/summary/.

[27]Stephen Freeland, Robin Knight, and Laura Landweber, "Do Proteins Predate DNA?," *Science* 286, no. 5440 (1999): 690–92, https://doi.org/10.1126/science.286.5440.690.

[28]Nilesh Vaidya et al., "Spontaneous Network Formation among Cooperative RNA Replicators," *Nature* 491, no. 7422 (2012): 72–77.

[29]Addy Pross, "The Evolutionary Origin of Biological Function and Complexity," *Journal of Molecular Evolution* 76, no. 4 (2013): 185–91, https://doi.org/10.1007/s00239-013-9556-1.

[30]Chrisantha Fernando and Jonathan Rowe, "Natural Selection in Chemical Evolution," *Journal of Theoretical Biology* 247, no. 1 (2007): 152–67, https://doi.org/10.1016/j.jtbi.2007.01.028; Andrés de la Escosura, "The Informational Substrate of Chemical Evolution: Implications for Abiogenesis," *Life* 9, no. 3 (2019): 66, https://doi.org/10.3390/life9030066; Bruce C. Gibb, "Abiogenesis and the Reverse Hofmeister Effect," *Nature Chemistry* 10, no. 8 (2018): 797–98, https://doi.org/10.1038/s41557-018-0111-y; and Don L. Armstrong, Doron Lancet, and Raphael Zidovetzki, "Replication of Simulated Prebiotic Amphiphilic Vesicles in a Finite Environment Exhibits Complex Behavior That Includes High Progeny Variability and Competition," *Astrobiology* 18, no. 4 (2018): 419–30, https://doi.org/10.1089/ast.2016.1615.

[31]We depart, for example, from Garte's argument that life's origin may be usefully distinguished from the origin of Darwinian evolution, with the latter as a true, typological innovation. See Garte, "Teleology and the Origin of Evolution."

[32]Bodie Hodge and Georgia Purdom, "Zonkeys, Ligers, and Wolphins, Oh My!," *Answers in Depth* 3 (2008): 71–73, https://assets.answersingenesis.org/doc/articles/aid/v3/zonkeys-ligers-wolphins.pdf.

[33]Douglas Axe, *Undeniable: How Biology Confirms Our Intuition That Life Is Designed* (San Francisco, CA: HarperOne, 2017).

[34]Stanley L. Miller, "A Production of Amino Acids under Possible Primitive Earth Conditions," *Science* 117, no. 3046 (1953): 528–29.

[35]Keith A. Kvenvolden, "Natural Evidence for Chemical and Early Biological Evolution," *Origins of Life* 5, no. 1–2 (1974): 71–86, https://doi.org/10.1007/BF00927014.

[36]J. Tze-Fei Wong and Patricia Bronskill, "Inadequacy of Prebiotic Synthesis as Origin of Proteinous Amino Acids," *Journal of Molecular Evolution* 13, no. 2 (1979): 115–25, https://doi.org/10.1007/BF01732867.

[37]Harold White, "Coenzymes as Fossils of an Earlier Metabolic State," *Journal of Molecular Evolution* 7 (1976): 101–104, http://hoffman.cm.utexas.edu/courses/cofactors_molecular_fossils.pdf.

[38]Carole Anastasi et al., "RNA: Prebiotic Product, or Biotic Invention?," *Chemistry and Biodiversity* 4, no. 4 (2007): 721, https://doi.org/10.1002/cbdv.200790060.

[39]G. Scott Hubbard, "What is Astrobiology?," *NASA*, October 1, 2008, https://www.nasa.gov/feature/what-is-astrobiology.

[40]Julie Fletcher, "Joint NASA-NSF Ideas Lab on the Origins of Life," *Astrobiology at NASA: Life in the Universe*, June 7, 2016, https://astrobiology.nasa.gov/news/joint-nasa-nsf-ideas-lab-on-the-origins-of-life/.

[41]"Assessment of the 2016 Origins IdeasLab: A Fresh Approach to Generating Scientific Research," https://inds.umbc.edu/files/2019/01/Ideaslab-Booklet_FINAL-1.pdf

[42]Aubrey L. Moore, "A Theory of Occasional Intervention Implies as Its Correlative a Theory of Ordinary Absence," in *Science and the Faith: Essays on Apologetic Subjects*, 6th ed. (London, UK: Kegan Paul, Trench, Trübner & Co., 1905), 184.

[43]As Denis Lamoureux describes, Darwin himself reflected on this topic, advocating that a God who creates life via natural processes is "far grander" than a God who relies on dramatic divine creative acts. He argues that biological evolution need not threaten the concept of teleology and divine intention in the development of life; it merely shifts the power of God to the creation of underlying "laws." For a thorough review of Darwin's writings in the context of debates of origins and intelligent design, see Denis O. Lamoureux, "Darwinian Theological Insights: Toward an Intellectually Fulfilled Christian Theism. Part 1: Divine Creative Action and Intelligent Design in Nature," *Perspectives on Science and Christian Faith* 64, no. 2 (2012): 108–20; and ____, "Darwinian Theological Insights: Toward an Intellectually Fulfilled Christian Theism. Part II: Evolutionary Theodicy and Evolutionary Psychology," *Perspectives on Science and Christian Faith* 64, no. 3 (2012): 166–79.

[44]See James Stump, "Does God Guide Evolution?," *Perspectives on Science and Christian Faith* 72, no. 1 (2020): 15–24.

[45]Frederick Copleston, *A History of Philosophy, Vol. 2, Mediaeval Philosophy, Part 1: Augustine to Bonaventure* (New York: Image Books, 1962), 271.

[46]Ibid., 306.

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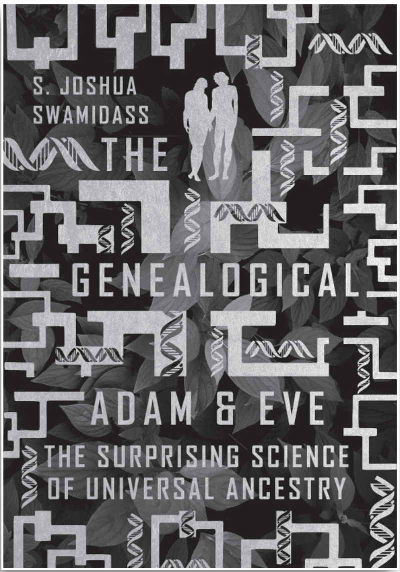

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Gary H. Loechelt

Accelerated Nuclear Decay in the Light of New Experimental Data

Gary H. Loechelt

One of the lines of evidence for accelerated nuclear decay promoted by young-earth creationists (YECs) is the high retention of helium in zircon crystals from a borehole in Fenton Hill, New Mexico, United States. More recent measurements of zircon samples from the Continental Deep Drilling Program, Germany, contradict this result. A model of the helium diffusion ages from that site shows that retention of helium is possible in these zircons for millions of years, consistent with the conventional radiometric age of the samples. A possible explanation for this discrepancy is the diffusion behavior of helium in zircon at relatively low temperatures below about 350 °C. The kinetic mechanisms of the low-temperature diffusion are discussed, along with possible implications for the accelerated nuclear decay hypothesis.

Radiometric dating methods pose a serious challenge to belief in a 6,000-year-old Earth held by young-earth creationists (YECs). Taken at face value, these dating methods indicate that Earth, and by implication the universe, is billions, not thousands, of years old. Not surprisingly, much has been written by the YEC community in an attempt to discredit radiometric dating.[1] Despite these efforts, compelling evidence remains that substantial amounts of radioactive decay have occurred in Earth's past. The simplest and most straightforward explanation for phenomena such as spontaneous fission tracks, the accumulation of radioactive decay products in rocks, and the overall trend of radiometric ages increasing with depth in the geologic column is that they are the result of nuclear decay. This evidence is so hard to dismiss that many young-earth creationists now concede that billions-of-years-worth of nuclear decay has occurred.

Two decades ago, a group of prominent YEC scientists initiated a research project called **R**adioisotopes and the **A**ge of **T**he **E**arth (RATE) to address this dilemma. At the end of their eight-year study, these scientists concluded that one or more episodes of accelerated nuclear decay had occurred in Earth's recent past.[2] Don DeYoung eloquently articulates the RATE argument in his book, *Thousands … Not Billions*:

> One principle agreed on by all the RATE members is that the earth is young, on the order of 6,000 years old. This is not simply a working hypothesis to be tested as to whether it is true or false. Instead, it is a basic conclusion drawn from the biblical record of creation as written by the only One who was present, God himself … A second guiding principle the RATE team realized from the start is that a large amount of nuclear decay has taken place in the past … We assume that the earth was not created with an appearance of age at this microscopic level of detail. Alongside this principle,

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> however, there is not the usual constraint that radioisotope decay has always been governed by today's measured nuclear half-life values. Instead, the RATE team concludes that there have been episodes of major acceleration of nuclear decay in the past.[3]

This explanation has been favorably embraced by many in the young-earth community,[4] but not without criticism by some.[5]

Regardless of its popularity, in order for accelerated nuclear decay to be more than just a philosophical supposition invented to salvage a YEC religious belief, independent scientific evidence is required. Realizing this objection, the RATE team offered several lines of physical evidence: discordant radioisotope dates, radiohalos in granites, fission tracks, and helium retention in zircon crystals.[6] Without going into detail here, many of these arguments are weak. For instance, most of the discordant radioisotope dates published by the RATE team disagreed by only 10–20%. It is hard to justify the six-order-of-magnitude increase in nuclear decay rates required by the RATE hypothesis from such a relatively small error. Regarding radiohalos, convincing evidence was made that a genetic relationship exists between uranium halos and polonium halos in many of the samples. The RATE team argued that this could be possible only if the polonium atoms were mobilized from uranium concentration sites by hydrothermal liquids in the cooling magma. Presumably, these hydrothermal liquids would only be able to create radiohalos over a narrow temperature and time window. However, an alternate explanation, which was not seriously considered, is that the mobile species is more likely radon in the uranium decay chain. Radon migration does not require the presence of hydrothermal liquids and can operate at low temperatures over long periods of time. The fission track argument is weaker still. No evidence for a young Earth was even given, only evidence for a substantial amount of nuclear decay. Above all, the common weakness in all three of these lines of evidence is that no alternate chronometer was proposed against which the age of the samples, and hence the rate of nuclear decay, could be measured. The one exception was the helium retention in zircon study, which used helium diffusion as an alternate chronometer.

In order to understand the helium retention in zircon argument, it is helpful to first consider some basics of the diffusion mechanism itself and how it can be used as a chronometer. In a zircon crystal containing trace amounts of uranium and thorium, the α-particle decay of these radioactive nuclei will ultimately produce lead and helium as end products. One can use the amount of lead and uranium to calculate a radiometric age for the sample using conventional techniques. In principle, one could also use the amount of helium and uranium in the same way. In practice, using helium for radiometric dating is more problematic since helium, as a light noble gas, is more readily lost from the crystal. The process by which helium or other atoms move through a solid because of random thermal motion is called "diffusion." The question at hand is, how fast will a helium atom leave a zircon crystal? The speed of this diffusion process is quantified using a number called "diffusivity." Given a value for the diffusivity and other information, such as the dimensions of the crystal and the boundary conditions, the diffusion process can be modeled mathematically. If one can determine the amount of helium lost from a sample by comparing the concentrations of radiogenic lead and helium, this diffusion model can be solved for time, resulting in a model age for the sample.

In principle, then, the RATE helium retention in zircon argument is quite simple: calculate the radiometric age of the sample using conventional techniques and compare the results with the model helium diffusion age. According to the RATE researchers, a large discrepancy between the two ages was observed, with the "nuclear decay clock" indicating over a billion-years-worth of nuclear decay, and the "helium diffusion clock" indicating only about 6,000 years of diffusion. Taking the "helium diffusion clock" to be the more reliable measurement, the RATE team claimed that they had found physical evidence for both a young Earth and accelerated nuclear decay.

It is worth considering the assumptions behind this conclusion. The biggest one is that the "helium diffusion clock" is more reliable than the "nuclear decay clock." As DeYoung expressed earlier, questioning the constancy of nuclear decay rates was a fundamental premise of the RATE study, even though α-particle decay rates have been empirically determined to be constant over a wide range of environmental conditions. In contrast, solid-state diffusion rates are known to be affected by a multitude of factors such as temperature, pressure, geometry, and crystal damage, just to name a few. The dependence on temperature is so strong that the system behaves more like a thermometer than a chronometer![7] In short, helium diffusion is not a good clock—there are far too many other factors which must be measured and controlled in order to get a reliable result. Several authors, including myself, have written about the numerous flaws in the RATE helium diffusion study.[8] This article expounds upon what I believe to be the most serious one—a naïve misinterpretation of the low-temperature helium diffusion kinetics.

Figure 1, which shows a popular graph widely publicized by the RATE team, illustrates the concern. The solid circles depict the laboratory-measured diffusivities of helium through zircon crystals. The solid squares depict the diffusivities calculated from a diffusion model which assumes geologically long time, and the open squares without labels (that is, excluding the squares labeled "Hot" and "Cold") show the corresponding young-earth diffusion model. Agreement between an extrapolation of the laboratory-measured data and the old-earth model is supposedly possible only when the model diffusivities are shifted to unrealistically low cryogenic temperatures (that is, open squares labeled "Cold"),[9] which is clearly highly improbable. Note carefully, though, that this extrapolation is based upon the four lowest-temperature diffusivities. At higher temperatures, the curve bends steeply upwards. If an extrapolating line is drawn through these higher-temperature points, it would nicely intersect in the vicinity of the old-earth model, not the young-earth model. In short, there is no discrepancy if the high-temperature diffusivity data are considered, or to put it another way, the young-earth argument rests entirely on just four low-temperature diffusion data points.

I spent several summers during my undergraduate years working on nuclear physics-related problems at the Hanford Nuclear Reservation in Washington State. After graduation, I transitioned into the semiconductor electronics industry, where I have been developing new technologies for the last twenty-five years. Solid-state diffusion is a bread-and-butter process in the manufacture of semiconductor devices, and I routinely run advanced diffusion simulation programs as part of my job function. Having worked in both the fields of nuclear physics and solid-state diffusion, I can say unequivocally that of the two phenomena, solid-state diffusion is much harder to model. The decades of research into solid-state diffusion invested by the semiconductor industry is a testament to this fact.

One cannot fully characterize complex solid-state diffusion phenomena using only a single experiment. It is surprising that the young-earth community makes such broad claims regarding the cosmic altering of fundamental physical processes on the basis of so little data. Perhaps their initial enthusiasm was excusable when the RATE team published their results back in 2005. However, since the publication of the RATE II book,[10] no additional experimental work on helium diffusion in zircon has been performed by the young-earth scientific community. Meanwhile, the secular geochemical community has

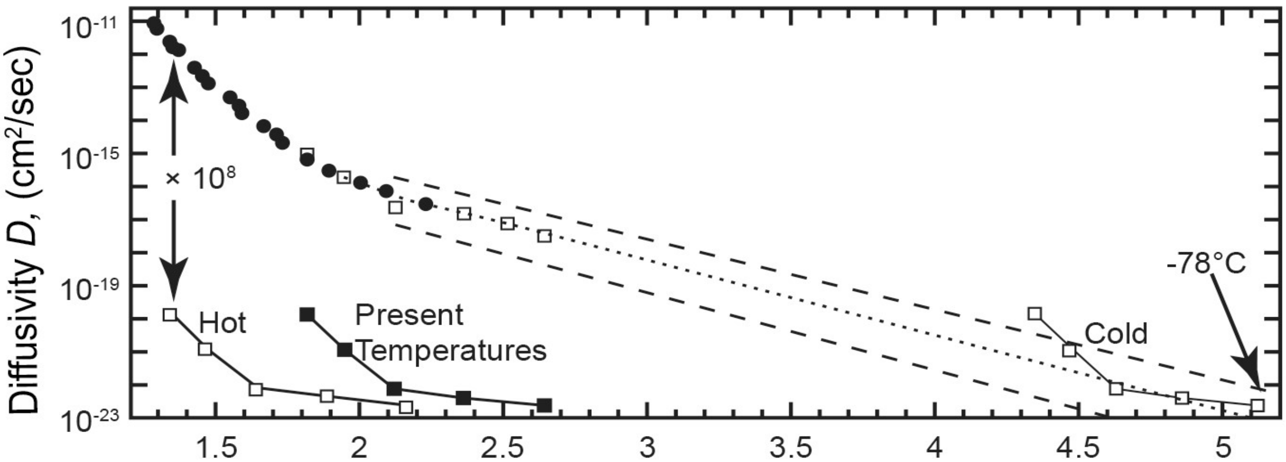

Figure 1. Arrhenius plot of helium diffusivity in zircon from the RATE study. Laboratory-measured data are filled circles. Model diffusivities from a young-earth model are open squares (not including the open squares labeled "Hot" and "Cold"). Model diffusivities from an old-earth model are filled squares. The dotted line is an extrapolation from the four lowest-temperature data points.[11]

been actively engaged in further research. This article summarizes essential findings of that scientific work and discusses its implications for the accelerated nuclear decay hypothesis.

Another Borehole

If an episode of accelerated nuclear decay has occurred at any time in Earth's recent past, one would expect the results of the RATE helium diffusion experiment at Fenton Hill, New Mexico, to be replicated at other sites around the world. In 2010, Wolfe and Stockli published results on helium diffusion from another borehole as part of the Continental Deep Drilling Program (KTB) of Germany.[12] One of the questions addressed by these researchers was, Can helium diffusivities measured in the laboratory be used to predict the retention of helium over geologic timescales in the field? In order to answer this question, they needed two independent chronometers, similar to the RATE study. For the nuclear decay age, they used the conventional helium/zircon radiometric (ZrHe) ages calculated from the measured helium content of the zircon samples. For the helium diffusion age, they used modeled ZrHe ages calculated using the laboratory-measured helium diffusivities and the known crystal geometry.

What does the accelerated nuclear decay hypothesis predict for the KTB borehole? According to secular geology, the basement rock experienced a major episode of faulting and uplift in the Late Cretaceous. In a young-earth Flood model, this event would be reinterpreted as a period of catastrophic uplift and cooling in the late Flood. According to the RATE hypothesis, accelerated nuclear decay occurred during the Flood, and roughly 70–90 million years (Ma) worth of radioactive decay, using current decay rates, would deposit helium in these rocks. Therefore, the measured ZrHe ages should be around 70–90 Ma and decreasing as one descends the borehole. As in the case of the Fenton Hill wells, deeper samples have a higher ambient temperature, and one would expect more helium loss and, hence, lower ZrHe ages. What is the prediction for the model ZrHe ages? Since zircon supposedly cannot retain helium for millions of years at any reasonable Earth temperature, one would expect an old-earth diffusion model to show severe helium loss at all depths. Consequently, the model ZrHe ages should be very small regardless of depth. This result would have created a major conundrum for the scientists. What did they observe?

Figure 2 summarizes the results of the Wolfe and Stockli study. The measured ZrHe ages are plotted as small squares, with averages for each depth plotted as large squares. Although there is some horizontal scatter in the data, the vertical trend is very clear. Near the surface of the borehole, roughly 85 Ma worth of helium was measured, assuming current decay rates. This quantity stayed constant until block C was reached. At a depth of just below 4000 m, the temperature rises sufficiently to cause some helium loss. By the time block D is reached at a depth of 7000 m, most of the helium is gone, and the measured ZrHe ages are close to zero. This trend matches the Fenton Hill samples, in which less helium was measured for the deeper and hotter samples.

To determine if the model ZrHe ages agree with the measured ZrHe ages, Wolfe and Stockli performed laboratory step-wise heating diffusion measurements on two zircon samples. The smooth curves with small solid circles and diamonds are the corresponding model ZrHe ages for samples ZKTB1516 and ZKTB4050, calculated using the zircon geometry and the measured helium diffusivity. In order to rule out the possibility of an error in their diffusivity measurements, they also calculated model ZrHe ages using helium diffusivities published by Reiners and others,[13] represented by the cross-hatched region labeled "Bulk Diffusion Envelope" in figure 2. As can be seen, there is good agreement between measured and modeled ZrHe ages, especially for sample ZKTB4050. A discrepancy between the "nuclear decay clock" and the "helium diffusion clock" was not found at the KTB site.

A Possible Explanation

What happened at the KTB borehole? Why was there such good agreement between the "nuclear decay clock" and the "helium diffusion clock," when the accelerated nuclear decay hypothesis predicts that it should not be possible? Perhaps there was a mathematical error in the diffusion model. A point to note, though, is the remarkably good agreement achieved between measurement and model. The data define a characteristic curve. Upper samples in blocks A and B have been closed to helium loss since the uplift and cooling of the basement rock. Lower samples in block D are open to helium loss. In between, samples in block C define a classic partial retention zone, where helium loss is highly sensitive to small changes in ambient temperature. If Wolfe and Stockli

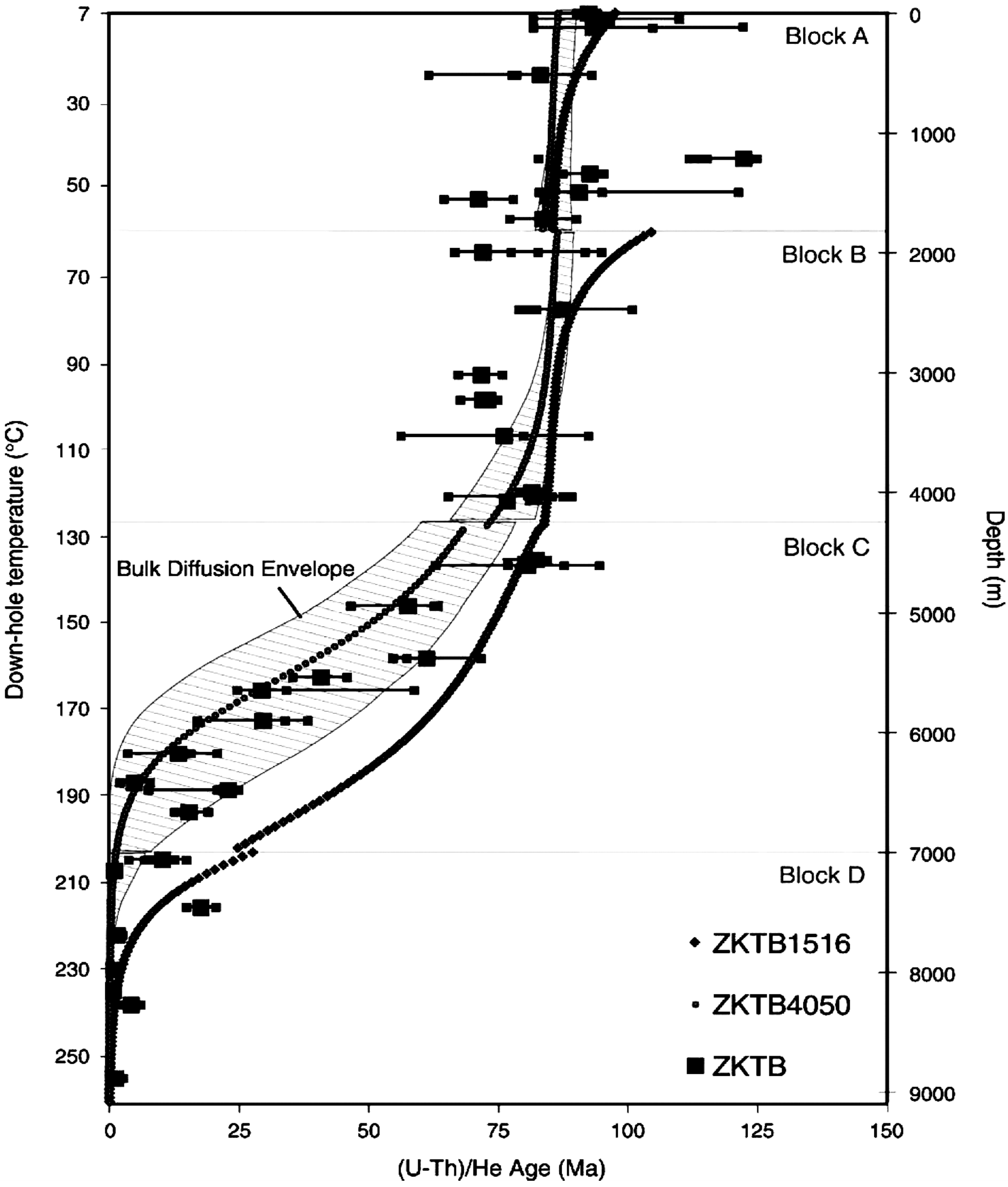

Figure 2. Comparison of measured helium/zircon radiometric (ZrHe) ages to helium diffusion model ages. The samples are from the Continental Deep Drilling Program (KTB) of Germany. Measured ZrHe ages are plotted as individual ages (small squares) and average ages (large squares) with the error bars representing the maximum age spread. The smooth curves with small solid circles and diamonds are the corresponding model ZrHe ages calculated using laboratory-measured helium diffusivities from two different samples, ZKTB1516 and ZKTB4050. The cross-hatched region labeled "Bulk Diffusion Envelope" covers the range of model ZrHe ages calculated using helium diffusivities published in the literature. Blocks A through D delineate different fault-bounded crustal blocks intersected by the drill hole. The overlap of measured and modeled ages demonstrates that there is a good correlation between the "nuclear decay clock" and the "helium diffusion clock."[14]

made a fundamental modeling mistake, they were very fortunate to have the results come out so close to measurement.

Was there perhaps an error in the measured ZrHe ages? This possibility is even less likely. Both the secular model and the accelerated nuclear decay hypothesis predict that about 85 Ma worth of radioactive decay should have occurred. The samples above 4000 m support this prediction. The eventual loss of helium with respect to increasing depth and temperature is exactly what would be expected.

A remaining possibility is that there is a difference in the measured helium diffusivities between the Wolfe and Stockli study and the RATE study. Since diffusion is the long-range effect of random atomic motion, it is highly sensitive to temperature. The higher the temperature, the faster atoms move. The faster atoms move, the greater the diffusion. Diffusivity is often graphically displayed on an Arrhenius plot, which is a plot of the logarithm of the diffusivity versus the inverse absolute temperature. The theoretical motivation behind the Arrhenius plot is that thermally activated processes such as diffusion often have the following temperature dependence,

$$D = D_o \exp\left(\frac{-E_a}{RT}\right) \qquad (1)$$

where E_a is the activation energy of the process, D_o is the prefactor, T is the absolute temperature, and R is the universal gas constant.

Graphical elements of a curve on an Arrhenius plot have direct physical meaning. The slope of the curve gives the activation energy. Think of helium atoms as being bound in the zircon crystal at certain sites. In order for them to move, enough thermal energy must be supplied to break this bond. The activation energy represents the strength of this bond. The y-intercept of the curve gives the prefactor and represents the speed of the process at essentially infinite temperatures. Once the thermal energy is sufficient to break the bond holding the helium atoms, the limiting factor to the speed of the diffusion process is the prefactor. Figure 3 illustrates these relationships.

If the diffusivity data fall along a single straight line in an Arrhenius plot, it indicates that the process operates by a single mechanism. When multiple slopes appear on the plot, as is sometimes the case with helium diffusion in zircon, it indicates that more than one mechanism is present. Multiple diffusion mechanisms complicate both the modeling of the long-term retention of helium in a sample and the interpretation of the laboratory measurement itself.

Table 1 compares the helium diffusivity measured in the RATE study with that of the Wolfe and Stockli study. Included are additional measurements from Reiners and others, Cherniak and others, and Guenthner and others.[15] Since the RATE data had a two-slope behavior on an Arrhenius plot, separate lines in the table are given for the high-temperature

Table 1: Comparison of published helium diffusion activation energies (E_a) and prefactors (D_o) to the results from the RATE experiment. The diffusivity at 87 °C extracted from the low-temperature RATE diffusion data differs by about five orders of magnitude from similar diffusivities extracted from data found in the literature.

E_a (kCal/mol)	D_o (cm²/s)	*D (T = 180°C)* (cm²/s)	*D (T = 87°C)* (cm²/s)	Reference
13.9	1.7E-10	3.1E-17	5.7E-19	Humphreys (low-temperature data)[16]
38.1	3.1E-01	1.3E-19	2.3E-24	Humphreys (high-temperature data)[17]
40.4	4.6E-01	1.5E-20	1.4E-25	Reiners[18]
34.9	2.3E-03	3.4E-20	1.5E-24	Cherniak, Watson, and Thomas (perpendicular direction)[19]
35.4	1.7E-01	1.5E-18	5.8E-23	Cherniak, Watson, and Thomas (parallel direction)[20]
38.2	3.0E-02	1.1E-20	1.9E-25	Wolfe and Stockli[21]
33.0	2.7E-02	3.2E-18	2.5E-22	Guenthner et al. (Mud Tank, parallel)[22]
39.7	2.3E-02	1.6E-21	1.8E-26	Guenthner et al. (RB140, parallel)[23]
38.9	2.7E-02	4.5E-21	6.4E-26	Guenthner et al. (M127, parallel)[24]

and low-temperature data. The first two columns give the activation energies and diffusion prefactors extracted from the measurements. These parameters were used in the Arrhenius formula to calculate the diffusivities at 180 °C and 87 °C in the next two columns (see eq. 1). The last column gives the references.

There is a striking consistency in the diffusivities measured in all of these studies with the exception of the low-temperature RATE data. At a temperature of 87 °C, there is a five-order of magnitude difference in diffusivity. Interestingly, a temperature of 87 °C corresponds to the upper end of where the helium partial retention zone begins in the Wolfe and Stockli study. Figure 1 illustrates this difference graphically. The extrapolation in this figure is through four low-temperature data points. The rest of the data lie upon a line with a much steeper slope, consistent with what other researchers have published. The conclusions of the RATE study rely heavily upon these four data points. It is crucial, therefore, to understand the diffusion kinetics of the helium-in-zircon system in this low-temperature regime.

Since these diffusion experiments all follow a procedure that was developed by Fechtig and Kalbitzer for the diffusion of argon in potassium-bearing solids, it is helpful to see how these authors handle the case

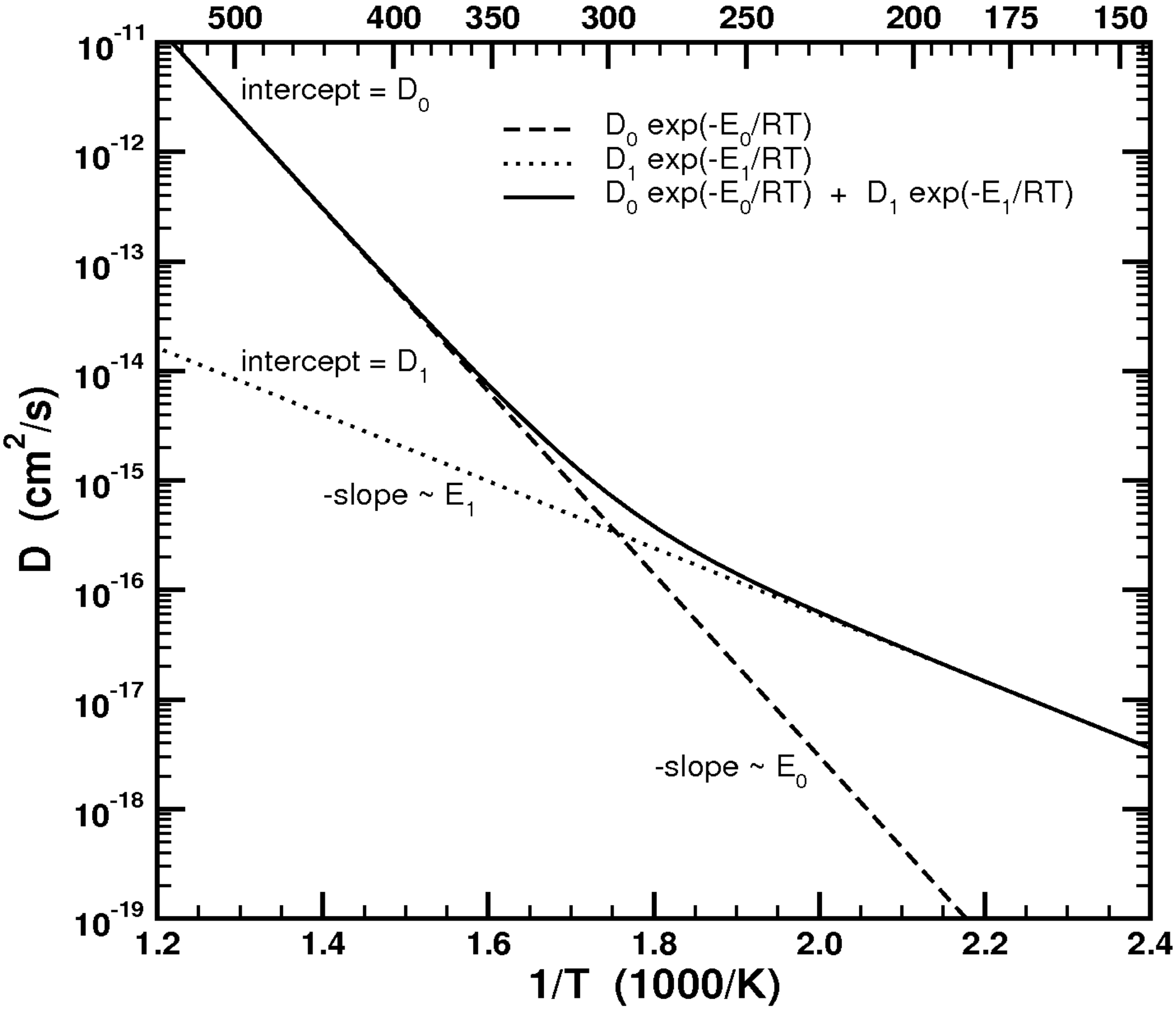

Figure 3. Examples of temperature-dependent diffusivities graphed on an Arrhenius plot. The expressions $D_0 \exp(-E_0/RT)$ and $D_1 \exp(-E_1/RT)$ plot as straight lines, with the negative slopes being proportional to the activation energies E_0 and E_1 and the y-intercepts equal to the prefactors D_0 and D_1. The sum of these two expressions plots as a curve in which the diffusion mechanism with the highest prefactor D_0 dominates at high temperatures and the diffusion mechanism with the lowest activation energy E_1 dominates at low temperatures. Values for E_0 and D_0 come from the Humphreys high-temperature data and values for E_1 and D_1 come from the Humphreys low-temperature data in Table 1.

of a diffusivity curve that does not follow a simple Arrhenius trend. They use the archaic term "non-volumic diffusion" to describe the phenomenon:

> Sometimes fractions of weakly bound argon are found in diffusion experiments. At lower temperatures a flat curve in the Arrhenius plot is observed, characterized by rather low activation energies … In crystals, where the potassium is a regular constituent, the existence of loosely bound argon may be explained by higher structural defects (such as dislocations, grain boundaries, etc.), in which case the argon will diffuse out easily.[25]

In general, they advise extrapolating the high-temperature data to lower temperatures rather than using the low-temperature data directly.[26] A good summary is given in their conclusions:

> Although the situation is quite complex one can say that at least for minerals which have K homogeneously distributed throughout the mineral practically all the argon can escape only by volume diffusion, if we do not take into account any metamorphism. For such minerals it is, therefore, allowed to extrapolate the straight line which represents the volume diffusion [i.e. high temperatures] down to the temperatures investigators are most interested in [i.e. low temperature].[27]

The situation can be complex. I previously presented a similar argument during an online debate program.[28] Humphreys, the lead RATE scientist on the helium diffusion study, challenged my interpretation of Fechtig and Kalbitzer in his later reply.[29] His primary argument regarding experiments on the K-halide system was the following quote:

> These results on this "simple" system clearly show that the diffusion of argon at low temperatures should not be calculated from high-temperature measurements, but that measurements have to be performed in the temperature interval of interest.[30]

Humphreys claims that this advice is a general principle which would reasonably apply to most situations. On the contrary, Fechtig and Kalbitzer never made such broad-reaching claims. The particular quote in question pertains to diffusion experiments on the K-halide system, which is highly unusual in that its high-temperature activation energy is lower than its low-temperature activation energy. This behavior is the exact opposite of the "non-volumic diffusion" effect described above. Such an unusual situation does not apply to the helium diffusion in zircon cases considered in this article.[31]

What is the rationale for the procedure of extrapolating the high-temperature diffusion data to lower temperatures when the low-temperature data deviate from an Arrhenius trend? Basically, laboratory experiments cannot measure diffusivity directly. Instead, only the gas release at a given temperature step can be measured. The challenge is to relate the measured amount of gas release back to the diffusivity. This connection is done by means of a model. If the assumptions of the model hold, then the diffusivity that is calculated is meaningful. If the assumptions of the model do not hold, then the diffusivity that is calculated does not relate to a real physical quantity. One of the assumptions of the Fechtig and Kalbitzer model is that all the gas comes from a single gas reservoir defined by a single activation energy. What happens if the gas comes from multiple reservoirs with different activation energies, as in the RATE diffusion experiment? In that case, the measured gas release at any given temperature step is some unknown combination of the two sources, and the diffusivity that is calculated is some weighted average of the individual diffusivities with unknown coefficients. This is the situation at low temperature when there are multiple diffusion mechanisms involved, and the problem is intractable.

At higher temperatures, however, the problem becomes tractable again. Once the temperature becomes high enough to mobilize all the helium atoms in the sample, the activation energy is no longer a limiting factor. Instead, at sufficiently high temperatures, the rate of diffusion is mostly determined by the prefactor, and the dominant mechanism with the highest prefactor will always win. What was intractable at low temperatures becomes manageable at high temperatures (see fig. 3).

As a side note, the RATE team outsourced their helium diffusion experiment to a well-respected researcher at a secular university. In the RATE publications, they mention, on multiple occasions, how they insisted that this researcher take more measurements at lower temperatures. In contrast, in the publications of this researcher and his students, they never go to the same low-temperature regime in their own experiments. Note the practical consequences of Fechtig and Kalbitzer's advice. If low-temperature diffusion data are problematic, then it is not worth wasting valuable experimental resources taking data there.

Some Implications

Before considering the implications of the low-temperature diffusion mechanism on the helium retention ability of zircon samples in the field, a couple of points need to be emphasized in order to avoid potential misconceptions. First, strictly speaking, none of the laboratory experiments cited in the previous section actually measured the helium diffusivity. Diffusivity is not a directly accessible material parameter. One does not have a "diffusometer" that can be placed in a sample like a thermometer. Instead, the directly accessible measurable quantity is the amount of gas released at a given temperature over a given time. Inferring a diffusivity from this gas release requires a model built upon underlying assumptions. If the assumptions of that model are not met, then the number that is calculated is not representative of the actual diffusion kinetics, regardless of how accurately the experiment was performed. This point should not be overlooked.

Second, any inference regarding the ability of a rock or mineral sample to retain helium over time scales on the order of the age of Earth requires the extrapolation of these laboratory measurements over time and temperature, often by orders of magnitude. Consider a simple example. If one wants to definitely know by direct observation if a mineral sample can retain a certain amount of helium for 6,000 years, the experimenter would have to put that sample in a laboratory instrument and wait that long. Clearly this is not practical. At best, a typical step-wise heating diffusion experiment will run over the course of many hours or perhaps even a few days in some instances. The challenge is how to best use data that were acquired over a relatively short period of time in the laboratory to predict the behavior that is expected over a longer period of time in the field. For this reason, a solid theoretical understanding of the underlying diffusion mechanism is invaluable.

Guenthner and others performed one of the most thorough and rigorous studies of helium diffusion in zircon that has been published in the literature.[32] Some of their samples showed low-temperature diffusion behavior similar to what was observed in the RATE experiment (fig. 4). They attributed the diffusion mechanism in this low-temperature regime to "grain-boundary-like sites." Here is what they mean. Empirically, they observed in their diffusion experiments that the majority of the helium released from a sample was due to a diffusion mechanism with a high-activation energy, and only a small fraction of the remaining helium in the sample was released due to a diffusion mechanism with a low-activation energy. A high-activation energy indicates a tight

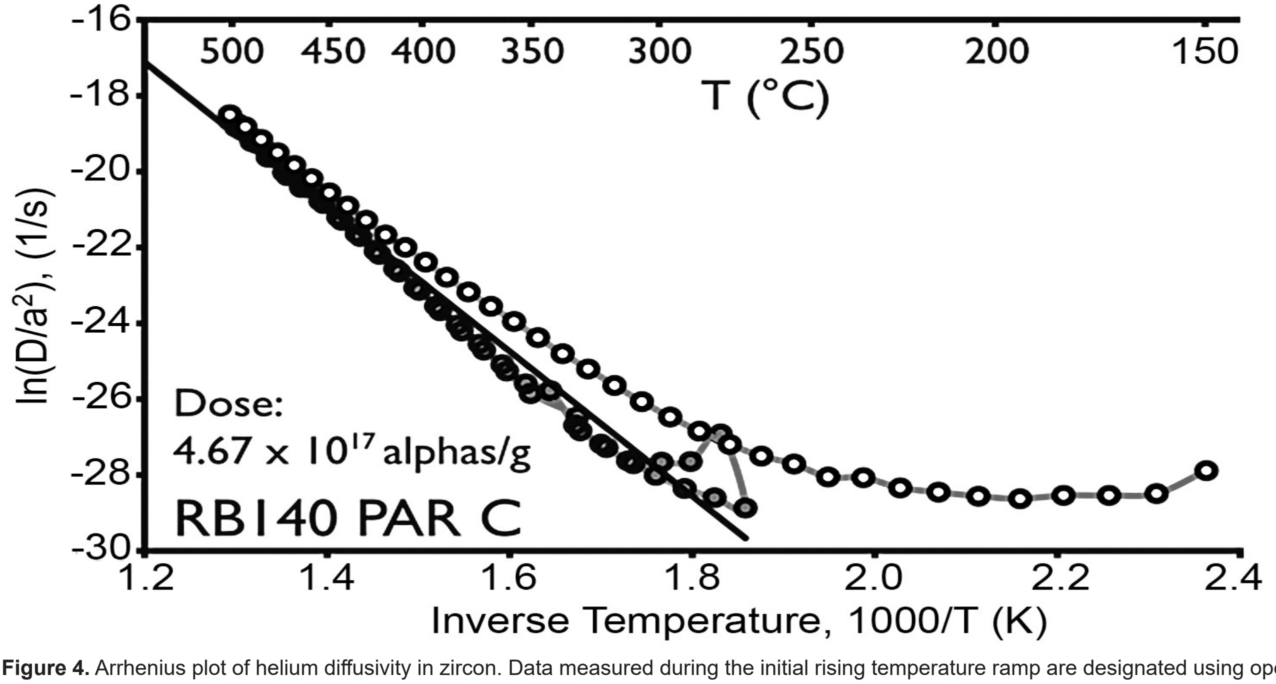

Figure 4. Arrhenius plot of helium diffusivity in zircon. Data measured during the initial rising temperature ramp are designated using open circles. Data measured after the maximum-temperature step are designated using grey-filled circles. Note the persistence of nonlinearity in the low-temperature diffusivity even after the initial temperature ramp. This behavior is similar to what was observed in the RATE experiment (compare with fig. 1). Guenthner and others attributed this low-temperature diffusion behavior to a small fraction of helium loosely bound to "grain-boundary-like sites" that were partially refilled with helium during the previous high-temperature steps.[33]

binding between the helium atoms and the crystal, whereas a low activation energy indicates a loose binding. Although Guenthner and others could not identify the exact nature of these loose-binding sites, they drew an analogy to polycrystalline systems in which there are crystalline grains separated from each other by grain boundaries. Even though this is probably not a perfect analogy, it illustrates an important point. The majority of the helium atoms are locked up in the crystal lattice "grains" and only the small minority that are wandering in the "grain-boundary-like sites" can diffuse at lower temperatures.

The findings of Guenthner and others open up new insights into the possible diffusion mechanism for helium in zircon at low temperatures in a step-wise heating experiment. The high diffusivity observed at lower temperatures could be from a small fraction of helium loosely bound to grain-boundary-like domains.[34] Although most of this loosely bound helium would be released from the sample during the initial heating ramp of the experiment, the release of helium from the tightly bound lattice sites at high temperatures partially refilled these loosely bound sites. Later in the experiment, helium in these loosely bound sites continued to be released, resulting in the high diffusivity that was observed. Contrary to the assumptions of the RATE researchers, this diffusion mechanism cannot account for any substantial amount of helium loss for samples held at these lower temperatures. The accelerated nuclear decay hypothesis cannot be supported in light of this preponderance of experimental work performed by Wolfe and Stockli, Reiners, Cherniak, Guenthner, and many others.

Reflections

Consider the RATE helium diffusion experiment. Take a rock sample from deep underground. Crush that rock and remove tiny zircon crystals. Place those bare crystals, which were previously surrounded by other minerals under high pressure, in a vacuum system. Heat the crystals up to high temperature and cool them down. Repeat this process a second time, measuring the amount of helium that is released at each temperature step along the way. After excluding the initial temperature ramp, the high-temperature steps above 350 °C accounted for over 22% of the total helium in the system, whereas the four low-temperature steps below 275 °C accounted for only 0.0008% of the total helium in the system, or about eight parts per million.[35] What do these eight parts per million of helium release tell us about the age of Earth? Very little, in fact.

The RATE authors considered these eight parts per million of helium release to be strong evidence for accelerated nuclear decay. Why? Because time on their "nuclear decay clock" disagreed with time on their "helium diffusion clock." Supposedly, nuclear decay rates had been drastically altered by an act of divine intervention. In making this supposition, they tacitly assumed that helium diffusion is a more reliable chronometer than nuclear decay. But is it? The α-decay of uranium is governed by the strong nuclear force and is insensitive to environmental influences such as temperature and pressure. The diffusion of helium in zircon is governed by long-range electromagnetic forces and is highly sensitive to environmental influences which include not only temperature and pressure, but other factors as well, such as crystal structure, surface boundary conditions, and the type and density of radiation damage and extended defects. In the final analysis, the RATE helium diffusion study tells us more about the properties of the zircon crystal than the age of Earth.

Epilogue

A manuscript similar to the one above was previously submitted to the *Journal of Creation*. Unfortunately, it was rejected. Knowing that the position of the paper would not be popular, I strongly encouraged the editors to conduct a fair and impartial review. In my opinion, their review of my manuscript was neither fair nor impartial. The young-earth creationist community will not gain any respect outside of their narrow circle if they refuse to engage in civil discourse with their fellow brothers and sisters in Christ who hold different views.

Acknowledgments

I would like to thank Steve McRae for his support and encouragement of this work. Kevin R. Henke and Jon Fleming assisted with the bibliography. Jon Fleming assisted with the figures as well. The review of my manuscript by them and many others is also appreciated. Finally, my deepest gratitude goes to those who have strengthened me through their prayers.

Appendix A: Adding Diffusivities

One of the central themes of this article is that, when attempting to model solid-state diffusion, it is vitally important to understand the diffusion kinetics of the material system of interest. I have faced this challenge many times over my last twenty-five years of experience in the semiconductor electronics industry. Because of its commercial value, diffusion in the silicon system has been studied better than just about any other material, and silicon diffusion models can become very complex, especially in a low-temperature regime where there are interactions with extended crystal defects.

Therefore, it was with a bit of surprise that I saw the following equation in the RATE literature:[36]

$$D = D_o \exp\left(\frac{-E_0}{RT}\right) + D_1 \exp\left(\frac{-E_1}{RT}\right) \qquad \text{(A1)}$$

This simplistic equation represents the combined diffusion of a species (helium in this case) for a material with both an intrinsic and defect diffusion mechanism (zircon in this case). The first term (with leading D_o) represents diffusion from the intrinsic mechanism and the second term (with leading D_1) represents diffusion from the defect mechanism. The problem with this naïve equation is that one typically cannot add diffusivities from two separate mechanisms any more than one can add velocities from cars traveling on two parallel highways. The diffusing species will be in either one state or the other, just as a traveling car will be on either one highway or the other, not both at the same time. This insight is the motivation behind multidomain diffusion models.[37] In multidomain diffusion models, the diffusing species is partitioned into separate domains. Each domain has a separate diffusion model with a unique concentration, diffusivity, and particle flux. After modeling the diffusion in each domain, the results are combined. In multidomain models, concentrations and particle fluxes can be added, but diffusivities, in general, cannot.

In a recent online debate program, I challenged Humphreys to defend his use of equation (A1) with either a derivation or reference.[38] Humphreys obliged by providing a derivation,[39] a critique of which is given here. If equation (A1) is graphed on an Arrhenius plot, a two-sloped curve results, with the intrinsic term creating a high-sloped line at high temperatures and the defect term creating a low-sloped line at low temperatures. A corner or knee forms at intermediate temperatures where these two lines intersect (see fig. 3).

Humphreys attempted a derivation of equation (A1). After several algebraic steps, he arrived at the following expression for the natural logarithm of the diffusivity:

$$\ln D = \left(\ln D_0 - \frac{E_0}{RT}\right) + \left(\ln D_1 - \frac{E_1}{RT}\right) \qquad \text{(A2)}$$

This equation supposedly represents the two-sloped curve described by equation (A1) and plotted in figure 3. The problem is that equation (A2) is not the natural logarithm of equation (A1), and it does not describe a two-sloped curve on an Arrhenius plot. A simple way to see this mathematical error is by regrouping the terms in equation (A2) as follows:

$$\ln D = (\ln D_0 + \ln D_1) - \frac{(E_0 + E_1)}{RT} = b - a\left(\frac{1}{T}\right) \qquad \text{(A3)}$$

This equation describes a simple straight line on an Arrhenius plot, not a two-slope curve with a high-slope intrinsic line and a low-slope defect line. Not only did Humphreys fail to give a rigorous physical derivation of equation (A1), he also failed to do the algebra correctly.

Appendix B: Unpublished Experimental Data?

An important point made in this article is that scientific theories should be established by multiple experiments whenever possible. As was discussed earlier, the Wolfe and Stockli study does not support the accelerated nuclear decay hypothesis.[40] Table 1 demonstrates that the low-temperature diffusivity data from the RATE study are inconsistent with published results from multiple researchers. Since the RATE conclusions rest heavily upon only four low-temperature data points from a single diffusion experiment, it is worth taking inventory of the experimental work performed by the RATE team.

The first helium diffusion data published by the RATE team was in a 2003 paper in the Fifth International Conference on Creationism (ICC).[41] Although the results were tantalizing, these data were considered to be inconclusive because they did not extend to low enough temperatures. The following year, results from another experiment were published in the *Creation Research Society Quarterly* (CRSQ).[42] Since the low-temperature diffusion data overlapped predictions from their young-earth model, the RATE team claimed that they had found definitive evidence for accelerated nuclear decay. No follow-up experiments to confirm their findings have been performed.

However, it is possible that additional unpublished experiments were performed. The 2004 CRSQ paper reviews the history.

> Then we sent both the biotite and the zircons to our experimenter. He sieved the biotite sample to get flakes between 75 and 100 µm, but he used all the zircons Kapusta extracted, regardless of size. Size of crystals (effective radius) is important in converting the raw data into diffusivities. He sent us the raw data [which was later published in 2003 ICC] in 2002 …
>
> After that, in the summer and fall of 2002, we tried several times to get lower-temperature data. However, we only discovered several wrong ways to make such measurements. First, we asked the experimenter to do new runs on the same batch of zircons, but at lower temperatures. The results were ambiguous, an effect we decided was due to exhaustion of helium from the smaller zircons in the batch (Fechtig and Kalbitzer, 1966, § 2.5, p. 72).
>
> Second, we sent the experimenter a new set of zircons from the same depth in GT-2 and asked him to sieve out crystals in the 50–75 µm size range. Before sieving, he decided to leach the crystals in cold concentrated hydrofluoric acid (HF) to remove flecks of biotite clinging to them. Though the technique was new, it seemed reasonable. However, the values of D/a^2 he then obtained were over fifty times higher than all previous zircon data, both ours and published. Scanning electron microscope images done later (see next section) revealed severe pitting and cracking in the HF-treated zircons. That would allow helium to leave the zircons much faster than normally.
>
> These were all the data we had by February 2003, the deadline for the final version of our conference paper (Humphreys et al., 2003a).[43]

The diffusion data for the 2004 CRSQ paper did not arrive until July 2003, well past the deadline for the 2003 conference. This history is fascinating for several reasons. First, it suggests that more than two helium diffusion experiments were performed by the RATE team. Second, apparently only data from the first experiment were published in the 2003 ICC paper,[44] even though all the data except for the last run were available prior to the conference deadline. Third, data from these intermediate experiments were not published in either the 2004 CRSQ paper or the 2005 RATE II book.[45] Finally, the argument for not using at least some of the data from these intermediate experiments was that the results were "ambiguous." It is not clear what the authors meant by this term, but because they attributed the effect to "exhaustion of helium from the smaller zircons in the batch," it may indicate that the diffusivity came out lower than expected. Perhaps this ambiguity is an indication that the RATE helium diffusion results are not reproducible?

In order to gain a better understanding, I requested the data for these intermediate diffusion experiments from Humphreys through Steve McRae, who was facilitating our dialogue for his Great Debate program. Below is Humphreys's uncooperative response.

> Sorry that I've given this such a low priority. I'm reluctant to spend several hours watching the Hanke [sic, Henke]/Loechelt videos, because I have a strong feeling that they have said nothing new or worthwhile. For example, I think I've published (in the RATE II book) all the diffusion data that Dr. Loechelt is asking for, along with all the relevant parts of the lab reports we received. See particularly the appendices to my chapter in the book. Thus it seems to me that Dr. Loechelt is grasping at non-existent straws, which implies to me that he's got nothing substantial. That in turn un-motivates me for spending more time on him.[46]

So according to Humphreys, all the diffusion data were published in the RATE II book. Yet, according to the 2004 CRSQ paper, additional experiments were performed. This mystery remains unresolved.

∞

Notes

[1]J. D. Morris, *The Young Earth* (Green Forest, AR: Master Books, 1994), 45–67; S. A. Austin, *Grand Canyon: Monument to Catastrophe* (Santee, CA: Institute for Creation Research, 1994), 111–31; J. Woodmorappe, *The Mythology of Modern Dating Methods* (El Cajon, CA: Institute for Creation Research, 1999), 1–118; V. R. Cupps, *Rethinking Radiometric Dating: Evidence for a Young Earth from a Nuclear Physicist* (Dallas, TX: Institute for Creation Research, 2019), 1–138; and M. J. Oard, *The Deep Time Deception: Examining the Case for Millions of Years* (Powder Springs, GA: Creation Book Publishers, 2019), 83–120.

[2]L. Vardiman, A. A. Snelling, and E. F. Chaffin, eds., *Radioisotopes and the Age of the Earth, Volume I: A Young-Earth Creationist Research Initiative* (El Cajon, CA, and St. Joseph, MO: Institute for Creation Research and the Creation Research Society, 2000), accessed October 20, 2019, https://www.icr.org/i/pdf/research/rate-all.pdf; ____, *Radioisotopes and the Age of the Earth, Volume II: Results of a Young-Earth Creationist Research Initiative* (El Cajon, CA, and Chino Valley, AZ: Institute for Creation Research and the Creation Research Society, 2005), accessed October 20, 2019, https://www.icr.org/rate2/; and D. DeYoung, *Thousands … Not Billions: Challenging an Icon of Evolution, Questioning the Age of the Earth* (Green Forest, AR: Master Books, 2005).

[3]DeYoung, *Thousands… Not Billions*, 174–75.

[4]J. Sarfati, *Refuting Compromise: A Biblical and Scientific Refutation of "Progressive Creationism" (Billions of Years) As Popularized by Astronomer Hugh Ross* (Atlanta, GA: Creation Book Publishers, 2004), 341–43, 394; A. Williams and J. Hartnett, *Dismantling the Big Bang: God's Universe Rediscovered* (Green Forest, AR: Master Books, 2005), 192–93, 197, 324; M. Riddle, "Does Radiometric Dating Prove the Earth Is Old?," in *The New Answers Book*, ed. K. Ham (Green Forest, AR: Master Books, 2006), 123–24; D. R. Faulkner, "A Review of Stellar Remnants: Physics, Evolution, and Interpretation," *Creation Research Society Quarterly* 44, no. 2 (2007): 76–84, see conclusions on p. 83, accessed October 20, 2019, https://creationresearch.org/review-stellar-remnants-physics-evolution-interpretation/; R. Patterson, *Evolution Exposed: Earth Science* (Hebron, KY: Answers in Genesis, 2008), 94, 98, 112; J. Reed, *Rocks Aren't Clocks: A Critique of the Geologic Timescale* (Powder Springs, GA: Creation Book Publishers, 2013), 121, 123–24; M. J. Findley and M. C. Findley, *The Conflict of the Ages, Part Three – They Deliberately Forgot: The Flood and the Ice Age,* Teacher Edition (Bixby, OK: Findley Family Video Publications, 2013), 347–50; B. Hodge, *Confound the Critics: Answers for Attacks on Biblical Truths* (Green Forest, AR: Master Books, 2014), 179–80; and J. D. Sarfati, *The Genesis Account: A Theological, Historical, and Scientific Commentary on Genesis 1–11* (Powder Springs, GA: Creation Book Publishers, 2015), 135, 143.

[5]C. R. Froede Jr., "Does Excess ^{40}Ar Support RATE's 6,000-Year-Old Earth?," *Journal of Creation* 26, no. 1 (2012): 37–39, accessed October 20, 2019, https://creation.com/images/pdfs/tj/j26_1/j26_1_37-39.pdf; C. R. Froede Jr. and A. J. Akridge, "RATE Study: Questions Regarding Accelerated Nuclear Decay and Radiometric Dating," *Creation Research Society Quarterly* 49, no. 1 (2012): 56–62, accessed October 20, 2019, https://creationresearch.org/wp-content/uploads/crsq-summer-2012-froede.pdf; and D. R. Humphreys, "Critics of Helium Evidence for a Young World Now Seem Silent," *Journal of Creation* 24, no. 1 (2010): 14–16, see list of critics in Table 1, accessed October 20, 2019, https://creation.com/images/pdfs/tj/j24_1/j24_1_14-16.pdf.

[6]D. R. Humphreys et al., "Helium Diffusion Rates Support Accelerated Nuclear Decay," in *Proceedings of the Fifth International Conference on Creationism,* ed. R. L. Ivey, Jr. (Pittsburgh, PA: Creation Science Fellowship, 2003), 175–95, accessed October 20, 2019, https://answersingenesis.org/geology/radiometric-dating/helium-diffusion-rates-support-accelerated-nuclear-decay/; ____, "Helium Diffusion Age of 6,000 Years Supports Accelerated Nuclear Decay," *Creation Research Society Quarterly* 41, no. 1 (2004): 1–16, accessed October 20, 2019, https://creationresearch.org/helium-diffusion-age-6000-years-supports-accelerated-nuclear-decay/; and D. R. Humphreys, "Young Helium Diffusion Age of Zircons Supports Accelerated Nuclear Decay," in *Radioisotopes and the Age of the Earth, Volume II*, ed. Vardiman, Snelling, and Chaffin, 25–100, accessed October 20, 2019, http://www.icr.org/article/young-helium-diffusion-age-zircons/.

[7]A useful quantity for representing the mean distance a particle travels by diffusion is the "diffusion length." The diffusion length is defined as $L = \sqrt{Dt}$, where D is the diffusivity and t is time. The diffusion length grows as the square-root of time, which is a rather weak, sublinear dependence. In contrast, it grows exponentially with respect to inverse temperature by means of the Arrhenius equation.

[8]K. R. Henke, "Humphreys's Young Earth Helium Diffusion 'Dates,'" *National Center for Science Education Reports* 30, no. 5 (2010): 27–32, accessed October 20, 2019, http://www.csun.edu/~vcgeo005/henke.pdf; ____, "Dr. Humphreys' Young-Earth Helium Diffusion 'Dates': Numerous Fallacies Based on Bad Assumptions and Questionable Data," *Talk Origins*, June 20, 2010, accessed October 20, 2019, http://www.talkorigins.org/faqs/helium/zircons.html; and G. H. Loechelt, "Fenton Hill Revisited: The Retention of Helium in Zircons and the Case for Accelerated Nuclear Decay" (American Scientific Affiliation, 2008), accessed October 20, 2019, http://www.asa3.org/ASA/education/origins/helium-gl3.pdf.

[9]Humphreys, "Young Helium Diffusion Age of Zircons Supports Accelerated Nuclear Decay."

[10]Vardiman, Snelling, and Chaffin, eds., *Radioisotopes and the Age of the Earth, Volume II*.

[11]Humphreys, "Young Helium Diffusion Age of Zircons Supports Accelerated Nuclear Decay," reproduced from fig. 16 (p. 62) in accordance with federal copyright (fair use doctrine) law.

[12]M. R. Wolfe and D. F. Stockli, "Zircon (U–Th)/He Thermochronometry in the KTB Drill Hole, Germany, and Its Implications for Bulk He Diffusion Kinetics in Zircon," *Earth and Planetary Science Letters* 295 (2010): 69–82.

[13]P. W. Reiners et al., "Zircon (U-Th)/He Thermochronometry: He Diffusion and Comparisons with ^{40}Ar/^{39}Ar Dating," *Geochimica et Cosmochimica Acta* 68, no. 8 (2004): 1857–87.

[14]Wolfe and D. F. Stockli, "Zircon (U–Th)/He Thermochronometry in the KTB Drill Hole, Germany," figure reprinted from fig. 7 with permission from Elsevier.

[15]Ibid.; D. J. Cherniak, E. B. Watson, and J. B. Thomas, "Diffusion of Helium in Zircon and Apatite," *Chemical Geology* 268 (2009): 155–66; and W. R. Guenthner et al., "Helium Diffusion in Natural Zircon: Radiation Damage, Anisotropy, and the Interpretation of Zircon (U-Th)/He Thermochronology," *American Journal of Science* 313 (2013): 145–92, accessed October 20, 2019, http://www.ajsonline.org/content/313/3/145.abstract.

[16]Humphreys et al., "Helium Diffusion Age of 6,000 Years Supports Accelerated Nuclear Decay."

[17]Ibid.

[18]Reiners et al., "Zircon (U-Th)/He Thermochronometry: He Diffusion and Comparisons with ^{40}Ar/^{39}Ar Dating."

[19]Cherniak, Watson, and Thomas, "Diffusion of Helium in Zircon and Apatite."

[20]Ibid.

[21]Wolfe and Stockli, "Zircon (U–Th)/He Thermochronometry in the KTB Drill Hole, Germany."

[22]Guenthner et al., "Helium Diffusion in Natural Zircon: Radiation Damage, Anisotropy, and the Interpretation of Zircon (U-Th)/He Thermochronology."

[23]Ibid.

[24]Ibid.

[25]H. Fechtig and S. Kalbitzer, "The Diffusion of Argon in Potassium-Bearing Solids," in *Potassium Argon Dating*, ed. O. A. Schaeffer and J. Zähringer (Berlin, Germany: Springer-Verlag, 1966), 74, accessed October 20, 2019, https://link.springer.com/chapter/10.1007%2F978-3-642-87895-4_4.

[26]Ibid. Examples of extrapolating the straight line which represents the volume (high-temperature) diffusion down to lower temperatures are given on pp. 82–83, 91, and 96–97.

[27]Ibid., 101.

[28]Steve McRae, "Dr. Kevin Henke and Dr. Gary Loechelt on Creationist Claims about He Diffusion Rates (LIVE)—Part II," Great Debate Community video, 2:18:14, January 19, 2018, accessed October 20, 2019, https://greatdebatecommunity.com/2018/01/19/dr-kevin-henke-and-dr-gary-loechelt-on-creationist-claims-about-he-diffusion-rates-live-part-ii-2.

[29]D. R. Humphreys, "Answer to a Persistent Critic of RATE Helium Research," *Journal of Creation* 32, no. 3 (2018): 49–57.

[30]Humphreys, "Young Helium Diffusion Age of Zircons Supports Accelerated Nuclear Decay," 84.

[31]Compare figure 12 of Fechtig and Kalbitzer, "The Diffusion of Argon in Potassium-Bearing Solids," with the figures of this article.

[32]Guenthner et al., "Helium Diffusion in Natural Zircon: Radiation Damage, Anisotropy, and the Interpretation of Zircon (U-Th)/He Thermochronology."

[33]Figure reproduced from Fechtig and Kalbitzer, "The Diffusion of Argon in Potassium-Bearing Solids," fig. 3, sample RB140 PAR C with permission of the *American Journal of Science* by J. D. & E. S. Dana, in the format Journal/magazine via Copyright Clearance Center.

[34]Essentially equivalent is the concept of "non-volumic diffusion" used by Fechtig and Kalbitzer in "The Diffusion of Argon in Potassium-Bearing Solids" (p. 74) to explain similar nonlinear Arrhenius behavior observed in the potassium/argon system.

[35]Calculated from Table II of Humphreys et al., "Helium Diffusion Age of 6,000 Years Supports Accelerated Nuclear Decay," 6. Also in Table 2 of Humphreys, "Young Helium Diffusion Age of Zircons Supports Accelerated Nuclear Decay," 45. From the high-temperature steps (10–13 and 21–27), 306 ncc of helium was released (22.58%). From the low-temperature steps (16–19), 0.0106 ncc of helium was released (0.0008%). From the initial temperature ramp (1–9), 56.5 ncc of helium was released (4.16%). From the remaining intermediate temperature steps (14–15 and 20), 0.118 ncc of helium was released (0.0087%). After the initial temperature ramp, the vast majority of helium was released from the high-temperature steps. Total helium yield, including final fusion step, was 1356 ncc.

[36]Equation (3) of the RATE II book (Humphreys, "Young Helium Diffusion Age of Zircons Supports Accelerated Nuclear Decay," 34). Note sign error later corrected in Humphreys, "Answer to a Persistent Critic of RATE Helium Research."

[37]Reiners et al., "Zircon (U-Th)/He Thermochronometry: He Diffusion and Comparisons with $^{40}Ar/^{39}Ar$ Dating"; P. W. Reiners and K. A. Farley, "Helium Diffusion and (U-Th)/He Thermochronometry of Titanite," *Geochimica et Cosmochimica Acta* 63, no. 22 (1999): 3845–59; D. L. Shuster et al., "Quantifying the Diffusion Kinetics and Spatial Distributions of Radiogenic 4He in Minerals Containing Proton-Induced 3He," *Earth and Planetary Science Letters* 217 (2003): 19–32; and D. L. Shuster et al., "Weathering Geochronology by (U-Th)/He Dating of Geothite," *Geochimica et Cosmochimica Acta* 69, no. 3 (2005): 659–73.

[38]McRae, "Dr. Kevin Henke and Dr. Gary Loechelt on Creationist Claims about He Diffusion Rates (LIVE)—Part II."

[39]Humphreys, "Answer to a Persistent Critic of RATE Helium Research."

[40]Wolfe and Stockli, "Zircon (U–Th)/He Thermochronometry in the KTB Drill Hole, Germany."

[41]Humphreys et al., "Helium Diffusion Rates Support Accelerated Nuclear Decay."

[42]Humphreys et al., "Helium Diffusion Age of 6,000 Years Supports Accelerated Nuclear Decay."

[43]Ibid.

[44]Humphreys et al., "Helium Diffusion Rates Support Accelerated Nuclear Decay."

[45]Humphreys et al., "Helium Diffusion Age of 6,000 Years Supports Accelerated Nuclear Decay"; and Vardiman, Snelling, and Chaffin, eds., *Radioisotopes and the Age of the Earth, Volume II*.

[46]D. R. Humphreys, private communication, May 24, 2018.

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History of Science

REACHING FOR THE MOON: A Short History of the Space Race by Roger D. Launius. New Haven, CT: Yale University Press, 2019. 256 pages. Hardcover; $30.00. ISBN: 9780300230468.

Reaching for the Moon: A Short History of the Space Race joins a small swarm of recent books riding the surge of interest in the early space program, thanks to the fiftieth anniversary of Apollo 11. Given this spate of recent works, and the vast trove of related works already in existence, it is hard to imagine what new insights might be provided. On this count, the book is a pleasant surprise. Roger Launius concentrates on geopolitics, domestic politics, and bureaucratic structures, in the US and USSR, in the years leading up to the first moon landing in 1969. The juxtaposition of the American and Soviet programs throughout the first half of the book is a novel approach that makes for fresh insights. As for the technical information, there is just enough to provide important context for the primary political-history story (with a few regrettable misstatements along the way).

The book starts with the Soviet space program of the 1960s in parallel with the US program. Especially interesting is the oft-neglected Soviet program to land men on the moon. Although the Soviets denied the existence of this effort at the time in order to save face, the Russians have since owned up to its existence. Placing it in parallel with the American program provides instructive lessons. This is especially appropriate here since it is the geopolitical cold-war rivalry of the 1960s that drove both space programs. A major lesson to be drawn from the comparison relates to the devastating internal fighting in the Soviet program. This jockeying for political influence and resources is very relevant to the Soviet failure to land men on the moon before NASA.

The text also discusses the 1957–1958 International Geophysical Year (IGY) of planned international research projects, and the fact that each nation knew that the other was working on an Earth satellite well before Sputnik "took us by surprise" in 1957. This is frequently overlooked. The political and public reaction in the US—which led to the space race—is explained in some detail.

The material on Wernher von Braun, the most famous of the German rocket scientists brought to the US after WWII to help with rocket development, is not new but is frequently overlooked. His work for Hitler always haunted his reputation, but was largely washed away in his charisma and excellent work for the American program. However, it never completely disappeared and is discussed fairly here.

James Webb, NASA's administrator during the initial phases of Apollo, comes across as one of the heroes of the story, and rightly so. Although President John F. Kennedy (JFK) was not that much into space, and expressed the desire to only spend the minimum necessary to get to the moon, Webb held out and was able to get the resources to build a multifaceted infrastructure for space exploration, for which we continue to reap the rewards (Launch Complex 39 at Kennedy Space Center was used for the Apollo lunar launches, repurposed for Space Shuttle launches, and is now used by SpaceX). It is for good reason that the next great space telescope is named after him, even though his most obvious success was in shepherding the flights of Apollo.

The background of the actual decision by JFK to put the nation on the path to landing a man on the moon "in this decade" is perhaps the most compelling, along with the penultimate chapter on reflections about the meaning of the accomplishment. The comparison of the responses of Eisenhower (president at the time of Sputnik) and Kennedy (president when Gagarin made the first human spaceflight) is instructive. Along the same lines as his warning about the rise of the military-industrial complex, Eisenhower put the "surprise" Sputnik launch into perspective and warned against the rush to an overreaction. This was turned into a political liability by the ambitious Lyndon Johnson, who used it as a way to convey the Eisenhower administration as underestimating the existential threat to the US presented by the new domain of spaceflight. Kennedy capitalized on this and, along with unfounded claims of a "missile gap" between the two countries, made America's relative lack of prominence in space a major political issue. This led to inspirational rhetoric and resonated with the image of the young and vibrant new president. The embrace of a moon-landing program as a way to recapture America's preeminence was a natural decision. A lunar-landing mission had already been under study by the Space Task Group (the predecessor of the Johnson Space Center, led by Robert Gilruth), but it was always seen as part of a larger and more methodical program that included orbital flights and space stations. Apollo was a detour from this larger and more coherent vision. NASA and the US have lived with this dichotomy ever since: the impressive space spectacular contrasted with the methodical long-term development of spaceflight capabilities.

One theme throughout the book is that a major goal—if not *the* major goal—of Apollo was to demonstrate the superiority of the American system in marshaling resources for great accomplishments. This was not just for pride and prestige, but to sway nonaligned nations which were choosing which nation-system to follow. As Kennedy said in his speech to Congress announcing the lunar-landing goal:

> Finally, if we are to win the battle that is now going on around the world between freedom and tyranny, the dramatic achievements in space which occurred in recent weeks should have made clear to us all, as did the Sputnik in 1957, the impact of this adventure on the minds of men everywhere, who are attempting to make a determination of which road they should take.

The goal is geopolitical persuasion, not science or exploration or heroism. That much is clear and undisputed. However, what is lacking is an objective assessment of the international impact on the "minds of men everywhere." Some anecdotes are provided as to the outpouring of international goodwill for the US after Apollo 11, but nowhere—in this book or otherwise—have I seen a popular account of the impact on unaligned nations.

By using human spaceflight as a tool for political ends, enormous resources were made available, but the public came to see space exploration as a series of spectacles. Anything less spectacular than Apollo was perceived to be an unfortunate loss of direction and lack of leadership by NASA—a sentiment that prevails even today. But Apollo is a hard act to follow. As the author points out, Apollo was a product of the times, and NASA did not seem to understand that; this left a "divided legacy as to the true meaning of the accomplishment and what it meant for the future of space exploration." It was astoundingly successful in the context of the time, and then the context changed.

Enthusiasm for space peaked when it was novel and heroic and geopolitically crucial. It is a mistake to think that there ever was a time that the American public overwhelmingly supported huge strides in human spaceflight in and of themselves. That is a sobering conclusion. It says much about us as a nation and makes one question just how bold and adventurous we are, as opposed to willing to take risks for pragmatic ends.

Apollo was a clear demonstration of technological prowess, which fed America's self-image as a great nation and contributed to a long sense of technological progress as inherent to American greatness and uniqueness. The technical virtuosity of Apollo was truly impressive, which also gave the impression that large government technology programs could solve any problem no matter how challenging. NASA reaped the rewards of this, and continues to benefit from this image, but NASA is also trapped by it since its resources do not match these expectations. Apollo was successful because it was constrained and bounded, the basic technology was understood and defined from the start, and no great conceptual leaps were needed for its fulfillment. The problems of world hunger and poverty are not so easily formulated.

That the Apollo moon landings still hold a fascination for us tells us something about ourselves, but what? To some extent, there is something for everyone, since the program was so wide ranging. Begun with purely political motivations, it touches on something much more fundamental, as explored in the final chapter. It has often been noted that seeing Earth in its wholeness from deep space was the start of the environmental movement. As T. S. Eliot stated, "We shall not cease from exploration, and the end of all our exploring will be to arrive where we started and know the place for the first time."

On a more regrettable note, some of the fascination with Apollo, in some quarters, is nostalgia for a time when America seemed to have a clear manifest destiny that was largely promulgated by white males. Also mentioned is the desire of many people to frame Apollo as a form of religious experience—humans touching the cosmos, reaching beyond physical limitations, and the like. This journal has previously published two of my reviews of books that attempted to make this religious connection, with little success. Apollo remains a major technical accomplishment, one of the most significant of the twentieth century, which was conceived under geopolitical necessity but continues to inspire and beg for more noble interpretations.

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THE CREATIVITY CODE: Art and Innovation in the Age of AI by Marcus du Sautoy. Cambridge, MA: Harvard University Press, 2019. 295 pages plus preface and acknowledgments. Hardcover; $30.00. ISBN: 9780674988132.

Following his international bestseller *The Music of the Primes*, mathematician and science popularizer Marcus du Sautoy, Simonyi Professor for the Public Understanding of Science at Oxford University, takes lay readers on a vibrant tour of the world of creativity and the history of attempts at automating the creative process. In so doing, he touches on deep questions of what it means to be human.

In his first chapter, du Sautoy poses what he terms "The Lovelace Test" of computer creativity, an analogy to the well-known "Turing Test" for determining machine intelligence, and in homage to computing pioneer Ada Lovelace. Lovelace's musings on the future applications of computers to creative pursuits form a recurring theme throughout the book.

> To pass the Lovelace Test, an algorithm has to produce something that is truly creative. The process has to be repeatable … and the programmer has to be unable to explain how the algorithm produced its output. (p. 6)

As for what counts as "creative," du Sautoy specifies that it must be *new, surprising*, and *of value*. Furthermore, "[f]or a machine to be deemed truly creative, its contribution has to be more than an expression of the creativity of its coder or the person who built its dataset" (p. 6).

So begins a discussion of *human* creativity, drawing on the work of cognitive scientist Margaret Boden, who identified three main types of creativity: exploratory (pushing the boundaries while keeping to the rules), combinational (achieving a synthesis by combining different constructs), and transformational (complete game-changers). Du Sautoy describes examples of these from the worlds of art, music, and mathematics, and notes that while computers may do well at exploratory and combinational creativity, transformational creativity is not yet well enough understood to be taught to humans, let alone machines. However, Boden believes that 97 percent of human creativity is of the exploration type, and thus machines present a potential "threat" that might overturn the human dominance in creative accomplishment.

Some might wonder what a mathematician knows of creativity, as du Sautoy concedes that "mathematicians are a bit of a misunderstood breed" (p. 145). In chapter 9, "The Art of Mathematics," he relates his quandary as a young man upon encountering the work of the great G. H. Hardy, who wrote in *A Mathematician's Apology* (Cambridge University Press, 2004),

> A mathematician, like a painter or a poet, is a maker of patterns … The mathematician's patterns, like the painter's or the poet's, must be beautiful; the ideas like the colors or the words must fit together in a harmonious way. (p. 141)

Du Sautoy confesses that, up to that point, "I'd never imagined mathematics to be a creative subject, but as I read Hardy's little book it seemed that aesthetic sensibilities were as important as the logical correctness of the ideas" (p. 141). Echoes of this appear in Douglas Hoftstadter's famous *Gödel, Escher, Bach* (Basic Books, 1979) and William Dunham's lovely *Journey through Genius* (Penguin Books, 1991), in which the great theorems of mathematics are presented as enduring masterpieces of art. To these discussions, du Sautoy adds the metaphor of mathematics as story: "I believe a good proof has many things in common with a great story or a great composition in that it takes its listeners on a journey of transformation and change" (p. 229). He ties this in with AI efforts toward story generation and essay writing. He even concedes at the end that a portion of the book's text was generated by an AI authorship tool.

It is an apt analogy, for narrative is a skill that du Sautoy shares with other successful science communicators, telling stories from history as well as from personal encounters with a host of leading computer scientists, artists, and musicians—names like art curator Hans-Ulrich Obrist and musician Brian Eno. Du Sautoy's lofty academic position provides him with the privilege of access to such luminaries, allowing for off-hand remarks such as the beginning to chapter 3 about the development of the *AlphaGo* program which soundly defeated the world's top-ranked player in the game of Go: "I was sitting next to [DeepMind co-founder] Demis Hassabis at one of the Royal Society's meetings …" (p. 218). Du Sautoy's personal story is woven throughout the book, from his own experiences in contributing to the mathematical study of symmetry to his appreciation for art and music. *The Creativity Code* contains narratives about the development of, if not *every* attempt at machine-based creativity, a vast panoply of major and minor systems throughout history: for example, from the dice-based compositional games of Mozart to the neural nets of *DeepBach*, from Gerhard Richter's *4900 Farben* to *The Next Rambrandt* of Microsoft and TU Delft, and from early choose-your-own-adventure stories to the interactive narratives of Mark Riedl's *Scheherazade-IF*.

Toward the end, the intensity and depth of feeling in the book escalate. After surveying developments in the fields of music, art, poetry, and more, he shares his own musings on mathematics via AI, in which one can feel his personal stake; for example, in concerns of computers taking over his livelihood. Remarks made earlier by artists and musicians about whether a computer-generated piece is not merely new, but also surprising and valuable, take on a new poignancy, as in his lament about the mathematical proof-generating program Mizar: "I left the DeepMind offices rather downcast … what I had seen was like a mindless machine cranking out mathematical Muzak" (p. 223). He then shares a quote from mathematician Henri Poincaré who might as well have been speaking of songwriting: "To create consists precisely in not making useless combinations. Creation is discernment, choice …" (p. 228).

Unlike his Simonyi Professor predecessor Richard Dawkins, du Sautoy demonstrates no antipathy toward religion, yet his musings on human identity and religious motivations for art ring, at times, strangely superficial in comparison to the other topics he covers so deftly. At one point, without any hint of irony, he tells a story about how religion arose from humans' need to tell stories to explain the world around them. Almost the entirety of the book is concerned with the *how* of creativity (i.e., in the processes), as well as concerns about the implications for the future employment of artists, writers, musicians, and, indeed, mathematicians in the face of AI advances. These lead naturally to the capstone final chapter, "Why We Create," in which he quotes from psychologist Carl Rogers and author Paul Coelho on the roots of creativity as a human need to communicate and to bind communities together. While du Sautoy doesn't go on to provide it, these reasons form a subset of a Christian response to the *why* of human creativity, for example, as seen in *Creator Spirit: The Holy Spirit and the Art of Becoming Human* (Baker Academic, 2011) by theologian/musician Steven Guthrie, who likens creativity to gift-giving: "God invites us into the ecology of gift that is at the center of God's own life … God's intention is that we would, like God, be agents capable of giving to others" (p. 158).

The Creativity Code is current with respect to AI developments up until the time it went to press. However, this was prior to the debut of the "transformer" language models in early 2019, which far surpassed many people's conceptions of the capabilities of generative language models, even inspiring widespread concerns regarding their potential misuse (for example, see J. Vincent, "OpenAI's New Multitalented AI Writes, Translates, and Slanders," *The Verge*, Feb. 14, 2019). Thus, in reading the later chapters on AI, language, and text-creation, one wonders how differently an updated edition of this book would read in light of these developments. With AI changing so quickly, it may be impossible to produce a book that will stand the test of time in every respect, and it remains to be seen what other "updates" the coming years will bring as far as AI's capabilities. Yet, as both a comprehensive historical survey and as an authoritative statement of values about creativity, du Sautoy's book will remain a significant contribution and should be read by anyone interested in the intersection of AI and creativity.

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Medicine and Health

CARE AND CURE: An Introduction to Philosophy of Medicine by Jacob Stegenga. Chicago, IL: University of Chicago Press, 2018. 248 + xiii pages, including bibliography and index. Paperback; $25.00. ISBN: 9780226595030.

As I began writing this review, our Minneapolis newspaper reported on the controversy that Blue Cross Blue Shield Minnesota raised when it decided to work with a for-profit contractor in South Carolina to use evidence based medicine (EBM) for prior approval of procedures that it will cover. Many physicians, hospitals, and patients are complaining that the newly aggressive denials are tantamount to fraud. This is the intersection of medicine, economics, and public policy and, according to Jacob Stegenga, philosophy of medicine can help us clarify the issues. He sees it as a branch of philosophy of science (he is a philosopher teaching in the Department of History and Philosophy of Science at the University of Cambridge) and defines philosophy of medicine as "the study of epistemological, metaphysical, and logical aspects of medicine, with occasional forays into historical, sociological, and political aspects of medicine" (p. 1). As defined, it covers a lot of territory, so an introduction that provides a map of the main issues and the controversies involved in them is very useful, and that is what Stegenga provides. He does not provide a detailed discussion, much less a resolution of all or any of the debates, but he gives an informed overview and a clear outline of the dueling positions and even of the intramural debates within them.

Part I, "Concepts," begins with chapters on health and disease: is the former simply the absence of disease or, more positively, the sort of flourishing that includes mental and social well-being? The reader will find problems (or, as Stegenga is fond of saying "puzzles") with either of these answers. And defining disease raises similar issues: both "naturalism" (disease is simply dysfunctioning physiological systems) and "normativism" (disease is a disvalued state), as well as the hybrid effort to mediate them, elicit enough puzzles that "eliminativism" tries unfruitfully to get along without a theory of disease. The role of phenomenology is to describe what it is like to be diseased, something even naturalists try to recognize with the category of "illness." Chapter 3, "Death," asks whether it is a biological event (such as the whole brain death of an organism) or a metaphysical one (higher brain death of a person). Some might like more detail here, especially when he discusses in a few pages whether one's death is bad for oneself (dating the argument as "going back to" Lucretius, when it actually goes back 250 years earlier to Epicurus) as well as the ethics of euthanasia and abortion. I think that he could have reiterated his decision to let medical ethics be its own field and have spent more time on the definitional issues, but he might reply that he is trying to provide only a high-flying overview or map of the debates.

Part II, "Models and Kinds," begins with an important chapter on nosology—the classification of diseases—that shows the puzzles involved in the three main theories: the *etiological* (with its three subtheories about what it means to cause a disease), the *pathophysiological* (what biological mechanism is malfunctioning?), and the *symptoms-based* such as we find in the *Diagnostic and Statistical Manual of Mental Disorders*. A chapter on reductionism (biomedically disease centered) and holism (patient centered) gives the book its title: the former is aimed at *cure* and the latter at *care*. Medicine needs both.

Part III, "Evidence and Inference," is the most philosophically ladened section and the one I found most revealing. Chapter seven lays out what counts as evidence for the effectiveness of pharmaceuticals. Randomized controlled trials (RTC) are thought to be the gold standard, and meta-analysis amalgamates the outcomes from multiple studies. So why do meta-analyses of the same primary evidence sometimes reach contradictory conclusions? Here Stegenga provides what for me is his eye-opening summary of the sources of bias in medicine (perhaps 56 of them), of threats to objectivity, of distressingly common fallacies of inference, of problematic elements in claims of effectiveness, and of difficulties in decisions about diagnosis and the wisdom of screening. It is enough to make one skeptical and, indeed, in 2018, the same year as this book, Stegenga also published a book sympathetic to *Medical Nihilism* (Oxford University Press). His informed medical skepticism (a better, albeit less snappy phrase than medical nihilism) about the effectiveness of medical interventions, such as anti-depressants, can elicit both praise and blame, as seen here: https://aeon.co/essays/the-evidence-in-favour-of-antidepressants-is-terribly-flawed. If you click on the comments you will see the contours of the debate, as well as his willingness to engage his critics.

The final section, "Values and Policy," has a chapter on "Psychiatry: Care or Control?" that shows the difficulties in reaching agreement on diagnoses and treatments when decisions are based mainly on symptoms. The resultant room for social and political abuse of psychiatry is underscored. The chapter on public "Policy" highlights the "10/90 gap": 90% of the world's medical research resources are devoted to studying diseases that affect only 10% of the world's population and, of course, it is the poor who are left to suffer the diseases that could easily be fought except that there is little financial incentive to do so. So, should medical research be socialized the way medical delivery is? The final chapter on "Public Health" raises the question of whether "prevention" should be added to "cure and care" as part of the mission of medicine. One problem is that most of the developments that prevent diseases are non-medical ones such as improved sanitation and clean drinking water. And when we consider preventative medicine, we encounter the problem of deciding how much mass screening (with its inevitable negative side effects) is worth how many lives saved. Stegenga does not raise the currently hot issue of vaccination and whether we should allow nonmedical exemptions that undermine herd immunity. This omission and others (is gun violence a public health issue?) underscore the fact that even a comprehensive map of philosophy of medicine cannot cover all the relevant issues in 250 pages.

Stegenga calls his approach "analytic naturalism," which connotes careful analysis of scientific ideas appealing only to empirical facts about nature and history (p. 3). As expected in analytic philosophy, the emphasis is on clarity and relevant distinctions. Indeed, he loves distinctions and subcategories, often saying, "Let's call this …" Sometimes I wondered if his labels are commonly accepted; for example, he refers to "Pre-Conscious Hypersomniferosis" (PCH) without defining it (he invites the reader to say which normal condition is being medicalized here), but when I googled it, the only reference I found was to this very book. The writing prizes clarity over eloquence, and prizes argument over consensus. Often in one paragraph, we find a claim, an objection or two to it, a response or two to the objection(s), and sometimes a reply or two to the response(s). This method gives a good overview of the debates, although it conveys the impression that we have an endlessly contested field.

Most of the book can be understood by laypersons, though at least one explanation—that of frequentism versus Bayesianism (theories of statistical inference)—presupposes more background knowledge than many of us have. And this was part of the very important points about the difference between "risk reduction" and "risk difference" and about the "base-rate fallacy," points that not only show how big pharma can commercially exploit the confusion, but also seem important to understanding problems with the use of EBM that I mentioned at the beginning of this review.

The "Note to Teachers" at the beginning of the book indicates that the main intended audience is college and medical school students. I think that the book could be an excellent supplemental text in college and medical school classes. In fact, the author lists his websites with sample syllabi for such courses. The readings listed at the end of each chapter are included (with links) in the syllabi; they are also the ones referenced in the chapters. Each chapter begins with a useful summary of the coming discussions and ends with discussion questions that tend simply to ask what the reader thinks about the arguments summarized. Anyone interested in the debates of the methodologies and effectiveness of contemporary medicine will find this clear and concise survey of the issues very useful.

Stegenga's "analytic naturalism" does not entail "metaphysical naturalism," which is the denial of any reality beyond the natural phenomena that science studies (though it can affirm that nature may well contain realities that are beyond what current science studies or can even imagine). But his approach does entail "methodological naturalism," which denies appeal to any supernatural realities. Many Christians in science accept the latter as intrinsic to doing science, and they will feel at home with Stegenga's approach. But even those who believe, say, in the supernatural power of petitionary prayer and see it as a legitimate part of medicine, can learn a lot from this well-informed study of the difficulties and limits of current medical practice and research.

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Origins

JESUS, BEGINNINGS, AND SCIENCE: A Guide for Group Conversation by David A. Vosburg and Kate Vosburg. Farmville, VA: Pier Press, 2017. 101 pages. Paperback; $12.95. ISBN: 9780996991513.

David A. Vosburg, a chemist, and Kate Vosburg, an InterVarsity Christian Fellowship campus minister, wrote this small book for groups that want to have healthy, respectful conversations about faith and science. Their book is organized into three sections with four chapters per section—perfect for a twelve-week adult Sunday school class or small group study. Each chapter is only 5–7 pages long, so the book will accommodate busy participants who would not take the time required to read lengthy assignments in preparation for a discussion. The three sections focus on science in the context of creation/origins. Part one is entitled "What does the Bible say about creation?" Part two shifts the creation focus to humans in "What does the Bible say about human origins?" The last part pulls the focus outward to science and faith broadly in "What does the Bible say about science?"

This book is a call to reflect on biblical texts that can inform our understanding of the relationship between science and the Christian faith. It is a gentle, faithful, easily accessible, thoughtful starting point for a respectful dialogue.

This book is not a resource in which you can find scientific evidence for or against evolutionary theory or an old earth. It is not a place to find deep, complex theological or hermeneutical arguments, although it includes an extensive list of excellent additional resources if a leader, small-group participant, or reader wanted to dig deeper. It does make the argument that science and faith are not in conflict, but it does not argue for a particular point of view on origins. It does not explore other points of integration between science and faith such as creation care, medical ethics, or genetic technologies.

People considering using this book to lead a small-group study do not necessarily need extensive scientific or theological knowledge, but some background in one or both would be helpful, depending on how deeply participants might want to delve into foundational information and/or evidence. If, however, participants are generally open to a discussion of what scripture says about science, anyone could use this book to lead a group.

Jesus, Beginnings, and Science has many strengths. The authors bring expertise in both science and faith to each chapter of this book. They both have experience working with young people who are struggling to put science and faith together faithfully. Vosburg and Vosburg use Genesis but do not limit themselves to Genesis. They include Old Testament texts from Psalms, Job, and Isaiah as well as passages from the Gospels, Paul's letters, and Revelation. I appreciated that their use of the whole of the Bible naturally broadens any discussion of origins/creation out from a singular focus on the creation narratives of the first chapters of Genesis. The open-ended and thought-provoking questions they include for reflection and discussion are excellent. Each chapter incorporates scripture, prayer, and worship, which I imagine help keep a group focused on the unifying tenets of their faith, even if they are discussing something about which they might strongly disagree.

I have taught a number of adult discipleship classes at my home church, some on issues that involve science. Bringing science into the church and helping people talk about science and faith is important to me. I consider helping Christians who are nonscientists to integrate science and faith faithfully, a responsibility of scientists who are people of faith. I am glad that I found and read this book, and I will be adding it to the list of potential topics for a future adult discipleship class at our church. It is a class I'd be eager to teach, in large part because this is such an excellent resource. I hope more scientists pick up this helpful book and use it to facilitate discussion on *Jesus, Beginnings, and Science* in many contexts.

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Φ Philosophy

ON HUMAN NATURE by Roger Scruton. Princeton, NJ: Princeton University Press, 2017. 151 pages. Hardcover; $22.95. ISBN: 9780691168753.

The distinguished writer and philosopher Roger Scruton has written an admirable and clear account of what we might call the human difference in his book *On Human Nature*. It is, in some respects, a scaled-down version of *The Soul of the World* (Princeton University Press, 2014). As in his earlier work, Scruton takes aim at reductionist accounts of human beings, whether from evolutionary psychology, biology, or neuroscience. This is, probably, the strongest part of the book and of most interest to readers of *PSCF*, so that is where I will be concentrating my energies in this review. Though he draws upon other philosophic traditions, Scruton's main influence is Immanuel Kant; throughout his book, Scruton demonstrates the continuing relevance and contribution of the Kantian tradition to an account of personhood.

While Scruton accepts that we are biological beings governed by biological impulses and demands, he rejects the notion that reductionist views of human beings could ever capture, without remainder, our humanity. We are middling beings with one foot in biology and the other in culture. We have emerged from our biological past into personhood, and that means not just consciousness, but also self-consciousness, freedom, and moral awareness. Scruton uses an analogy to talk about the nature of personhood as an emergent reality. A portrait painter may work with lines and blobs of paint, and, looking at the painting, we may see mere lines and blobs, but assuming that the painter is skilled, eventually we shall also see a human face emerge from the canvas. At some point, never mind when exactly, the number of lines and blobs "conspire" to become a face. There is, Scruton says, quoting Hegel, "a transition from quantity to quality" (p. 38). On the one hand, the face can be viewed as a property of the canvas distinct from the blobs of paint "for you can observe the blobs and not see the face, and vice versa" (p. 31). On the other hand, it can be argued that the face is *not* "an additional property of the canvas, over and above the lines and blobs." This is true because, as soon as we see the lines and blobs, we see the face. Scruton suggests that this is the way we should view our personhood: rooted in the life and behavior of the body, but not reducible to it. Put another way, Scruton believes that reality is multilayered, that some new and unprecedented whole can spring from the parts.

As persons, we come to exist in a new order of things with new potentialities. One of these potentialities is that we are free beings. The emergence of freedom opens a new relation with ourselves as a conscious center of self and a new kind of relation to others, as we realize that they, too, are self-conscious beings. We come to recognize that we not only have desires but that we can also evaluate those desires, asking ourselves whether those particular desires are worthy of being desired. This process of recognition and evaluation is the emergence of the ethical in us. For Scruton, the emergence of these things makes human beings qualitatively different from our closest living ancestors, the chimpanzee and bonobo.

Related to these points, but with a little different emphasis, is Scruton's discussion of "the intentional stance." The intentional stance means that we experience ourselves from the first-person perspective and can know and welcome others as sharing in our life when we address them as "you." Scruton takes issue with the "eliminative materialism" of Paul and Patricia Churchland, since they seek to dissolve the human self and agency in a welter of neurological soup. The first-person comportment so essential to Scruton's worldview is lost to a third-person account of synapses and the neurochemistry of the brain. No place for personhood here, let alone such things as intentionality or moral responsibility. Scruton is wary of the Churchlands' project since what is eliminated in their materialist account of the person is *the person*. For Scruton, the first-person stance peculiar to human beings is the essential ground of our ability to experience and appreciate "the second-person standpoint" (p. 50). The second-person perspective (in conjunction with the first-person stance) serves as the basis of our sense of moral responsibility to the other.

Scruton ventures into an analysis of the nature of the political, a critique of utilitarianism ("moral arithmetic"), and the sacred, but space prevents me from considering these. Instead, let me close by turning to his engaging, Kantian-inspired critique of pornography. I turn to this topic chiefly for the way in which Scruton's analysis touches upon some of the important themes of the book, namely the emergence of the self and how this is related to the ethical dimension. Scruton makes the interesting point that porn depicts such a depersonalized space in which arousal and desire occur that observers are encouraged to regard themselves as if they were disengaged automatons, that is, non-selves engaged in using the other as a kind of apparatus. With porn, human agency and intimacy is banished since there is, in a sense, no "I" or "You" in relation, only "It."

> The real evil of porn lies not in its portrayal of other people as sexual objects but in the radical decentering that it effects in the sexual feelings of the observer. It prizes sexual excitement free from the I-You relation and directs it to a nameless scene of mutual arousal, in which arousal too is depersonalized, as though it were a physical condition and not an expression of the self. This decentering of arousal and desire makes them into things that *happen* to me, occurring under the harsh light of a voyeuristic torch instead of being part of what I am to you and you to me, in the moment of intimacy. (p. 74)

I do not know if this is the best book on the topic, but, in his many books, Scruton has surely done us a service in helping us to see the vital role that philosophy and the humanities must play in a world increasingly given over to the conviction that only the quantifiable is real, only the measurable is important. I recommend this book for undergraduate libraries in the humanities.

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THE ASHTRAY (OR THE MAN WHO DENIED REALITY) by Errol Morris. Chicago, IL: University of Chicago Press, 2018. xii–207 pages plus cast of characters, bibliography, and index. Hardcover; $30.00. ISBN: 9780226922683.

Perhaps you long have had your fill of reading Thomas Kuhn's *The Structure of Scientific Revolutions* [*SSR*] (University of Chicago Press, 1962, 1st edition) or one of the later three editions, as well as books or articles by his many philosophical and historical critics. *The Ashtray* by Errol Morris, the illustrious filmmaker and creator of such classics of documentary investigation as *The Thin Blue Line* and *The Fog of War*, provides an account that may reawaken your interest. This book revives an argument that Morris had with the historian and philosopher of science Thomas Kuhn in 1972. And what a combative revival it is—complete with personal anecdotes, illustrations, film references, and interviews with philosophers and scientists. This book recalls a formative event: the tossing of an ashtray filled with cigarette butts and ash at a belligerent graduate student in the hallowed halls of the Institute for Advanced Study in Princeton, New Jersey—the event that led to Morris's expulsion from Princeton University and ended his intended study of the history of science. One could question: Should we even attempt to revive the past? Morris clearly thinks it is imperative that we do. Is it time, after almost half a century, for a student to take revenge on his former professor? Morris is not obtuse. He intends to launch a personal "vendetta" (p. 3, fn. 5). But why (the ashtray aside)?

In *SSR*, Kuhn outlined a revolutionary model of scientific change and examined the role of the scientific community in preventing and then accepting change. Kuhn's conception of scientific change, occurring through revolutions, undermined (or at least questioned) the traditional scientific goal of finding "truth" in nature. The picture Kuhn presents is one in which exemplary achievements yield a family of techniques constituting a paradigm which, in the course of its extension, proves appropriate for solving certain problems or puzzles.

A paradigm is not specifiable as a list of theoretical propositions or methodological rules; it is not developed by logical deduction from premises. Rather, the exemplar is learned as a model problem solution and is applied by analogy to what are judged as similar phenomena. To the extent that the problems presented by new phenomena are solved, the paradigm continues to be adhered to, expanding and modifying its range as time goes on. This is what Kuhn calls normal science. As exemplary problem solutions, paradigms are learned as ways of seeing and doing. Quite a lot of the process of scientific education, in Kuhn's view, consists of imparting unarticulated skills and interpretive dispositions. The required perceptual and motor abilities that apprentice scientists must learn cannot be fully spelled out as a set of rules.

Clearly there are circularities in Kuhn: "A paradigm is what members of the scientific community share, and conversely a scientific community consists of men [people] who share a paradigm" (*SSR*, 1970 edition, p. 176). The circularity could be avoided, he suggested, if the investigation were to begin with a discussion of the community structure of science. In his effort to explain a community's consideration of a paradigm shift or conversion, Kuhn appealed to certain extra-scientific factors (or arbitrary elements), particularly the role of psychological factors. This appeal to subjective elements opened the door to an array of other factors: sociological, economic, political, feminist, and religious (worldview).

For Morris, Kuhn's appeal to these subjective factors is an assault on truth and progress, and ultimately leads to a "denial of reality." Kuhn questioned how language attaches to the world and challenged the nature of truth, reference, realism, and progress. For Morris, Kuhn is an avatar of post-modernism. Kuhn is one who advocates "that truth cannot be anything like correspondence to reality." With reference to the recent appeal of "alternative facts," Morris adds, "This book, I hope, will serve as an antidote to those poisonous views" (p. 3, fn. 5).

Morris spells out his own frame of reference: "For me, truth is about the relation between language and the world, a correspondence idea of truth." Other theories of truth such as coherence theories "are of little or no interest to me" (p. 4). Three areas of dispute are central to Morris's account: (1) the character of paradigm change; (2) the question of incommensurability; and (3) the affirmation or denial of reality. In short, Morris argues, Kuhn characterizes paradigm change as irrational, believes communication between those holding different paradigms is impossible, and denies reality.

The Ashtray is a potpourri of Morris's encounters with other scholars. Morris appeals to scholars who affirm his general position, such as Saul Kripke and Steven Weinberg. He enters into dialogue with Stanley Cavell, Noam Chomsky, Hilary Putnam, among others, attempting to understand their reading of Kuhn. One quickly notices that Morris is extremely selective. There is not a hint of recent work by Hans-Jörg Rheinberger or pragmatic thinkers such as Joseph Rouse, Richard Rorty, or Philip Kitcher. In a way, Morris is stuck in the past, attempting, it seems, to resurrect the arguments of the day when he was a graduate student. He is also wedded to an extremely one-sided reading of Kuhn. Kuhn clearly does not deny reality. Puzzle-solving would make no sense if there were not a reality that pushes back. And Kuhn does, in fact, hold to a notion of truth. In his Rothschild lecture (Nov. 19, 1991), Kuhn states:

> [If] the notion of truth has a role to play in scientific development, which I shall … argue that it does, then truth cannot be anything quite like correspondence to reality. (*The Trouble with the Historical Philosophy of Science* [Harvard University Press, 1992], p. 14)

If Morris's reading of Kuhn's *SSR* (a "postmodern bible," p. 20) is indeed accurate—namely that it leads to relativism and a denial of reality—then this could raise a pressing issue for evangelical Christians. As the philosopher James K. A. Smith expresses it in his book *Who's Afraid of Relativism?* (Baker Academic, 2014):

> If all our knowledge is contingent, social, dependent, and relative, then isn't God contingent, a product of our creative impulses … Doesn't Christian faith require that our claims about God "correspond" to the reality of God? (p. 101) [Smith denies that it does, in the sense of a correspondence theory of truth.]

For anyone wanting to relive some of the philosophical arguments from the recent past, see how one's life work could be evaluated, judged, even sabotaged, by a succeeding generation, read this book. *The Ashtray* does provide a challenge. Clearly a naïve realism is no longer viable, but what should take its place? We need, it seems, a richer and more expansive view of truth that encompasses the notion of "factual truth" so dear to the natural sciences, but which is much broader in scope and includes understanding truth as *being* true, as a way of life. Kuhn was aware of that, as he clarifies in *The Road Since Structure* (University of Chicago Press, 2000), "I wasn't saying that I want to know what is true; I was saying I want to know what it is to *be* true. And that's not something that one gets from physics" (p. 278).

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Science and Religion

A RECKLESS GOD? Currents and Challenges in the Christian Conversation with Science by Roland Ashby, Chris Mulherin, John Pilbrow, and Stephen Ames, eds. Eugene, OR: Wipf & Stock, 2019. 338 pages. Paperback; $37.00. ISBN: 9781532687389.

How do Christians in science around the world think about science and faith? What issues do they find important and why? What strategies do they use to address those issues? How do regional and local perspectives help shape the conversation? *A Reckless God? Currents and Challenges in the Christian Conversation with Science* edited by Roland Ashby, Chris Mulherin, John Pilbrow, and Stephen Ames does not seek to answer these questions—at least not for the entire world. Instead, it seeks to provide a window into the science-faith conversation that has been taking place through the Institute for the Study of Christianity in an Age of Science and Technology (ISCAST), the main organization for Christians in the sciences in Australia. Indeed, it is the first book in the ISCAST Nexus series, published in Australia by Morning Star Publishing—a series which at present also includes Mark Worthing's *Unlikely Allies: Monotheism and the Rise of Science* (Morning Star, 2019).

In between Jennifer Wiseman's foreword and Rodney Holder's reflective afterward, *A Reckless God?* consists of a collection of 67 pithy essays, interviews, and book reviews written by 35 mostly Australian contributors, some of which have been published in various forms elsewhere and including a high proportion contributed by the editors themselves. The essays are loosely organized into topics that include the historical relationship between Christianity and science, the New Atheism, natural evils, technology and creation care, psychology and spirituality, biographical examples, reflections on the prospects and state of the science-Christianity relationship, design and fine-tuning, and evolutionary biology and genetics.

Together, the essays touch on almost all aspects of the contemporary academic science and religion conversation, although some topics are noticeably absent and many others are only touched on tangentially or in passing. The book begins with an essay by Peter Harrison arguing that, contrary to myths of conflict between science and Christianity, the historical record suggests the two mutually reinforced each other. Other themes which form a common backdrop to the essays include the importance of Christian theology as a theoretical underpinning for science and a means of answering questions of meaning and existence which lie outside of science; an openness to God's "reckless" working through evolution as consistent with creational theology and the overall plan of redemption revealed in the scriptures; a willingness to see issues as answerable through a combination of reasoned philosophical discussion and the gospel; and the church's living out the gospel in the world.

Collectively, the essays lay out a convincing and impressive case for the consistency of science's picture of reality and orthodox Christianity. Readers who are open to the viewpoints represented will be both exposed to a substantial body of recent science-faith conversation, and also left with an increased appreciation of the importance of science and technology in the church's mission. They will be encouraged to see science as a means of enriching our understanding of God's character and working; to understand science-informed technology as an opportunity for created co-creators to leverage scientific knowledge in stewardship of the created order; and to delight in science-faith dialogue as an opportunity to better discover how to faithfully live as Christ's disciples in the midst of a secular age.

Despite these impressive achievements, however, the book should not be used haphazardly as a tool to convince either unbelievers or Christians who are apprehensive over nonliteral readings of Genesis. The authors write from a distinctly Anglican background and generally assume that their readers are Christians open to an evolutionary creationist viewpoint. Thus, although some time is spent in carefully arguing for their views against those of the New Atheists, biblical literalists, and the sort of intelligent design arguments put forward by the Discovery Institute, the essayists tend to present their arguments as if to insiders, sometimes creating a seemingly ungracious us-them dynamic.

Several other limitations should be noted. First, the book is written in an informal style and freely invokes Australian public figures and jargon that will be unfamiliar to most North American readers. Second, despite the frequent use of quotations and occasional references to the impressive array of literature that might be cited in support of an idea, *A Reckless God?* lacks any sort of endnotes, footnotes, or index of its own. Third, very little science is explained in depth. Generally, this helps keep the focus on the theological dimensions of the conversation. However, at times it results in a distorted view of the relevant science. Particularly notable instances involve fears of humanity being supplanted by robots, and parapsychology's commendation by a few intellectual luminaries as sufficient reason to render it as a "gift horse," which religion should not dismiss out of hand (p. 153). Finally, the book as a whole could have used much tighter editing. Often there were two very similar essays or a series of essays that repeatedly drove home the same point. Sometimes authors seemed to lose their train of thought, moved from idea to idea without really developing any one of them, trailed off in a barrage of seemingly tangential questions, or allowed a provocative statement to stand without further explanation or development. For example, on page 105, an essay concluded by noting that "we need a genuine, working theology of the computer" without even suggesting how we might go about developing one. On page 112, readers were told that altruistic behavior among hyenas "impinges on our divine mandate to bear the image of God" as if it were self-evident what that might mean.

However, for readers who are willing to look past these weaknesses, the book offers a rich menu of food for thought and, read carefully and perhaps selectively, could serve as an excellent resource for book discussion groups, college classes, and anyone looking to get a sense of the science and religion conversation or seeking to develop a vision of what themes might be fruitfully integrated into the North American evolutionary creationist science and religion dialogue. In this respect, the authors and editors of *A Reckless God?* are to be commended for their willingness to offer these nuggets from the Australian conversation about science and religion to the wider world.

Reviewed by Stephen M. Contakes, Department of Chemistry, Westmont College, Santa Barbara, CA 93108.

Technology

BITWISE: A Life in Code by David Auerbach. New York: Pantheon Books, 2018. 304 pages. Paperback; $16.95. ISBN: 9781101972144.

From its subtitle, one might expect this book to be an autobiography of its author, David Auerbach. It actually includes some of that, but also quite a bit more. The author devotes over half the book to musings concerning the intersection between the humanities and technology. As he says about himself,

> I have kept my feet in multiple social environs simultaneously, most often through a combination of humanities and technology work … The exactitude of computer science provided me with useful checks on linguistic hot air. Humanistic fancy, however, enabled me to figure out what I was doing in this technocratic labyrinth, and to ask myself why I was doing it and where it was going. (pp. 80–81)

As a student, Auerbach's studies included literature and philosophy along with computer science. Professionally, he worked as a software engineer at Microsoft and Google when he was in his twenties, and is currently a writer on technology for a number of publications including *Slate* and, most recently, *Tablet*.

About two-thirds of the way through the book, Auerbach discusses the tension that led to this change in career focus. While working at Google, he became increasingly aware of the difference between a web page as data to be analyzed (the focus of his work at Google) and the *meaning* of that page. He further wrote,

> I was also distressed by the disconnect I felt between my work and reality. The god's-eye view of the world's data had numbed my relations to the world … Even in 2008 there was an increasing sense that we, the engineers, were in a significant way other from the people who used our work. (p. 194)

The author devotes several chapters to developing the key idea behind many of his musings: the contrast between discrete encoding of data (which computers manipulate as numbers), on the one hand, and meaningful descriptions, on the other. He illustrates this contrast by encodings for personality types (e.g., Myers-Briggs), attributes such as gender (57 different options in Facebook as of the time of writing), and role-playing game character attributes. He devotes most of one chapter to an extended discussion of the evolution of the encodings for disorders in the *Diagnostic and Statistical Manual of Mental Disorders (DSM)* in its third, fourth, and fifth editions. (Both the author's parents were psychiatrists, and he became familiar with this system at an early age.)

In the last chapter, Auerbach discusses factors contributing to the drive for discrete encodings:

> The categorization and taxonomizing of human beings was not itself a new trend … the emergence of mass computation in the latter part of the twentieth century enabled large-scale, centralized classification of *individuals* … driven by national defense and advertising. (p. 225)

He takes agencies like the NSA, CIA, and TSA to task for using what he calls a "vacuum cleaner" approach to collecting data while being unable to analyze it properly (p. 226). He cites Facebook as the "centralization point for the *collection* of personal information in order to target individual consumers" (p. 229). He lists 98 axes along which Facebook can segment data; these are sometimes based on information voluntarily posted by users and others based on "information obtained from third-party sources such as car registrations, residential information, and corporate information" (p. 232).

Along the way, Auerbach muses about other matters as well. For example, in the chapter titled "Programming My Child," Auerbach begins by saying, "A few years after leaving Google, I started another long-term engineering project which is still ongoing" (p. 199). He continues by describing his daughter's newly learned skills as "upgrades" and bodily growth as "chassis replacement." This serves as a precursor to musings on similarities between individual humans and network systems such as Google and Facebook. A key characteristic of such systems is that, like persons, while individual algorithms can be replaced, the system as a whole can never be reset once it is started.

For the *PSCF* reader who is concerned about how personal data is increasingly being collected and analyzed by organizations such as Google and Facebook, this book is an interesting and perhaps frightening exploration, written by a person who has been inside one of them. In this reviewer's opinion, though, it is marred by what seems to me to be overly long and sometimes irrelevant digressions.

Reviewed by Russell C. Bjork, Professor of Computer Science, Gordon College, Wenham, MA 01984.

Transhumanism

TRANSHUMANISM AND THE IMAGE OF GOD: Today's Technology and the Future of Christian Discipleship by Jacob Shatzer. Downers Grove, IL: InterVarsity Press, 2019. 192 pages. Paperback; $22.00. ISBN: 9780830852505.

Most people have thought about how they would like to change themselves—get more sleep, read more, eat healthier, learn a new programming language, or master combinatorial proofs. A growing number of people have radical ideas about improvement: grow a tail; replace their eyes with optics that have zoom capabilities and can capture the infrared and ultraviolet spectrums in addition to what humans normally see; integrate memory chips and internet connectivity directly with their brain; or copy/transfer their mind to a computer or android body.

The book *Transhumanism and the Image of God* examines these more extreme ideas about human improvement. The author, Jacob Shatzer, is a theology professor at Union University in Tennessee. Shatzer's footnotes provide a rich collection of other documents that the interested reader can explore. He defines the related notions of "transhuman" and "posthuman" and carefully introduces the main ideas behind these terms—using the words of their proponents. He also provides the reader with ideas to help consider these topics from a biblical perspective. Here are some brief definitions:

> Posthumanism argues that there is a next stage in human evolution. In this stage, humans will become posthuman because of our interaction with and connection to technology. Transhumanism, on the other hand, promotes values that contribute to this change. … In a way, transhumanism provides the thinking and method for moving toward posthumanism. … Transhumanism is the process, posthumanism the goal. They share a common value system … (pp. 12, 16)

The first half of the book explores, in some depth, the major components of the transhumanist vision. After a chapter that sets forth the basic concepts of transhumanism, there are three chapters that consider "morphological freedom" (using technology to modify and enhance the human body), "augmented reality" (using technology to modify and enhance the human brain or the mind), and "artificial intelligence (AI) and mind uploading" (creating intelligent nonhuman beings and moving the human mind to a different medium).

The second half of the book examines where we are now. Those chapters look at ways in which our current technologies and habits contribute to a willingness to embrace the transhumanist agenda. He also introduces practices that would counter those inclinations.

Two concepts are foundational to the entire book. First, Shatzer asserts that there are two ideas that are essential to all the variants of transhumanism. He summarizes these two ideas in the following sentence:

> If we had to boil transhumanism down to two features, they would be an optimism regarding the possibility of radically altering human nature via technology and belief in a fundamental right of an individual to use technologies for that purpose. (p. 53)

The belief in a fundamental right to use technology to change oneself places the individual at the center of the transhumanist value system. Shatzer presents statements by transhumanists that indicate a responsibility toward others. The following two extracts from the Transhumanist Declaration indicate the direction of that concern:

> Policy making ought to be guided by responsible and inclusive moral vision, taking seriously both opportunities and risks, respecting autonomy and individual rights, and showing solidarity with and concern for the interests and dignity of all people around the globe. We must also consider our moral responsibility towards generations that will exist in the future. (p. 51)

> We favor allowing individuals wide personal choice over how they enable their lives. This includes use of techniques that may be developed to assist memory, concentration, and mental energy; life extension therapies; reproductive choice technologies; cryonics procedures; and many other possible human modification and enhancement technologies. (p. 53)

But Shatzer argues that ultimately "this final statement in the Transhumanist Declaration makes the primary element in decision making clear: individual choice" (p. 53).

The second foundational idea that underlies the book is that tools are not neutral. Referencing Richard R. Gaillardetz, Shatzer says, "Tools aren't neutral; rather, they encourage us and shape us toward certain goals, and they often do so in hidden ways" (p. 8). This is an assertion that a majority of my students disagree with upon first encounter. Here are some of the examples that Shatzer uses to reinforce his claim.

- As we play video games, we perform actions, resulting in learning new skills and reflexes (p. 67).
- "Creating a self in a virtual world can lead one to value certain ways of creating the self in the real world. In this way, virtual worlds induce us to be more open to the values of transhumanism" (p. 68).
- Our use of current weak AI predisposes us to value convenience and ease over human interactions (pp. 106, 147). (As I was reading this page of the book, my Roomba was cleaning the floor in an adjacent room.) If it is easier to have an AI respond to my voice commands, why not extend this to having a robot or android personal assistant? We can avoid the messiness of human interactions by using a technological replacement that never has a bad day and never argues with me.
- People are already sharing much about themselves on social media. It may not be too large a leap to consider creating a "mind file" that may eventually be copied onto a computer, thus creating a replica of oneself (p. 107).
- Social media and virtual worlds appear to be providing us with a richer variety of interpersonal contacts. But the reality is often the opposite—we choose a group of people to interact with who are almost identical to ourselves. We select by age, by interests, by shared views, and by income level. This predisposes us to eventually welcome reality filters: for example, a brain enhancement that could filter undesired objects and people from our perception in the same manner that a spam filter hides unwanted email (pp. 148, 79).
- Quoting Naomi Baron, Shatzer writes, "Computers, and now portable digital devices, coax us to skim rather than read in depth, search rather than traverse continuous prose" (p. 160).
- "The internet has led to shorter attention spans and difficulty processing longer written arguments" (p. 162).
- Spending time on internet-connected devices is a way of selling (cheaply) our attention. The point of social media sites such as Facebook is not to connect us to friends; it is to capture detailed information about ourselves that can be sold to marketers. "What we pay attention to shapes who we are, and our technology offers some very immersive ways to pay attention to who others want us to be, and then it provides us with ways to shape ourselves and present ourselves in that vein" (p. 167).

These changes are already shifting our perceptions of reality in dramatic ways. In a recent conversation, my friend said, "Homosexual used to be a behavior; now it is an identity." The implication is that sexual orientation is a fluid construct that a person chooses and can change at any time. This is in line with the transhumanist value of humans having a fundamental right to shape themselves, often using technology, into whatever form they desire.

How does God fit into this? Shatzer introduces a number of key ideas on how we might apply our understanding of and relationship to God to attitudes and practices promoted by transhumanism. One idea that is foundational is to recall that Christians are no longer the central, autonomous decision makers—they owe allegiance to God. His call on our lives takes precedence. We have a calling to fulfil (pp. 29, 30, 97).

In the second half of the book, Shatzer suggests various ancient practices that help center us in the reality that God has created and that help us form genuine communities. He discusses such practices as storytelling, gardening, homemaking/hospitality, communion and shared meals, and attention to friends.

This book is worth a serious read. I chose to read just one chapter per day in order to have time to reflect on the rich collection of ideas in each chapter. If transhumanism is a topic that is unfamiliar to you, this book is a great place to start building a solid understanding.

Reviewed by Eric Gossett, Department of Mathematics and Computer Science, Bethel University, St. Paul, MN 55112. ∞

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:

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- 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.

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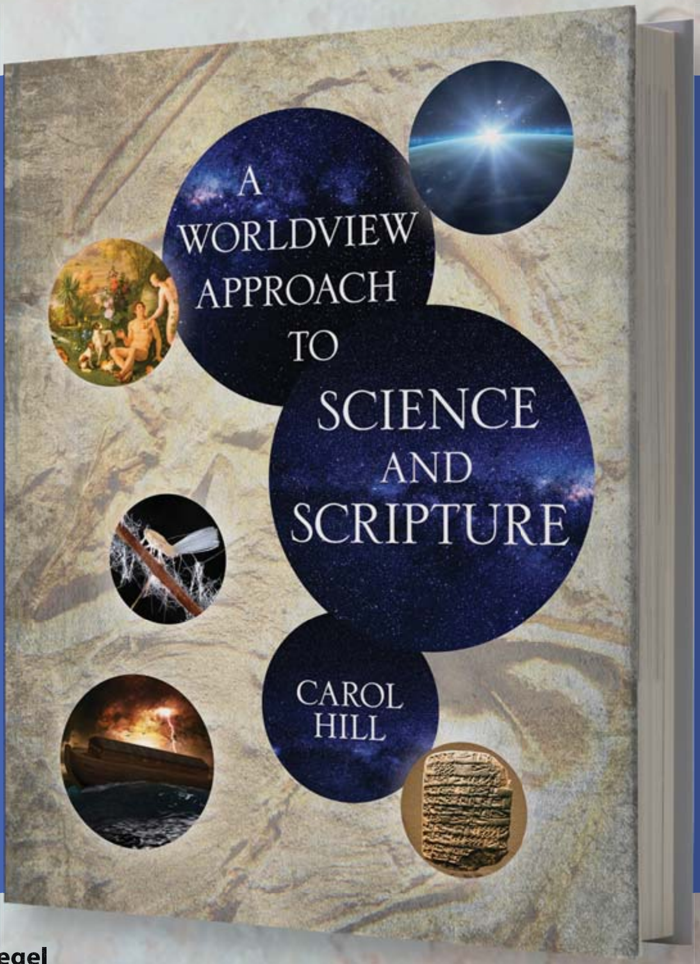

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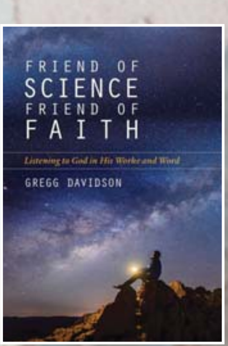

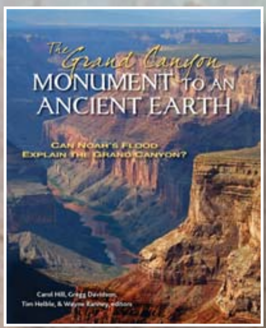

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