PERSPECTIVES on Science and Christian Faith

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"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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Interpreting What We See through the Sciences, Scripture, and *PSCF*

James C. Peterson

Chong Ho Yu, William Whitney, and their team open this issue with a survey of the relationship between scientific and biblical literacy. Seeking truth requires listening carefully to the data in both the sciences and in scripture. Each one requires thoughtful interpretation to understand what is really there. For example, physics and biochemistry are both sciences, yet they offer distinct foci and kinds of description to approach different aspects of one reality.

There are different foci and kinds of description in the Bible as well, to express aspects of one revelation. The disciple John writes about the life of Jesus, telling what he saw and heard and touched (1 John 1:1–3). This is the genre of history. John also reports Jesus using metaphors, such as he (Jesus) is the vine, and his disciples are the branches (John 15:5). That instruction is about their relationship, not gardening. When Jesus tells Nicodemus that he must be born again (John 3), Nicodemus is flummoxed that he is too big to re-enter his mother's womb. Jesus tells Nicodemus not to take him so literally. He is using what Nicodemus knows about physical birth to tell him something about the spirit, of a new start in life. John also writes the book of Revelation that tells of what is to come, in apocalyptic visions of a beast with ten horns and seven heads (13:1) and the ocean turned to blood (16:3).

We see then that one apostle uses different types of writing within the library that we call the Bible. One will miss what John is saying if one insists that everything should be in only one format of history, or metaphor, or apocalyptic vision. So much more, when reading multiple authors of scripture, the reader needs to listen for what a particular text is teaching through the genre the author has chosen. This is crucial in reading the opening chapters of Genesis too. In this issue, S. Joshua Swamidass and Luke Janssen agree substantially on the involved science, but write their essays to address different readings of the literary forms in those chapters. Is the opening of Genesis to be read more like the Revelation of John, or the Gospel of John, or yet some other genre of its own?

Swamidass, a computational biologist, and the three geneticists who peer reviewed his essay (alongside peer review from other relevant disciplines) are all convinced that the genetic evidence is clear that no one couple is the origin of all human DNA. One couple was not, together, the first to have human anatomy. The genetic evidence from multiple concurring angles is that human beings anatomically came from incremental changes over time in a population. They also agree that most of the people alive 10,000 years ago had children who had children who had children, until now the earliest ancestors are genealogically linked to most of the people who are alive today.

Each human being today has so many ancestors that we are all genealogical descendants of particular people in the past. Among them there might even be some particular couples. Swamidass argues, in his article, that God could have called a particular couple in that population of anatomical human beings to be ancestors to everybody alive today. Despite the genetic dispersal and dead ends of various lines of heredity, the people of this generation could all be *genealogically* related to such a couple. Descendants alive today would likely not carry any specific genes from that couple, but there could be a genealogical connection of relationships, parent to child to grandchild to great grandchild ... Swamidass thinks further that such a line could include people who intermarried and migrated quickly and extensively far enough that the genealogical relationship could extend from the inhabitants near the Euphrates River to the aboriginals of Australia and the denizens of southern Argentina—in other words, to all current human beings.

Would such a genealogical connection to one particular couple be theologically important? Romans 5 describes Jesus as the one in whom all human beings

Acknowledgment

can be reconciled with God. Yet there is no claim there that all human beings are genetically or genealogically related to Jesus of Nazareth. Why would it be important that a couple, called Adam and Eve, be genealogically related to all human beings? Is the brokenness of sin passed on by the physical connection of parent to child? It could not be by genetics because people alive today have very few, if any, genes from any one or two persons in the past. Is there something about a genealogical connection of parent to child that passes on actual guilt or something else?

If, in this proposed scenario, that genealogical connection determines one's guilt or character, then what of the people who have *not* been genealogically related to Adam and Eve as that connection may have slowly spread across the world? And why would there be such an inheritance? Jeremiah and Ezekiel emphasize that God holds each generation accountable for its own actions (Jer. 31:29–30; Ezek. 18:1–4). Would it be consistent to affirm then that each human being's relationship with God is established by an ancestor at least 250 generations in the past (following Swamidass's working estimate of say 10,000 years since Adam and Eve, and each generation as about forty years)?

In contrast with Swamidass's effort to make room in what we have learned from genetics for Adam and Eve as a particular couple, Luke Janssen offers a different reading of Adam and Eve. He thinks that the opening chapters of Genesis are to be read more like the call to be born again in John chapter 3 or the dramatic imagery of the book of Revelation. When you read a story of a bone being molded into a woman, a fast-talking snake, a tree with fruit that makes one eternal, and an angel guarding it with a flaming sword, such a story appears to be using symbols to represent something deeper, as Jesus does in much of his teaching and as John does in the book of Revelation. Janssen thinks that the opening chapters of Genesis are a symbolic story, expressing essential truths that God still wants us to hear. As in the thought of the church father Irenaeus, for Janssen, our devastating fall as human beings came from not accepting an offered relationship and calling; that is, it was not from already-present perfection in two particular people.

In the last article of this issue, George Murphy, a physicist and pastor, wants us to see the grand scale of time in which God chooses to enable choices other than the Creator's. God's intentional self-limitation in creation, and later in incarnation, makes possible life that can be received and freely returned by grace to a right relationship with the Creator.

A wide range of book reviews rounds out this issue. There is much to consider. Many thanks to the thoughtful authors. ✯

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

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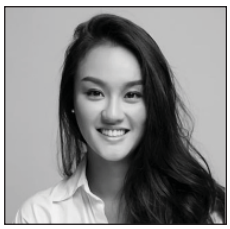
Surveying the Relationship between Views of Scripture and Attitudes toward Science

Chong Ho Yu, William Whitney, Emily Brown, Siyan Gan, and Hyun Seo Lee

Chong Ho Yu

William Whitney

Emily Brown



Siyan Gan

Hyun Seo Lee

The relationship between science and religion has too often been characterized in the United States by heated debates and strong accusations. The public is given a perspective of conflict between these two domains and is swayed to support either science or religion. This study aims to evaluate this relationship based on archival data from the National Opinion Research Center. It was found that participants who viewed the Bible as the Word of God in a literal sense earned lower test scores in objective science tests and were less interested in taking science courses than those who did not hold this view. This is a conflict between a way of interpreting scripture and science, rather than a conflict between Christianity and science per se. Efforts should be devoted to helping Christians develop positive ways to engage science and promote working within scientific fields of inquiry.

Particularly of late, the relationship between science and religion has often led to heated discussions, inflexible belief systems, and strong accusations. The public is given a perspective of conflict between these two disciplines, which often leaves only two options: to support science or to support religion. Media portrayals of science educators such as Bill Nye, and of Christian fundamentalists such as Ken Ham, heighten interest in this topic as well as underlining the concerns of each discipline regarding the other.[1]

Bill Nye[2] and theoretical physicist Lawrence Krauss[3] question whether religious education is at odds with science education since religiosity might lead to an antiscience mentality. They argued that the United States needs more scientists and engineers in this era of globalization, and that religiosity is a stumbling block to science education.

On the other hand, there are Christian apologists who argue that Christianity is compatible with science and that Christian theology can actually inform science in some cases.[4] However, very often the concepts in this type of debate are conflated or not specific enough. In these debates, it is not always clear whether the perceived conflict between Christianity and science is about the tension between faith and science, or between specific doctrines/theology and science, or between certain religious institutions and science. As Vincent Smiles pointed out,

> Faith is not the same as belief. Belief has to do with doctrines and creeds that are particular to individuals and traditions. Faith is a more universal aspect of human experience.[5]

In this sense, the conflict between faith and science is a false dichotomy, since faith does not always rest on scientific evidence. However, belief in certain doctrines and interpretations of scripture, which does result from rational inquiry, could potentially be in conflict with science. Moreover, science could mean different things to different people. The alleged conflict between Christianity and science could mean that certain doctrines are incompatible with certain scientific

theories (e.g., recent creation vs. evolution, young earth theory vs. modern geology). Or, it could also mean that, in a general sense, religious attitudes either hinder people from thinking reflectively and logically or discourage people from studying science.

Often the assertions on both sides of the Christianity vs. science debate are theoretical, and the debate could benefit from more empirical evidence that demonstrates how beliefs shape attitudes toward science. Empirical evidence is necessary and helpful when opinions begin to lead the debate. Hence, in this study, multiple statistical methods are utilized to examine multiple indicators related to biblical interpretation and attitudes toward science. Data is sourced from the independent research organization National Opinion Research Center (NORC) at the University of Chicago (UC). NORC and the UC jointly staff seven collaborative Academic Research Centers located at UC. The mission of NORC is to provide researchers with reliable data and rigorous analysis for decision support in the areas of economics, education, global development, health, and public affairs.[6]

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We selected religion-related variables from NORC that represent different aspects of Christianity: belief in interpretations of the Bible, faith (confidence in God, born-again experience, belief in afterlife), religious institutions (strength of religious affiliation, confidence in organized religion), religious activities (convincing others to accept Jesus), and self-perceptions of religiosity and spirituality (considerations of the self as religious or considerations of the self as a spiritual person). Similarly, variables reflecting different aspects of science are chosen from the NORC database; these include "Having overall interest in science" (affective), "Having an objective knowledge of science" (cognitive), and "Having taken science courses" (behavioral). Our theoretical conjecture is that not every aspect of religion is necessarily at odds with every aspect of science. We believe it is more likely that a literal interpretation of the Bible conflicts with the affective, cognitive, and behavioral aspects of science.

Conflicts between science and Christianity often arise when scientific conclusions are seen to be at odds with "prevailing modes of biblical interpretation," as Alister McGrath notes.[7] Some notable examples here are Copernicus (when proponents of a literal reading of scripture argued for a geocentric view of the solar system) and Darwin (when proponents of a literal view of scripture argued that humanity was created suddenly as full human beings).

Prior Studies on the Relationship between Religion, Intelligence, and Science

International assessments have shown that the science literacy in the United States is significantly lower than that in other developed countries/regions, specifically in West European and East Asian nations.[8] Researchers have begun to investigate the reasons why this is the case and how religion might play a part. Several studies are pertinent to the discussion here; they have specifically explored the relationship between low scientific literacy/science education and things such as religion, intelligence, and cognitive style. Darren Sherkat found that, in the United States, religious influence has contributed to a low level of scientific literacy.[9] He explained that this contribution is more significant than gender, race, and income. Jerry Coyne stated that religion is the primary culprit that keeps evolution from being

accepted by the majority of Americans.[10] He claimed that resistance to evolution becomes resistance to science as a whole, and that this resistance contributes to the low rate of scientific literacy in the United States.

Further, some studies indicate that there is a negative association between religiosity in general (not specific to Christianity) and intelligence in terms of standardized IQ tests.[11] The causal mechanism in this association is open to debate; thus, it is uncertain which of the mentioned factors is a cause (i.e., an independent variable), which factor is an effect (i.e., a dependent variable), and whether the indicated relationship is bidirectional. Indeed, conflicting explanations underlie this effect. One of the most well-established arguments is that people who lack critical thinking skills tend to depend more on belief systems which offer final answers, while individuals who are intelligent gravitate toward more rational systems.[12] Specifically, based on experimental data, Shenhav, Rand, and Greene suggest that one's belief may be influenced by one's cognitive style. People who think intuitively are also likely to believe in God, but people who think reflectively tend to be less religious and tend to have higher cognitive abilities (IQ). In this example, cognitive style and abilities are independent variables.[13] In short, people with high IQs prefer employing rational and empirical approaches to understanding and guiding their lives rather than employing supernatural and intuitive thinking.[14]

According to one longitudinal analysis on changes of religiosity, those who are intelligent gradually turn less religious over time.[15] As a result, these people are less likely to adopt religious dogmas that are inconsistent, even in the presence of a predominantly religious society. This approach advocates that religious beliefs are "irrational, not anchored in science, not testable, and therefore, unappealing to intelligent people who know better."[16] Others approach the issue with an evolutionary perspective that views scientific knowledge as the novel capacity to adapt and survive, and religious belief as an evolutionary asset in ancient times.[17] These evolutionarily novel preferences may refer to liberalism and atheism. This claim posits that religiosity and intelligence may be functionally equivalent, as some of the functions of religion—such as compensatory control, self-regulation, self-enhancement, and secure attachment—can also be conferred by heightened intelligence.

Another intriguing argument points out the secluded tendencies of some religious groups; these tendencies may hinder religious individuals from obtaining higher education, particularly analytic and purely scientific knowledge that works against these individuals' religious values.[18] For example, some conservative Christians tend to disdain secular education, and thus maintain homogeneous social networks.[19] Interestingly, lower levels of IQ have been strongly associated with higher levels of fundamentalism,[20] and information-processing ability—one of the components of intelligence—has been inversely related to literal interpretations of sectarianism of a particular religious group, as well as with literal interpretations of religious scriptures.[21] Membership in a sectarian religious denomination or fundamentalist belief can result in avoidance of or opposition to the scientific findings that are inconsistent with one's religious dogmas (e.g., embryology based on evolution, geology based on radiometric dating). In this sense, religious individuals may be less likely to be interested in or have lower access to educational attainment; this outcome may, in turn, result in achievement of lower scores on related subjects.

Last, but not least, a recent study indicates that people who subscribe to Judeo-Christian traditions are less concerned about environmental protection when compared with their nonreligious peers.[22] It would be easy for religious people to take a defensive stance on this subject. However, exploratory and data-driven research is necessary in order to achieve open discussion of this topic and to determine the extent to which religion influences scientific knowledge and literacy. If research indicates that religion hinders the progress of scientific literacy, then it is time for a change in perspective on the parts of religious individuals. Using exploratory analysis and letting the data speak for themselves would allow researchers to reflect openly on the changes that are necessary within religious institutions.

Method

Data source and variables

The data for this project were sourced from the General Social Survey (GSS) administered by NORC. Since 1972, GSS has been used to research attitudes and behaviors of the US population regarding social matters.[23] The original sample size was 2,538, but

after excluding missing values, the effective sample size was reduced to 1,238. NORC collected data via the web, mobile devices, telephone, mail, and in-person interviews. To reduce sampling bias, NORC recruited participants from numerous populations and subpopulations. To achieve high response rates which would enhance the quality of the data, NORC used differing data-collection methods.[24] Responses to selected survey questions in 2014 relating to education, religiosity, and science were extracted (table 1). The continuous variables are on a four-point Likert scale, and thus no extreme scores affected the analysis. Other variables, such as the scores of scientific knowledge, have a wider range of responses, but no outliers were detected.

Table 1. Dependent and Independent Variables

Variable	Original scale	Converted scale
Dependent variables		
Overall interest in science	Ordinal	Composite and continuous
Scientific knowledge	Ordinal	Composite and continuous
Taken science courses	Mixed	Composite and continuous
Independent variables		
Belief	Nominal	Collapsed to three categories: None, Non-Christian religion, Christian
Strength of religious affiliation	Ordinal	Continuous
Belief in life after death	Ordinal	Continuous
Feelings about the Bible	Nominal	
Confidence in the existence of God	Ordinal	Continuous
Ever had a "born again" experience	Ordinal	Dichotomous (1 or 0)
Tried to convince others to accept Jesus	Ordinal	Dichotomous (1 or 0)
Consider myself a religious person	Ordinal	Continuous
Consider myself a spiritual person	Ordinal	Continuous
Confidence in organized religion	Ordinal	Continuous

It is important to note that there are multiple variables in the NORC data set that can indicate how fundamentalist a participant is. They include "How fundamentalist are you currently?" and "Christian denomination." Of the options for variables, this research team selected the variable "Feelings about the Bible." The reasons for this were as follows. First, "How fundamentalist are you currently?" is of a highly subjective nature. Without a given context, the meaning of this question is subjective. Second, "Christian denomination" might not be a strong indicator of one's fundamentalism. At first glance, the larger denominational beliefs could be used to generalize the fundamentalism of its members. However, even within a single denomination, there can be a variety of beliefs regarding prevalent issues and stark differences in the approaches to those issues. For example, some Christians who attend a conservative church are quite open minded. Someone may belong to a fundamentalist church simply because of the influence of a spouse or other family members.

In contrast, the variable, "Feelings about the Bible" can provide a direct indicator of aspects of one's theology. Excluding responses of "Don't know," "No answer," and "Other," there are three remaining options in the statement as follows: (1) The Bible is the actual word of God and is to be taken literally, word for word; (2) The Bible is the inspired word of God, but not everything in it should be taken literally, word for word; and (3) The Bible is an ancient book of fables, legends, history, and moral precepts recorded by men. The first position exemplifies a fundamentalist interpretation.

For modeling efficiency, most variables were converted, and some were combined. For example, "Overall interest in science" is a composite variable derived from these variables: "Interest in new scientific discoveries," "Interest in technologies," "Interest in medical discoveries," and "Interest in space exploration." The original scale is ordinal in nature: "Very interested," "Moderately interested," and "Not at all interested." For data reduction, numbers "2," "1," and "0" were mapped into these three response categories, respectively, after which the average of the three variables was transformed into a new variable named, "Overall interest in science."

"Scientific knowledge" is also a composite variable. It was derived from the average of the scores of the following thirteen questions and statements:

1. The center of the earth is very hot.
2. All radioactivity is man-made.
3. Father gene decides sex of baby.
4. Lasers work by focusing sound waves.
5. Electrons are smaller than atoms.

6. Antibiotics kill viruses as well as bacteria.
7. The universe began with a huge explosion.
8. The continents have been moving.
9. The earth goes around the sun.
10. How long does it take the earth to go around the sun?
11. A doctor tells a couple that their genetic makeup means that they have a one in four chance of having a child with an inherited illness. Does this mean that if their first child has the illness, the next three will not have the illness?
12. Does this mean that each of the couple's children will have the same risk of suffering from the illness?
13. Two scientists want to know if a certain drug is effective against developing high blood pressure. The first scientist wants to give the drug to one thousand people with high blood pressure and to see how many of them experience lower levels of blood pressure. The second scientist wants to give the drug to five hundred people with high blood pressure, to not give the drug to another five hundred people with high blood pressure, and to see how many people in both groups experience lower levels of blood pressure. Which is the better way to test this drug? Why?

Similarly, "Have taken science courses" is also a composite score. This score is derived from three questions relating to science classes; the questions yield dichotomous (i.e., 1 = "yes"; 0 = "no") answers: "Have you ever taken a high school physics course?" "Have you ever taken a high school chemistry course?" and "Have you ever taken a high school biology course?"

Another question yields continuous-scaled data: "Number of college-level science courses taken." The distribution of the last variable was extremely skewed, and all transformation methods failed to normalize this variable. Furthermore, its measurement scale was incompatible with the first three questions. As a remedy, this variable was converted to a dichotomous scale (i.e., 1 = "yes"; 0 = "never"). When the composite score was created, the weight of the first three variables became "1," whereas the weight of the last one became "2." The rationale for this was that college-level science courses are more challenging than high-school-level science courses.

In sum, "Overall interest in science," "Scientific knowledge," "Highest degree," and "Have taken science courses" were chosen for this study because they represented three different domains: how much participants like science (i.e., subjective interest), what participants know about science (i.e., objective knowledge), and what participants do about science (i.e., behavior: Have taken science classes).

There are many religion-related variables in the survey. However, some are too specific (e.g., "Do you agree that the Pope is infallible on matters of faith and morals?" "… that anti-religious materials should be banned?" "… that professional athletes should give thanks to God?" and "… that religious extremists should be allowed to hold public meetings to express views?"). These questions are not highly relevant to the objective of this study, and therefore only general items such as "Feelings about the Bible," "Confidence in the existence of God," and "Strength of religious affiliation" were included.

Data analysis

When a single statistical procedure examines a pair composed of a dependent variable and an independent variable only, there is a risk that the finding is nothing more than a capitalization on chance. As a remedy to this problem, multiple indicators were extracted from the database (as described above), and two different methods were used for triangulation. When a sample size is very large, as it was in this study (i.e., n = 1,238), conventional statistical procedures are inappropriate; the reason is that over-powered tests tend to yield significant results regardless of data patterns. On the other hand, authentic significant variables might be undetected by conventional procedures, due to multicollinearity among independent variables. Furthermore, the variable, "Christian denomination," has many missing values, because only those attending church provided answers to this question.

To rectify these shortcomings, the bootstrap-forest approach was used. It is capable of constructing a predictive model based on the merged predictive values from many exploratory decision-tree models, by randomly selecting independent variables and observations. Variable selection by means of shuffling the variables could address the issue of multicollinearity, whereas subsetting the sample by resampling could counteract inflating statistical

power. In addition, this approach is immune against outliers and missing values.

In each bootstrap forest, both the number of splits and the sum of squares (SS) were used to determine which predictor should be retained. One of the features of the bootstrap forest is its capability of avoiding model complexity; as such, the simplest explanation tends to be adopted. After bootstrap forests had identified significant predictors, decision trees and Mosaic plots were utilized to illustrate the relationships between the dependent and independent variables.

Last, to comprehend the "big picture" by data reduction, the partial least squares (PLS) approach was employed. PLS aims to extract several latent factors and responses from several dependent and independent variables, respectively. The philosophy behind PLS is vastly different from variable selection methods, such as the bootstrap forest. In PLS, not every "redundant" variable is excluded; rather, they are retained and combined to form latent factors. It is believed that a construct should be an open concept, triangulated by multiple indicators, rather than by a single measure.[25] In this sense, redundancy enhances the reliability of measurement, resulting in a better model.

Although PLS modeling can accept both categorical and continuous data, every level of a categorical variable in PLS is treated as a factor, resulting in a more complicated model. Hence, in PLS, the variable "Belief in God" is converted into a numeric value. In the conversion process, a reference point was chosen for coding. For example, "Belief in God" was coded as "1" and all the rest were coded as "0." This involved mapping "1" to "Yes" and "0" to "No." It is important to point out that this coding scheme does not imply any value judgment.

The PLS analysis is composed of three stages. First, all potential predictors were included in the first PLS, which performed the initial screening; this was done to determine the optimal number of principal components. At the same time, the most significant predictors were selected, based on the variable importance plot (VIP) scores. A VIP score is a measure of a variable's predictive power; it is determined by taking all dependent and independent variables into account. If both the coefficient and the VIP score of a predictor are small, then this predictor is removed from the model. The cut-off for VIP is 0.8.[26] The next step involves the running of another PLS, using the remaining predictors. The interrelationships among these variables were examined in the loading plot in order to determine which variable belonged to which principal component. Last, a principal component regression was run in order to determine whether the reduced set of religious variables could well predict the criterion variables.

Results

Demographics

The demographic information of this sample is as follows: the average age of the respondents is 48.98 years with a standard deviation of 17.39. The age range is between 18 and 89. The sample is composed of 544 females (43.94%) and 694 males (56.05%). Among these participants, 922 are White (74.48%); 179, Black (14.46%); and the rest (137), self-identified as "other" (11.07%—NORC did not specify Hispanics, Asians, and Native Americans). The education level of the majority (800) is high school or lower (64.62%). Three hundred and two participants are classified as "undergraduate" (24.39%), and 131 had earned graduate or professional degrees, including Master's degree, PhD, MD, and JD (10.58%). Only five respondents reported "other" (0.40%). The denomination information is presented in table 2.

Table 2. Christian Denomination of NORC Participants

Denomination	N	(%)
Baptist	188	15.19
Episcopal	24	1.94
Lutheran	38	3.07
Methodist	70	5.65
Presbyterian	24	1.94
No denomination	151	12.20
Other	124	10.02
No report	619	50.00

Overall interest in science

Table 3 shows the result of a bootstrap forest using "Overall interest in science and technology" as a dependent variable. According to the criteria of the number of splits and the SS, the most important predictor was "Feelings about the Bible." As indicated by the bars in table 3, there was a sharp drop off in SS, which occurred after the first variable. In this situation the decision based on a sharp drop is

analogous to the decision of keeping the number of constructs in factor analysis using a scree plot, as well as the decision of keeping the number of clusters in hierarchical cluster analysis using a dendrogram. Although this operates on subjective decisions, prior research based on this type of visual pattern recognition yielded fruitful and valid results.[27] Nonetheless, the authors realize the limitation that disagreement might exist between different researchers given the same data.

The decision tree in figure 1 illustrates the relationship between "Overall interest in science" and "Feelings about the Bible." If participants perceived the Bible as the literal Word of God, their mean score for "Overall interest in science" was 1.1; this value was significantly lower than that for those who accepted the Bible as inspired word or as fables (m = 1.32). It is important to point out that lumping the categories, "Scripture as inspired word" and "Scripture as a book of fables," was not a decision made by the authors. Rather, the recursive partition tree algorithm detected a common response pattern of these two groups, with relation to "Overall interest in science" and a distinct response pattern of the group "Word of God." The recursive partition tree, as the name implies, uses pattern recognition to partition data.

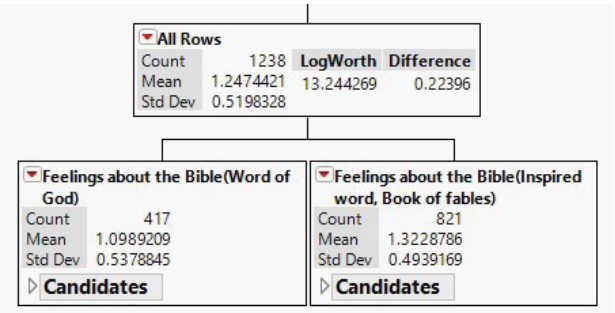

Figure 1. Decision Tree of Overall Interest in Science and Technology

Scientific knowledge

Another bootstrap forest was created using "scientific knowledge" as the outcome measure (table 4). Once again, "Feelings about the Bible" stood out as the most important predictor, based on the number of splits and on the SS. Furthermore, there was a sharp drop in SS, between the top variable and the rest of the variables.

The decision tree in figure 2 indicates that participants with beliefs in the inerrancy of the Bible were more likely to have a lower mean value in scientific knowledge, when compared with those who viewed the Bible as a set of God-inspired words or as a book of fables.

Table 3. Bootstrap Forest of Overall Interest in Science and Technology

Term	Number of Splits	Sum of Squares (SS)
Feelings about the Bible	190	3.87135046
Beliefs	132	2.67426894
Confidence in the existence of God	178	2.22923067
Strength of religious affiliation	195	1.67001140
Consider myself a spiritual person	214	1.39284729
Consider myself a religious person	211	1.30786922
Confidence in organized religion	191	1.30775836
Belief in life after death	159	0.82028824
Tried to convince others to accept Jesus	140	0.65619992
Ever had a "born again" experience	131	0.39167255

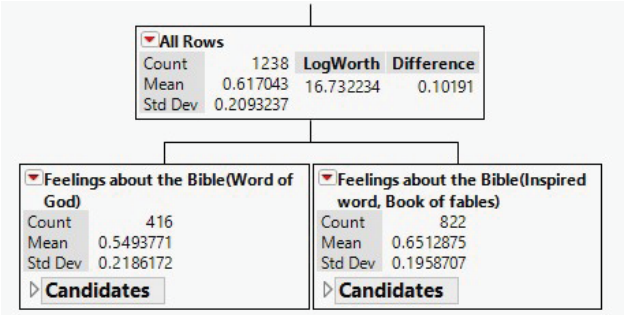

Figure 2. Decision Tree of Scientific Knowledge

This interesting phenomenon necessitates further scrutiny. Figure 3 is a Mosaic plot indicating the portion of different answers to "The earth goes around the sun" by "Feelings about the Bible." As shown in figure 3, more than 10% of respondents associated with a misbelief that "the sun goes around earth." Surprisingly, nearly one fifth of respondents who viewed the Bible as inspired words reported the incorrect answer, which is higher than what is expected. Nevertheless, a substantially larger percent of people who believe the Bible is literally the Word of God asserted that the sun goes around the earth (27.16%) when compared with those who view scripture as fables (13.00%) or inspired word (18.16%). Both a Chi-square test (X^2 = 38.66, p < .0001) and a Fisher's exact test (p < .0001) indicated that this discrepancy between groups of different perspectives toward science was significant. Consequently, the error rate was highest among respondents with the belief in biblical inerrancy and lowest among those with the belief in the fictional nature of the Bible.

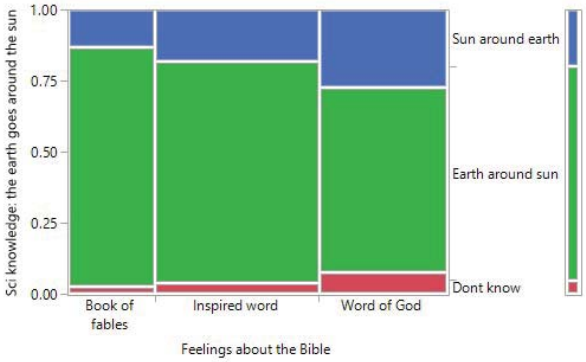

Figure 3. Mosaic Plot of "The earth goes around the sun" and "Feelings about the Bible"

A similar pattern could be observed in the question "How long does it take the earth to go around the sun?" (fig. 4). Only 62.84% of participants who perceived the Bible as the literal Word of God could correctly answer the question, compared with those viewing the Bible as fables (76.50%) or as inspired word (71.25%). The top area of figure 4 shows the percentage of the right answer (one year) by attitudes toward the Bible. A Chi-square test indicated that this difference was significant (X^2 = 15.33, p = 0.0178), and a Fisher's exact test provided further support

Table 4. Bootstrap Forest of Scientific Knowledge

Term	Number of Splits	Sum of Squares (SS)	
Feelings about the Bible	312	1.15961425	
Confidence in the existence of God	243	0.58560112	
Consider myself a religious person	311	0.35657313	
Consider myself a spiritual person	290	0.29113425	
Confidence in organized religion	287	0.26364798	
Strength of religious affiliation	270	0.22868984	
Beliefs	183	0.21576889	
Ever had a "born again" experience	181	0.16698924	
Tried to convince others to accept Jesus	222	0.12133396	
Belief in life after death	200	0.10656636	

for this conclusion (p = 0.176). These two items (i.e., "The earth goes around the sun" and "How long does it take the sun to go around the earth?") were singled out for further examination, because—relative to more difficult questions (e.g., "Father gene decides sex of baby," "The continents have been moving")—these two items are generally considered as common knowledge. As such, it is alarming that a large percentage of participants failed to answer these questions correctly.

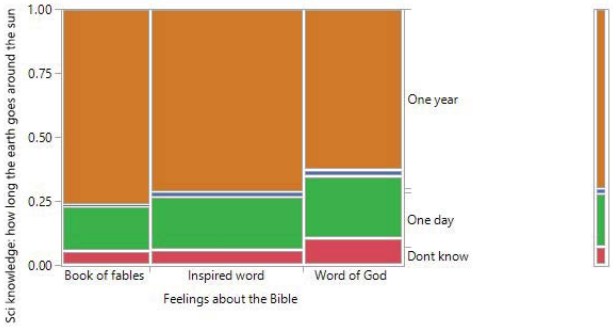

Figure 4. Mosaic Plot of "How long does it take the earth to go around the sun?" and "Feelings about the Bible"

Taken science courses

For the dependent variable "Taken science courses," the bootstrap forest (table 5) shows that "Feelings about the Bible" is again the greatest predictor.

The decision tree in figure 5 shows that if the participants believed that the Bible was the Word of God, then the expected score of "Taken science courses" was 1.897. If the Bible was taken as either fables or inspired word, the expected score was 2.699.

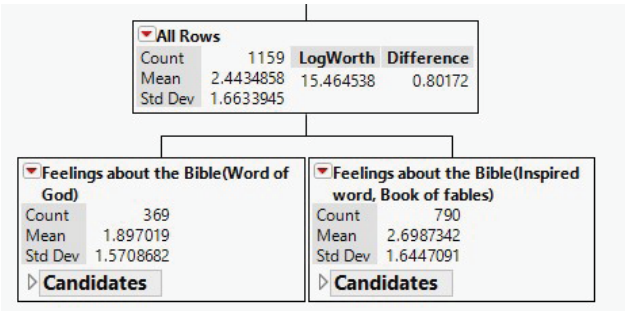

Figure 5. Decision Tree of "Taken science courses"

Partial least squares

Although the preceding bootstrap approach consistently indicates that one's perception of scripture is the most important predictor of all dependent measures, this indication cannot be extended to suggest that other religion-related variables have no contribution to measured outcomes. In a similar vein to the bootstrapping approach, a preliminary partial least squares (PLS) analysis was employed to identify the most powerful predictors. However, unlike the method in the bootstrapping approach, PLS takes

Table 5. Bootstrap Forest of Taken Science Courses

Term	Number of Splits	Sum of Squares (SS)	
Feelings about the Bible	242	54.0479782	
Confidence in the existence of God	215	21.8126617	
Consider myself a spiritual person	234	17.1031395	
Consider myself a religious person	232	15.8546498	
Beliefs	163	14.9132990	
Strength of religious affiliation	224	14.4932626	
Confidence in organized religion	212	12.2354652	
Tried to convince others to accept Jesus	176	8.54974659	
Belief in life after death	152	6.99398268	
Ever had a "born again" experience	153	6.28336062	

all three dependent measures into account simultaneously. Table 6 indicates that five variables might be retained, based on the criterion of VIP score > 0.8.

Table 6. VIP Scores of All Potential Predictors

Variables	VIP
Feelings about the Bible	**1.9262**
Consider myself a spiritual person	**1.1584**
Confidence in the existence of God	**1.1561**
Beliefs	**0.8775**
Strength of religious affiliation	**0.8411**
Belief in life after death	0.7491
Consider myself a religious person	0.6935
Confidence in organized religion	0.6391
Tried to convince others to accept Jesus	0.6137
Ever had a "born again" experience	0.5539

Note: Variables with high variable importance are bolded

In figure 6, the X-Y score plots suggest a two-factor solution. When a one-factor solution is forced into the model, the observations show no pattern, as is indicated in the first X-Y plot. An ellipse is formed in a two-factor solution, as shown in the second graph. However, when the solution goes beyond two factors, the ellipse disappears.

A second PLS model was run, using the five variables with the highest VIP scores. Figure 7 shows the clustering pattern of the dependent variables (Ys) whereas figure 8 presents the grouping pattern of the independent variables (Xs). Apparently, the dependent variables "Scientific knowledge" and "Taken science courses" go together as a group, whereas "Overall interest in science and technology" is a stand-alone outcome. The loading plot of Xs indicates an interesting clustering pattern (fig. 8). "Feelings about the Bible" appears to be a distinct

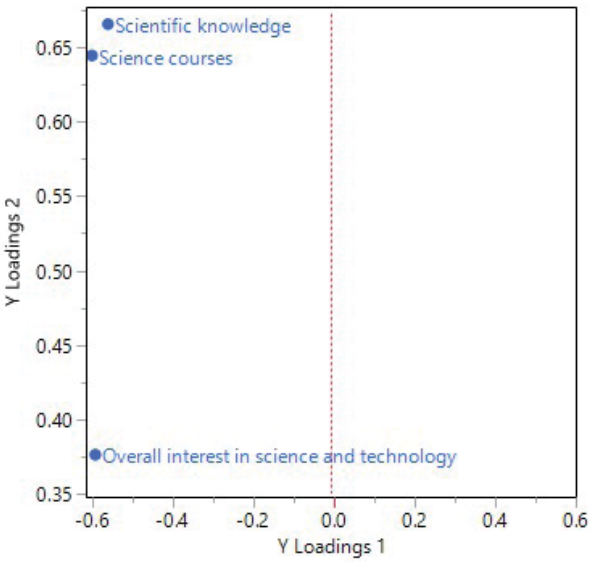

Figure 7. Loading Plot of Dependent Variables

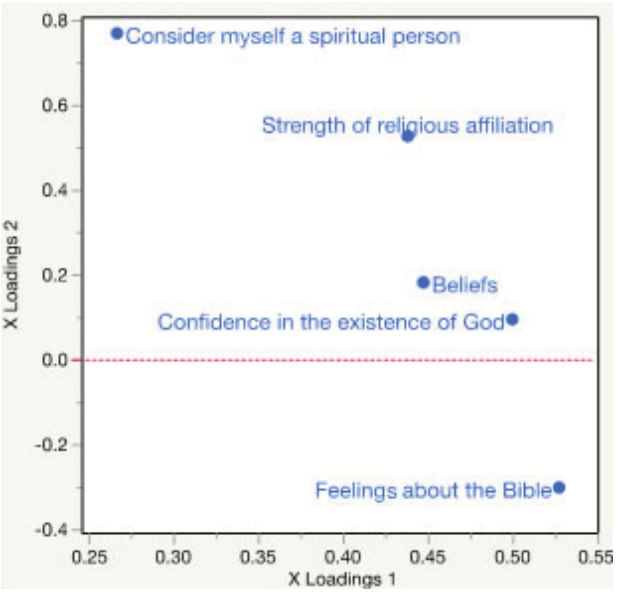

Figure 8. Loading Plot of Independent Variables

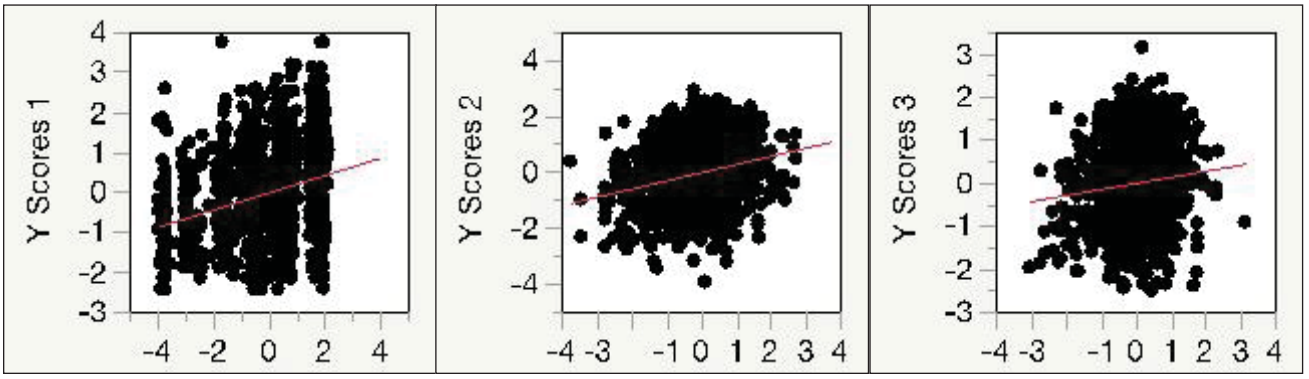

Figure 6. X-Y Score Plots

independent variable, whereas all the other variables can be lumped together as one factor. This result is in alignment with that of the bootstrap analysis, in which "Feelings about the Bible," by itself, was a substantial factor.

In the light of these findings, a new component consisting of "Science knowledge" and "Taken science courses" was created, while five religion-related variables were loaded onto another element named "Religious component." A regression analysis indicated that the religious segment was a significant predictor of science knowledge and courses with a negative association (b = -0.11, p = 0.0048). The same inverse relationship is also observed between "Overall interest in science/technology" and "Religious component" (b = -0.09, p = 0.0001).

Conclusion

Discussion

This study demonstrates a strong relationship between "Feelings about the Bible," "Scientific knowledge," and "Taken science courses." Multiple data analyses revealed that "Feelings about the Bible" alone is a strong predictor of all variables regarding attitudes toward science. Results of the bootstrap-forest approach indicate that this variable trumps all other religion-related variables, while results of the PLS approach indicate that "Feelings about the Bible" is also a stand-alone predictor. While other religion-related variables (i.e., "I consider myself a religious person" and "Strength of religious affiliation") are also predictors of one's level of scientific knowledge, "Feelings about the Bible" is the strongest predictor of scientific knowledge. Moreover, when a few other religion-related variables were grouped together by PLS as a component (in addition to "Feelings about the Bible"), these items together also played a role in predicting the outcome of one's scientific knowledge and overall interest in science and technology.

Since "Feelings about the Bible" is the strongest predictor of overall attitudes toward science, more discussion about how one's perception of scripture influences interest in science is warranted. Those who responded that the Bible is the actual word of God and is to be taken literally (i.e., word for word) reported having the lowest degrees of scientific knowledge and interest in science. Conversely, those who had the highest level of interest in science were also those who did not believe that scripture was inspired (as measured by the variable, "The Bible is an ancient book of fables, legends, history, and moral precepts recorded by men"). Among those who were Christian and had the highest degree of scientific knowledge were those who understood scripture as inspired, but did not believe that scripture should be taken literally.

A cursory glance at this data set might result in the assumption that religious persons are less competent in the sciences. The NORC data do, in fact, indicate the tendency for Christians holding a more literal interpretation of scripture to be less interested in science and technology, less competent in scientific knowledge, and less likely to take science courses. A cursory examination of this data set might also cause one to conclude that religion or Christianity is an obstacle to science education, or that Christianity is antiscience (as some New Atheists argue). However, it would be premature to draw such conclusions from this data set. Here it is essential to note that the most significant and major roadblock to positive attitudes toward science is not Christianity per se, but how scripture is to be understood or interpreted. This perspective demonstrates the centrality of scriptural interpretation in the discussion, and more broadly, the centrality of scriptural interpretation in the contemporary science/religion dialogue for Christians.

One way to begin to make sense of the data represented here is to see these results as residual elements of historical events that occurred within the United States, regarding the inspiration and authority of scripture. While a comprehensive survey of inerrancy, inspiration, and fundamentalism falls outside the scope of this article, it will be helpful to highlight several historical features that relate to literal interpretations of scripture and science in the United States.

The late nineteenth century presented significant challenges to Bible-believing Christians in the United States. With the rise of the modern sciences and the growing use of biblical criticism by liberal Protestant theologians, the authority of the Bible seemed to be threatened for many Anglo-American evangelicals. Fundamentalism can best be understood as a movement that was unique to the American scene, and which was thought to be a reaction against modern ideas (such as the theory of evolution and historical critical approaches to scripture).[28] As Martin Marty

notes, "Fundamentalism was the product of people who encountered modernity, did not like what they saw and regrouped or refashioned their faith."[29]

During this latter part of the nineteenth century, evangelical Christians in America rallied together to identify the "fundamental" and essential elements of Christianity in order to prevent the deterioration of the Christian faith by elements of modern thought and liberalism. These five central doctrines were the authority of scripture, the virgin birth, substitutionary atonement, bodily resurrection, and Christ's divinity. Sometimes the second coming was also added to this list.[30]

Moreover, since the historical reliability of scripture was being called into question (particularly through the theory of evolution), American fundamentalism reacted by attempting to safeguard the authority of scripture. One of the results was an emphasis on the authority of scripture that promoted the Bible's accuracy regarding facts about the physical world. While the authority of scripture was defended in previous centuries, particularly in the Protestant Reformation, a strict understanding of inerrancy did not appear until the modern time period. During this period, it assumed a unique flavor among early-twentieth-century American fundamentalists, with theologians such as A. A. Hodge and B. B. Warfield contributing to the establishment of such views.[31] By emphasizing the authority of scripture, a plain-sense literalism, and scripture's inerrancy (i.e., scripture is free from error), the fundamentalist movement attempted to establish a sure foundation that knowledge could be built upon.[32] This literal reading of the text offered an almost "scientific" view of the Bible, since scripture could be read literally and the facts of the Bible could be made clear to any person who could read the scripture.[33] George Marsden noted that pietistic American evangelical revivalism in the late nineteenth and early twentieth century further strengthened the idea that any intellectual activity or reading outside of the Bible was to be used as a "resource" to "get in touch with people" and lead them to faith in Christ.[34] Additionally, strict literalist and inerrant readings of scripture grew in popularity among Christians, since such readings seemed to combat new scientific ideas that appeared to contradict biblical "data."

As the question of the authority of scripture continued to be hotly contested on the American scene, new variations emerged, relating to how authoritative the text could be in giving factual information about the natural world. "Inspiration" is the theological term that denotes God's Spirit working through prophetic messengers to author scripture, while "authority of scripture" primarily refers to an acknowledgment that the Triune God is behind the authorship of the biblical text and that scripture is trustworthy in the matters that it speaks of. While evangelical groups agreed that scripture had "authority" and was "inspired," differences arose regarding whether scripture was trustworthy in its depictions of the natural world, or whether scripture was only authoritative in its explanations of matters of faith and salvation. These differences can be seen in the development of the terms "strict inerrancy" and "limited inerrancy."

Evangelicals in the mid-twentieth century, such as Carl Henry and Harold Ockenga (the first president of Fuller Theological Seminary), promoted a movement called "new" evangelicalism (or neo-evangelicalism) that agreed on the theological importance of the core fundamentals of the faith, while disagreeing with fundamentalism's separatist stance toward culture. This "new" evangelicalism was interested in engaging in dialogue with science and advocated a softer stance toward inerrancy that was more accommodating toward science. The term "limited" inerrancy (scripture is authoritative in matters of faith and salvation) became associated with this group of evangelicals, while fundamentalists continued to promote more literal renderings of the text advocating "full" or "strict" inerrancy, a view which was often skeptical of science. The fundamentalist notion of "full" or "strict" inerrancy understood that scripture is without error when it speaks on any subject (including history, geography, and science) and promoted a more literal interpretation of the text.[35] For fundamentalists, if scripture is without error, then it could also serve as the foundation for understanding the natural world, and could be authoritative in determining matters of history and science. Advocates of strict inerrancy argued that any error in scripture calls into question the trustworthiness of the entire Bible.[36]

Advocates of moderate or limited inerrancy insisted that scripture is free from error in matters of faith and salvation, whereas other matters related to science are outside the Bible's primary goal.[37] Evangelical

Christians involved in science in the mid-twentieth century also popularized the use of the terms "concordist" and "accommodation"; these terms refer to how much one can assume that scripture is accurate in matters related to science. Concordism posits that there should be a "concord" or agreement between what scripture speaks of and what science says—that is, that scientific claims about the world made by scripture must be true. The "accommodation" position recognizes that biblical writers used an ancient worldview and "phenomenological language" (e.g., the sky appears to be a blue dome containing water) to explain the physical realm—which might not necessarily coincide on all accounts with the current scientific view of created reality. The terms "concordist" and "accommodation" also coincide with basic understandings of "strict inerrancy" and "limited inerrancy," respectively. In the 1950s, theologians such as Bernard Ramm popularized the use of these terms among neo-evangelicals and within groups such as the American Scientific Affiliation.[38]

Moving into the new millennium, literal interpretations of scripture continue to influence one's degree of openness to the age of the earth, particularly shaped by one's interpretation of Genesis. Young earth creationists interpret the Bible in a literalist fashion by claiming that God created the cosmos and life in six 24-hour days, about 6,000 years ago; this view is the least compatible with the contemporary scientific consensus. Progressive creation and evolutionary creation rely on models of the authority of scripture that move away from literalism. Progressive creationists claim that God created life in sequential stages in 4.5 billion years. This school of thought is also known as "old earth creation" and "day-age theory." This theory accepts micro-evolution (i.e., the occurrence of changes within the same species) but rejects macro-evolution (i.e., the turning of one species into another). Evolutionary creation, as its name implies, asserts that creation operates upon an evolutionary process which was designed by God. This theory is also known as theistic evolution.[39]

During the 1990s, the Presbyterian Church of America (PCA) published a report in an attempt to answer a seeming incompatibility between a modern scientific theory of the origin of the universe, and the creation account in Genesis. According to the PCA report, there are at least four ways to interpret the word "day" in Genesis 1. These include (1) Calendar day: a day consists of 24 hours; (2) Day-age: six days are six consecutive ages; (3) Framework: the creation week is a metaphor for the creative act of God; and finally, (4) Analogical day: days in Genesis do not have any specified length. The PCA committee emphasized that all these views are compatible with orthodox Christianity.[40] However, while all these views are compatible with orthodox Christianity, some of the views are more amenable to the science/faith dialogue than are others. Current media trends and "New Atheists" typically conflate the complexity of views within the Christian faith regarding scriptural interpretation.

What began in the late nineteenth century as a well-intentioned move toward affirming key doctrines of the Christian faith, resulted in a heightened literalist interpretation of scripture within the United States. This new level of literalism was pushed to a higher degree than had occurred in previous centuries. Such a literalist interpretation of the Bible is by no means a long-standing tradition. Rather, as described above, strict "inerrant" views of the text are a fairly recent phenomenon. Already in the fifth century, for example, St. Augustine had warned that the first chapter of Genesis should not be taken literally, because the Holy Spirit did not care about "the form and shape of the heavens" and did not want to teach things that were irrelevant to salvation. In a similar vein, Galileo said, "The intention of the Holy Spirit is to teach us how one goes to heaven, not how heaven goes."[41]

While the results of our study show the association between literal interpretations of the Bible and a lack of knowledge in science, this study does not confirm that these historical events are the only cause of the data results. However, given the history of literal interpretations of the Bible associated with fundamentalism, as well as a degree of skepticism toward science which is often associated with fundamentalism, it seems amiss not to make such observations and historical connections. It is important to note that the desire to read the Bible literally will naturally produce interpretations that are in conflict with science. Strict literalist interpretations of scripture promote conflict with aspects of science. Given this historical backdrop, perhaps it should not come as too much of a surprise that those less interested in science are those who also adhere to more literal readings of the biblical text.

Recommendations and Further Research

For those interested in the current religion/science dialogue within the United States, the NORC data present sobering reminders about the current state of Christianity's interaction with science. While those who read scripture more literally show the least amount of interest in science, there is also less interest in science among those who hold a nonliteral approach to scripture, when compared with those who do not believe in the inspiration of scripture at all. Furthermore, earlier study highlighted a negative influence of one's fundamentalist orientation on educational attainment, including post-secondary education and graduate study.[42] This general ethos has the potential to discourage Christian youth from participating in science or higher education, while also contributing to Christian scholars feeling ostracized in their fields. Whether there is a negative relationship between the Christian faith and performance in social sciences and the humanities awaits further research. Overall, there is more work to be done to help Christian churches and communities develop positive ways to engage science and promote working within scientific fields of inquiry. That being said, we propose three recommendations for furthering the science and faith dialogue among Christians.

First, faith-learning integration should be (and should continue to be) the area of focus in Christian universities and churches. Faith-learning integration is defined as "a scholarly project whose goal is to ascertain and to develop integral relationships which exist between the Christian faith and human knowledge, particularly as expressed in the various academic disciplines."[43] This solution aims to be a bridge that initiates dialogue between science and religion rather than a battle or barrier between the two disciplines. The task of faith-learning integration is critical to Christians, as it assists believers in finding a balance between science and religion, as well as promoting the development of more efficient and high-quality researchers. The core to this task lies in understanding the unified nature of truth, although there may be various ways of revealing, perceiving, and interpreting this truth.[44] As Alister McGrath notes, both scripture and science are viewed as tools to facilitate the study of the natural world, as well as the nature of humanity (or human condition).[45] In this case, both religion and science are equally important, as each discipline represents part of the circle. Faith integration can complete the circle by providing in-depth education in both disciplines, and brings a sense of wholeness to our understanding of reality.[46] Other than helping scholars to understand the importance of each tool or how to utilize each resource in finding the truth, faith-learning integration is also known to provide a platform for personal growth. Through this process, an individual will become more aware of his or her own strength and weakness, which often leads to self-introspection that is reflected in one's research work. In this way, a researcher is less likely to be manipulated by human heuristics. That allows more openness to critiques from the outside world or other disciplines.

The task of integration does not rely on a sole or fixed model to educate Christians, but rather aims to equip scholars to recognize "the privilege of participating in the work of revelation by engaging in research."[47] In general, faith-learning integration wishes to aid Christians to be more open to the scientific world rather than making people feel as if they are forced to choose between science and religion. As J. D. Guy wrote, "This process will regard controversy and diversity as catalysts for growth, bring excitement and joy rather than fear and defensiveness."[48] This unified approach to knowledge is significant for scholars to bring a holistic approach to research.

Second, within Christian universities and churches, it is important to stress the contributions of Christians to science. Many prominent scientists who contributed to major breakthroughs in science were Christians; these included Isaac Newton, Michael Faraday, James Maxwell, and Lord Kelvin. For these scientists, Christian belief was not a hindrance to scientific exploration; rather, these scientists were motivated to reveal the glory of God by showing the order of the universe via science.[49] T. F. Torrance argues that Christianity's belief that the universe is orderly contributed to the birth and development of modern science.[50] Similarly, Japanese scholar Naoki Komuro asserted that the root of science in the modern sense could be traced to the Judeo-Christian heritage.[51] According to Komuro, deities of other earlier religions are members of nature or the universe rather than creators of the natural order. However, the Hebrew God is unique, because the cosmic order arises from Yahweh. More importantly, as the Bible documents wrestling and debates between God and humans, Komuro argues that the debating of Jews

and Christians paved the way to logical reasoning, an element that is critical to scientific thinking. In short, the story of how Christians have interacted with science is a story that needs to be told, as well as one that is worth hearing.

Third, in addition to advocating faith learning, and telling the story of Christian interaction with science, particular efforts should focus on providing Christians with better nuanced explanations of how one might read and understand scripture. This recommendation, while overlapping with faith learning, focuses specifically on the importance of hermeneutics within the science/faith dialogue for Christians. As the NORC data have revealed, the strong predictor in levels of interest in science and scientific knowledge is one's feelings about the Bible and how scripture is interpreted. Again, given the history of conservative evangelicalism and fundamentalism's emphasis on more-literal readings of the scripture in US history, especially in dialogue with science, this should not come as a surprise. Since this data set clearly indicates that one's method of reading scripture correlates with how one understands and engages science, faith-learning integration should demonstrate sensitivity and instruction devoted to how one reads scripture.

The data here highlight that interpretive tools are needed to understand scripture and to make sense of the narrative of the world, as told by science. Hermeneutics is an activity that takes place within a community of readers (and hearers) and is an element of Christian spiritual formation.[52] Understanding the church as an interpretive community offers much room for individual, spiritual, and professional growth, by stressing the idea that biblical data and scientific evidence are not in conflict. Consequently, when science and faith appear to be in conflict, one's view of biblical interpretation may require revisitation. Understanding churches as communities of interpretation, particularly around science and faith, is critical—both for the growth of persons interacting critically with science and for the growth of researchers and scientists themselves. ✯

Notes

[1]"Bill Nye vs. Ken Ham Debate," YouTube, 2014, https://www.youtube.com/watch?v=z6kgvhG3AkI.

[2]Bill Nye, *Undeniable: Evolution and the Science of Creation* (New York: St. Martin's Press, 2014).

[3]L. Krauss, "Teaching Creationism Is Child Abuse," YouTube, 2013, https://www.youtube.com/watch?v=UTedvV6oZjo.

[4]A. Plantinga, *Where the Conflict Really Lies: Science, Religion, and Naturalism* (New York: Oxford University Press, 2011); H. Ross, *A Matter of Days: Resolving a Creation Controversy* (Covina, CA: Reasons to Believe Press, 2015); ____, *Hidden Treasures in the Book of Job: How the Oldest Book in the Bible Answers Today's Scientific Questions* (Covina, CA: Reasons to Believe Press, 2014); ____, *Navigating Genesis: A Scientist's Journey through Genesis 1–11* (Covina, CA: Reasons to Believe Press, 2014).

[5]V. Smiles, *The Bible and Science: Longing for God in a Science-Dominated World* (Collegeville, MN: A Michael Glazier Book published by Liturgical Press, 2011).

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The Overlooked Science of Genealogical Ancestry

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Do we all descend from a single couple? Most are convinced that the genetic and archeological sciences answer with an unequivocal "no." It appears that our ancesters share common ancestors with the great apes and arise as a large population, never dipping in size to a single couple. Without contradicting the findings of genetic science, genealogical science gives a different answer to the question. It is likely that there have been many individuals, and potentially couples, across the globe who are each individually genealogical ancestors of all those alive when recorded history began. These ancestors stretch from our distant past to very recently in our history. Consistent with the genetic and archeological evidence, therefore, it is possible that God could have chosen, or specially created, one of these couples for a special role. No argument is offered here that such a historical couple is what the text of Genesis teaches; however, if the text intends a particular couple in the recent past, such a couple could be among the ancestors from whom all those alive today descend.

It seems such a simple question, but it carries a great deal of subtlety and complexity: Do all humans descend from a single couple?

Genetic science appears to answer with a "no." From genetic data, the population size of our ancestors at different times is estimated. It appears that population sizes never dipped to a single couple in the last several hundred thousand years, during the time in which *Homo sapiens* arises.[1] This conclusion is robust, based on several independent signals: our ancestors arose as a large population, not as a single couple.

It is a subtle and consequential error, however, to think that these findings demonstrate that there are no individual couples from whom we all descend. For the "no" to be correct, we must have inserted into the original question a genetic notion of ancestry. This insertion of "genetic" into the question neglects a key scientific fact: genealogical ancestry is *not* genetic ancestry. Genealogical ancestry traces the reproductive origins of individuals, while genetic ancestry traces the origin of stretches of DNA. A question about "descent" can be a question about genealogies, and genealogical questions should be answered with genealogical science.

Furthermore, the term "human" is imprecise when referring to those in the distant past. Certainly, all members of the species *Homo sapiens* alive right now are human. In the ancient past, however, the term is ambiguous in both science and theology. For example, there are parallel intracamp debates amongst scientists, theistic evolutionists, and young earth creationists about whether Neanderthals and *Homo erectus* are "human." Genetically, different species of the *Homo* genus might be less different from one another than subspecies of chimpanzees. There is also

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evidence of interbreeding between Neanderthals and *Homo sapiens*. For these reasons, "human" is a term without scientific precision in the past. In view of this ambiguity, several models of human origins do not even consider all *Homo sapiens* in the distant past as "human."[2]

With these subtleties in mind, we find a different answer if we mean ancestry and descent in a genealogical sense. Instead of genetics alone, we should look to genealogical science. Could a single couple be among the ancestors of all humans? The answer from genealogical science is a definitive "yes." There are *many* universal genealogical ancestors (UGAs) in our past, each *individually* from whom we *all* descend. These *genealogical adams and genealogical eves*[3] are likely to appear just thousands of years ago, and continue back until ancient times. Two of them could be a particular couple, named Adam and Eve in scripture, from whom we all descend.

Whether this belief is theologically warranted or hermeneutically founded is beside the point of this article: such a belief is not contradicted by the scientific evidence. If Adam and Eve are a particular historical couple in our past, the evidence tells us only that their offspring mixed with a large population of biologically compatible beings. Far from a grand innovation, this history is already put forward in ancient readings of Genesis and suggested by textual analysis of scripture (Gen. 3:1; 4:14,17; 6:1–4; Rom. 5:12–14).[4] The cited authors can defend these hermeneutical claims for themselves, but our focus is on clarifying what science does and does not say.

There is an ongoing debate about Adam. Is Paul really teaching that we all descend from Adam? Is descent from Adam required to construct a coherent theological system? Does scripture teach that Adam and Eve were specially created? As important as is this debate, the focus here is on the scientific question, seeking to truthfully articulate what science does and does not say. Whether a genealogical Adam is required by theology, or not, the genealogical science here still stands.

Is it scientifically possible that we all descend genealogically from one and only one UGA couple? From a scientific point of view, this is an interesting question that deserves proper treatment. In this article, I neither disclose, defend, nor assert my personal beliefs. As it should be, my personal position is irrelevant to the question at hand. Instead, this article's focus is on what science does and does not say. Undoubtedly, this discussion will raise theological and hermeneutical questions of many sorts, but our focus here is on the science.

Genetics Is Not Genealogy

It cannot be overemphasized that genetic ancestry is not genealogical ancestry (fig. 1). Genealogical ancestry traces the reproductive origin of people, matching the common use of "ancestor," "descendant," "parent," and "child." In contrast, genetic ancestry has a much more exotic meaning, tracing the origin of stretches of DNA. Two assertions begin to clarify the distinction.

1. **Genealogical ancestry does not imply genetic ancestry**. Consider a child's father and grandfather. They both are fully the child's genealogical ancestors. However, they are only partially the child's genetic ancestors, approximately 1/2 and 1/4, respectively. The same is true of the child's mother and grandmother. Genetic ancestry continues to dilute each generation: 1/8, 1/16, 1/32 … to a number so small that it is unlikely a descendant has any genetic material from a specific ancestor.[5] The many genealogical ancestors that pass to us no genetic material are not our genetic ancestors.

2. **Genetic ancestry does not imply genealogical ancestry.** About 45% of the human genome is composed of a specific type of DNA, transposable elements. Transposable elements arose initially from viruses that inserted their genetic material into the genomes of our distant ancestors.[6] These viruses themselves are our genetic ancestors and contributed to our genetic inheritance. They are not, however, our genealogical ancestors.

Genetic ancestry, therefore, is not genealogical ancestry. Which type of ancestry is most relevant to our central question: could all humans "descend" from any individual couple? In nontechnical discussion, questions about "descent" are questions about genealogical ancestry. DNA is a recent discovery, and genetic ancestry is a very new way of looking at the world. In the genomic age, our tendency is to start with genetic ancestry, but we must look to genealogic science to answer genealogical questions.

The scientific literature, in contrast, is predominantly focused on genetic ancestry. References to *most recent common ancestor* (MRCA) refer almost exclusively to the genetic ancestry of a defined stretch of DNA. For example, *mitochondrial eve* (m-MRCA) and *Y-chromosomal adam* (y-MRCA) are genetic MRCAs of the DNA inherited exclusively by one parent, mothers and fathers, respectively. As we will see, these genetic ancestries work entirely differently than does genealogical ancestry.[7] To answer genealogical questions, we must instead look to the science of genealogical ancestry.

Four Surprises in Genealogical Ancestry

Genealogical ancestry is surprising. The common meaning of ancestry is genealogical. However, constant exposure to genetic ancestry in science calibrates our intuition around genetics instead.

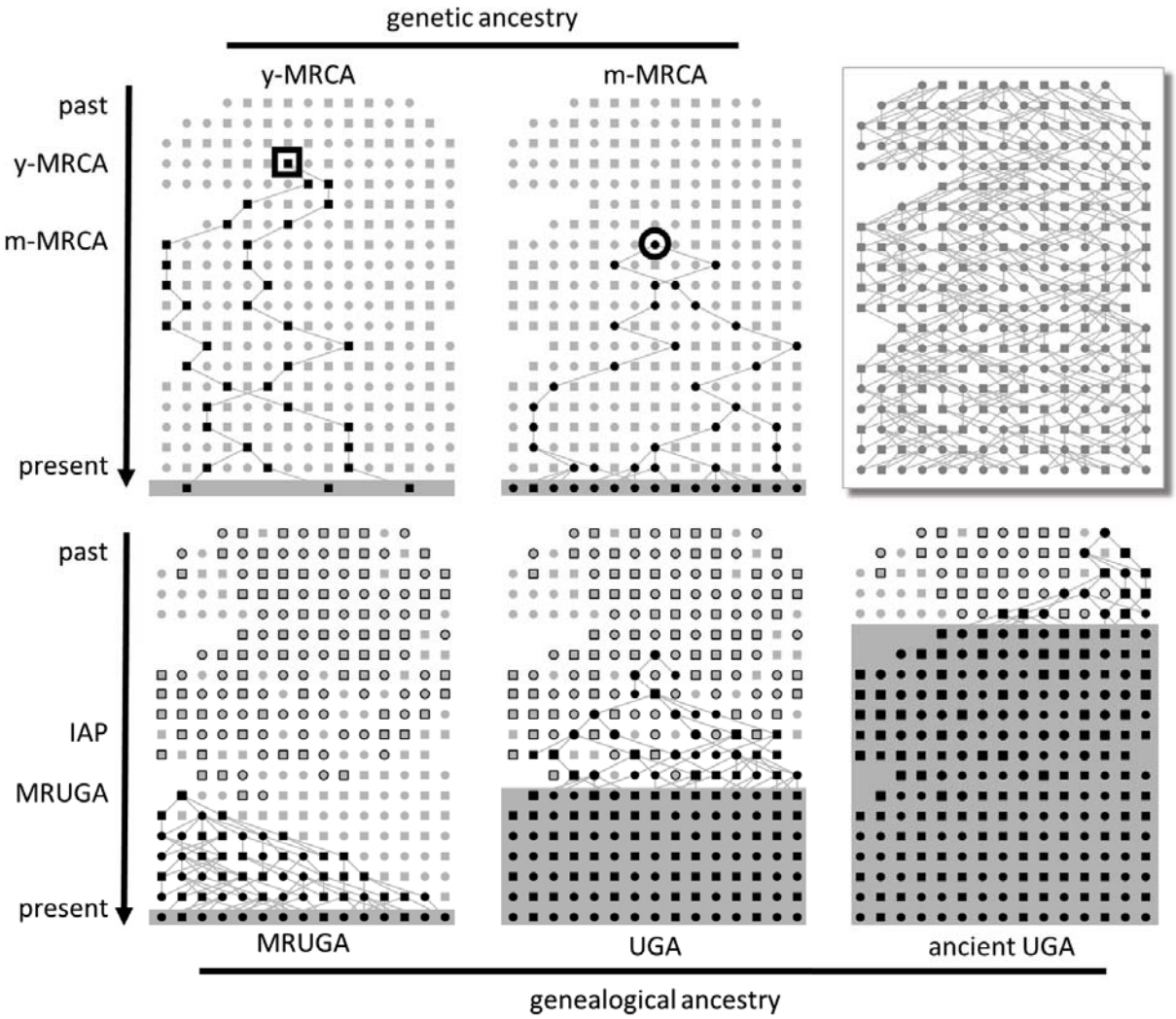

Figure 1. Genetic ancestry is not genealogical ancestry. *Universal genealogical ancestors* (UGAs) are individuals in our past, *each* from whom we all descend. UGAs arise quickly in a large crowd. To illustrate the difference, each panel gives a different view of the same pedigree (top right inset), in which ancestral relationships are displayed as lines, men as squares, and women as circles. The grey rectangles highlight the era in which the specified ancestor is a universal ancestor, a parent of all those in the region. Y-chromosomal adam (y-MRCA, top left) and mitochondrial eve (m-MRCA, top middle) are types of genetic ancestry (top), all of which take linear time to arise. Autosomal alleles take about twice as long to converge, and are excluded from the figure because they are more difficult to display on a pedigree like this. Genealogical ancestry (bottom), on the other hand, arises in logarithmic time with the *most recent universal genealogical ancestor* (MRUGA), and quickly becomes a cloud of many ancestors. At the *identical ancestor point* (IAP), everyone farther back in the past is either a UGA (black outline) or leaves no descendants. The descendants of three UGAs are marked (bottom), and similar pedigrees are possible for any UGA.

As surprising as this may be, *genealogical adams* and *genealogical eves* (UGAs) are numerous, recent, robust, and unobservable. None of these surprises about UGAs undermine the findings of genetic science. The error, rather, is in using genetic ancestry to answer genealogical questions.

1. *UGAs Are Numerous*

Many individuals are *each* individually ancestors of "all the living" (fig. 1). All humans alive descend from each of these universal ancestors. The same can be said for all alive in AD 1, or all alive when recorded history begins. Intuition can be built by considering a group of grandchildren that share the same grandfather. The grandfather is their common genealogical ancestor, but so also is every ancestor of the grandfather. Considering the distant ancestors shared by their parents, we find even more genealogical ancestors. Unlike genetic ancestors (e.g., y-MRCA and m-MRCA), genealogical ancestors are very numerous. In one scenario,[8] we expect more than 100 million individuals to be genealogical ancestors of everyone; *all* of us descend from *each* of them. They arise in a sudden cloud of individuals that quickly grows as we look back in time. All our different lineages quickly "collapse" into one family.

2. *UGAs Are Recent*

The *most recent universal genealogical ancestor* (MRUGA) of all living humans might have been situated as recently as 3,000 years ago.[9] We can build intuition about this by counting back generations while simultaneously tracking the total population and the number of ancestors we expect from a naïve calculation. First, we have two parents, then four grandparents, then eight great-grandparents. The number of ancestors appears to increase *exponentially* as we go back; however, the number of people in past generations either stays comparatively *constant* in much of paleo-history or *decreases exponentially* over the last 10,000 years.[10] How is this possible? Very quickly, all our genealogies begin to "collapse" by sharing more and more ancestors.[11] The first universal genealogical ancestor appears quickly, in just a few thousand years in realistic simulations.

Intuition calibrated by genetics misguides us regarding genealogies. The math illuminates the difference. In a random mating model, universal genetic ancestors, such as y-MRCA, appear proportionally to n generations, where n is the population size. But universal genealogical ancestors appear in merely $\log_2 n$ generations.[12] Moreover, the variability of when UGAs arise is much lower than the variability of when universal genetic ancestry arises.

3. *UGAs Are Robust*

The theoretical results are not substantially increased as more complexity is modeled; the time to UGA remains logarithmic. When migration is restricted to the idealized geography of a graph, the time to UGA is increased by a constant factor that linearly depends only on the size of graph.[13] Moreover, time to UGA does not depend on high migration rates between nodes in the graph; less than a single migrant per generation in the distant past robustly yields recent UGAs.[14] Likewise, increasing inbreeding increases time to UGA by a small, constant factor.[15]

Moreover, genealogical ancestry propagates more rapidly and reliably than genetic ancestry across a two-dimensional map. Genetic ancestry propagates in a dissipating wave that slows proportionally with $\sqrt{t}$, where t is the number of generations. But the wave of genealogical ancestry propagates at a constant speed t, without dissipating.[16] Genealogical ancestry, therefore, spreads much more rapidly and reliably than genetic ancestry, even without taking realistic migration into account.

How do these mathematical models extrapolate to more realistic simulations of human history? A study published in *Nature* simulated the ancestry of present-day humans across the globe (fig. 2), taking into account the effect of geographical constraints, migration, local barriers to mixing, and population growth.[17] Surprising even experts, these barriers do not substantially increase the time to universal ancestry.[18] With low levels of migration, universal ancestors can arise in as few as 3,000 years.

4. *UGAs Are Unobservable*

UGAs are unobservable in genetic data. Detectable ancestors must (1) leave DNA to their descendants, and (2) this DNA must be identifiable as coming from them.

Genealogical ancestors in the distant past, however, are only rarely genetic ancestors; they usually leave their descendants no DNA.[19] As one study explains, commonly, UGAs are *genetic ghosts* who leave DNA to only some of their ancestors, not all.[20] Many of our ancestors are *genetic super-ghosts* "who are simul-

taneously (1) genealogical ancestors of *each* of the individuals at the present, and (2) genetic ancestors to *none* of the individuals at the present."[21] Genetic ghosts are more likely with populations' bottlenecks and small populations, both of which increase the rate at which DNA is lost. This is a critically important point. Since most of our ancestors leave us no identifiable DNA, genealogical relationships are "essentially unobservable" in genetic data past about fifteen generations.[22]

The low level of ancient migration required for recent genealogical ancestry is undetectable in genetic data too.[23] A *single* migrant per generation to an isolated population is enough to reliably give rise to recent genealogical ancestors. Even when migrants do leave DNA, it is not usually identifiable as from a different population. The most likely migrants are those from the founding population, with DNA very similar to the isolated population.

The evidence of individual ancestors in our genomes degrades exponentially. UGAs themselves, and the ancient migration that makes them possible, are unobservable in genetic data.

Genetic Science Still Stands

None of these surprises in genealogies contradict genetic science in any way. The problem is not genetic science itself, but the error of using genetic ancestry to answer a distinctly genealogical question. Genetic ancestry is not genealogy.

Nonetheless, it still appears that *Homo sapiens* (1) shares ancestry with the great apes and (2) arose from a larger population that never dipped in size to a single couple.[24] Nothing in genealogical science undermines these two conclusions. If Adam as an individual existed, the notorious problem of intermarriage of his descendants with one another is avoided; instead, their descendants mixed with a larger population of biologically compatible beings. However, we would also count a particular couple called Adam and Eve as among our genealogical ancestors. They would be two people among those from whom we all descend, with theological or historical significance.

If Adam was a particular individual in our past, what happened to the population "outside the garden"?[25] Their history is rightfully and carefully

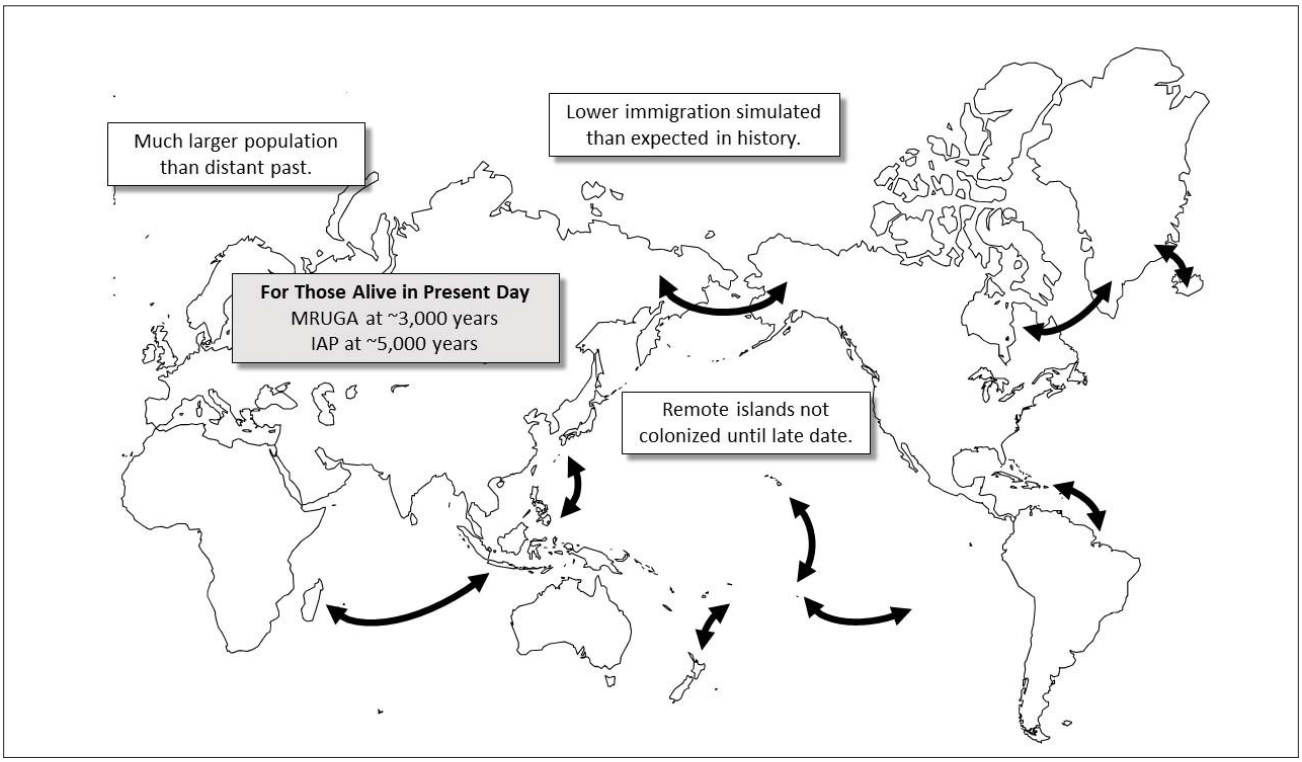

Figure 2. Simulating recent common ancestry. Universal common ancestry has been studied both analytically[26] and with simulations.[27] A 2004 study in *Nature* simulated world geography, migration, and local population structure.[28] Small amounts of migration were enough for MRUGA to arise in about 3,000 years, and to reach the IAP point in about 5,000 years. The arrows show some of the migration routes used in the simulation, and the insets identify three reasons why a simulation like this might overestimate the true wait times in the ancient past.

studied with genetics and archeology. They provide strong evidence for large-scale population movements and intermixing in our ancient history. It was once thought that our ancestors arose in Africa and spread across the globe, leaving some populations isolated for long periods of time. It is now clear that our ancestors arose from multiple regions at once, with a complex history of intermixing across the globe. Often individuals or groups migrated in the opposite direction of the larger populations.[29] The full story of human evolution is that of populations across the globe linked in a common evolutionary fate by pervasive interbreeding everywhere.[30]

What does genealogical science add to this account? Very quickly, in just thousands of years, those "outside the garden" mix with Adam's lineage. At the present time, therefore, everyone alive is a descendant of Adam, as well as of others. Interbreeding across the globe links us both genetically and genealogically together.[31] This statement of *monophylogeny* is how modern science counters polygenesis, a false theory of origins often marshaled in support of racism.[32] Both genetic and genealogical science affirm *monophylogeny*.

One Plausible Assumption

We can estimate when universal genealogical ancestors arise with one scientifically plausible assertion: at minimum, low levels of migration and intermixing prevent any population from becoming genealogically isolated for more than a few generations. Genetic and geographic isolation are still expected, but low levels of migration prevented genealogical isolation.

The most important scientific objection arises from the observation or inference of isolated populations.[33] Three types of isolation are important here: genetic, geographic, and genealogical isolation. The critical question is whether genealogical isolation can persist for several thousand years. Due to the limits of genetic data, genealogical isolation is not directly observable. Consequently, this question is answerable only if genetic or geographic isolation can reliably identify genealogical isolation.

As we will see, genealogical isolation does not correspond with genetic or geographic isolation. Instead, the question of genealogical isolation poses a dilemma of complementary universal negatives. A *single* genealogically isolated population will prevent a universal ancestor from arising. However, a *single* migrant or mixing event will break genealogical isolation. On the one hand, it is nearly impossible to rule out the isolation of every population. On the other hand, however, it is nearly impossible to rule out low levels of migration in order to demonstrate that a population was genealogically isolated for long periods of time. Science, therefore, cannot determine whether genealogically isolated populations have existed in our past or not.

Consequently, rather than trying to prove that genealogical isolation does not exist, we seek only to show that it is scientifically plausible to presume low levels of migration that prevent populations from being genealogically isolated. Undetectably low levels of migration are all that is required for UGAs to arise in the recent past.

Genetic Isolation Is Not Genealogical

It is possible that some populations have been genetically isolated for long periods of time. For example, portions of DNA from the Khoisan people of southern Africa and the Aborigines of Australia appear to be genetically isolated for tens of thousands of years.[34] This evidence is consistent with substantial cultural and geographic barriers that made mixing and migration difficult and uncommon. Initially, there was hope that genetics might determine if and when populations were genealogically isolated in the distant past.[35] However, genetic data cannot detect low levels of migration in the distant past.[36]

Genetic isolation, therefore, does not demonstrate genealogic isolation. The most likely consequence of rare interbreeding is genetically isolated populations that are not genealogically isolated. Remember, genealogic isolation is broken with a *single* successful dispersal event. Consequently, to demonstrate genealogical isolation, one has to prove that absolutely zero successful immigration has taken place over hundreds or thousands of years. Most genealogical ancestors, however, do not leave any genetic evidence in their descendants.[37] Most ancient ancestors leave no identifiable DNA, and are, therefore, unobservable in genetic data. This is not a low-probability loophole. Genetic data is unable to determine genealogical relationships in the distant past.

Genetic evidence can falsify genetic isolation. In this way, genetics has produced strong evidence

against genealogical isolation, which supports the hypothesis of recent UGAs. Most genetics studies consider only small portions of the genome.[38] Whole genome sequencing could reveal mixing in the past. Similarly, ancient genomes provide additional evidence for ancient migrations,[39] even though human populations are fragmented and might be genetically isolated at times.

The Rising Seas

Rising seas limit our view of migration in the distant past. From about 12,000 to 8,000 years ago, seas rose about 120 meters, submerging very large coastal areas across the globe. As the seas rose, they erased much of the archeological evidence for migration and early settlements.[40] Colonization in paleo-history time might have been in boats, often along coasts and rivers, enabling rapid dispersal over long distances.[41] This dual problem of coastal dispersion and submerged evidence limits our understanding of the most geographically isolated areas. For this reason, lack of positive evidence for migration is *not* evidence of isolation.

Moreover, for UGAs 10,000 years or earlier, most of the land bridges would still be passable for thousands of years. During this time, Australia, Tasmania, and the Americas would all be easier to access.

Isolation of the Americas

At first glance, the geographic isolation of the Americas seems insurmountable. It was thought that migration to the Americas was contingent on an intermittently open land bridge in Beringia or seafaring technology to cross the Pacific Ocean. Evidence, however, suggests continuous immigration in boats along a coastal route and the Aleutian islands.[42] Even if immigration ebbed at times, genealogical isolation would require zero successful migrants to the Americas for centuries and millenniums. Though we might expect genetically isolated populations in the Americas, it does not follow that the Americas were genealogically isolated too.

Isolation of Australia

Australia is often offered as definitive evidence against recent common ancestors.[43] Rising seas submerged land bridges across the world, making it more difficult to cross from South East Asia to Australia and separating Tasmania from Australia. For this reason, we might expect Australia to be genealogically isolated.[44]

The initial colonization of Australia adds important information. Land bridges never extended all the way to Australia. The last stretch required crossing a 50- to 100-kilometer-wide body of water. Until the arrival of *Homo sapiens* about 60,000 years ago, this final gap was not crossed. It is thought that boats or rafts might have been a unique capability of *Homo sapiens*, at least in this region, and were used to cross the strait in order to colonize Australia.[45] Similar seafaring feats enabled *Homo sapiens* migration to unexpected places for at least 100,000 years.[46] This is evidence that ancient *Homo sapiens* were capable of crossing large bodies of water. The geographic isolation of Australia does not demonstrate that it was genealogically isolated.

Isolation of Tasmania

Tasmania was connected to Australia by a large land bridge that was submerged by rising seas 8,000 years ago. From this time forward, crossing to and from Australia was impossible without seafaring capability. Nonetheless, there remain several habitable islands between Tasmania and Australia. Using these islands as a broken bridge, the crossing is possible with the same boats or rafts that enabled colonization of Australia in the first place. Before seas had fully risen 8,000 years ago, the crossing might have been much easier, with large portions of the land bridge still intact.

It was certainly difficult to reach Tasmania after 8,000 years ago. The real question is whether the barriers prevented *all* mixing. Even if mixing was limited to rare events, universal ancestors would arise. For this reason, we cannot know for sure if and when small amounts of migration took place to Australia and Tasmania. It seems reasonable to expect that at least a few boats every century still crossed.

Isolation of Remote Islands

The most remote islands—such as Hawaii, Easter Island, and the most eastern end of Polynesia—are very difficult and dangerous to find without modern technology. For this reason, these islands are key bottlenecks that push back estimates of the most recent ancestor of all present-day humans.[47] However, these islands were colonized just within

the last few millennia.[48] They are not, therefore, relevant to UGAs later than about 6,000 years ago.

Caught between Two Negatives

For any multimillennium period in our distant past, were any populations genealogically isolated? Answering either "yes" or "no" requires making one of two absolute negative claims, each of which is difficult to substantiate.

On the one hand, answering "yes, there were genealogically isolated populations" requires asserting that there was zero successful migration or intermixing for thousands of years. This negative is not possible to demonstrate with evidence from either genetic or archeological data. Those skeptical of the "yes" answer can posit at least a tiny amount of migration and intermixing, which would undetectably break genealogical isolation.

On the other hand, answering "no, there were no genealogically isolated populations" requires asserting that there were zero populations that were isolated for thousands of years. This negative requires comprehensive knowledge of all populations in our distant past. Those skeptical of the "no" can posit that somewhere, somehow, an isolated population existed.

Absolute negatives of either sort are impossible to know confidently about the distant past. Reasonable scientists will legitimately disagree which absolute negative is most likely. However, it is scientifically plausible to assert the levels of migration and mixing required for universal ancestors to arise. Reaching the limits of science, there is flexibility in the scientific account.

"Humans" in Theology and Science

To estimate when UGAs arise, we must first define who is required to descend from them. We cannot just define this group as the "human race." In both science and theology, the terms "human" and "humanity," and their variants, are ambiguous in our distant past. They can mean a wide range of things. This ambiguity arises for deep and intractable reasons.

In science, there is a range of opinions and, at times, a raging debate. We see smooth transitions of forms from our distant ancestors to the present day. Historically, in communication with the public, "human" is *anatomically modern* humans, or equivalently *Homo sapiens*. Some point to *Homo erectus* as the first human, noting their mastery of fire, complex language, and impressive tool industry. Most recently, the entire *Homo* genus is being called "human," in recognition of their high similarity to one another and pervasive interbreeding. *Homo sapiens* is different from *Homo erectus*, but a dividing point defined by biology alone appears arbitrary. Consequently, using the term "human" in statements of scientific findings is imprecise and can artificially constrain theology when this imprecision is not clarified.

There are similar ambiguities in theology. At which point did "humans" become the "mankind" of scripture? How and when did we receive God's image and then fall? Are Neanderthals and other hominids part of humankind too? Which milestones are theologically significant?

There are many theological definitions of "human," but none of them clearly map to science. Consequently, there is a wide range of options explored in the literature. Denis Alexander and John Stott identify Adam about 10,000 years ago in the Middle East to preserve the agrarian details of the Genesis narrative and timeline.[49] Denis Lamoureux identifies theological humans of about 50,000 to 40,000 years ago with *behaviorally modern* humans.[50] Hugh Ross, Fazale Rana, and Greg Davidson identify humans with *Homo sapiens* and y-MRCA and m-MRCA at about 100,000 years ago.[51] Without providing specific dates, C. John Collins suggests milestones such as language and knowledge of moral law.[52]

Adding additional options, John Walton proposed that humankind is first created in the image of God, but then at a later time Adam is identified, perhaps specially created, and then subsequently falls.[53] Of note, this portion of his argument is purely textual and does not rely on Ancient Near Eastern literature. Moreover, Adam and Eve are the *first* and *only* theological "humans," both inside and outside the garden, when they are created.[54] Walton himself does not specify his model more precisely, but one might look for markers of the Fall to identify when Adam or Eve might have lived. An attractive feature of this model is its affirmation that, at any specific time in the past, all our ancestors equally bear the image of God. This supports important theology of race and lays a foundation for universal rights.[55] Though

outside the scientific scope of this study, Walton's model merits more consideration.

Keeping in mind that Adam's line would exist alongside others for a time, we might consider those alive at other critical milestones in history, such as at the rise of civilization about 6,000 years ago, and 2,000 years ago when Paul writes Romans, referencing Adam in his theology. As we will see, even this late date could be consistent with identifying everyone mentioned in scripture after Genesis 11 as a descendant of Adam. Once again, the theological status of those outside Adam's line is a question outside the realm of science. It is possible that Walton's model may be helpful in making sense of these options.

Universal Ancestors of Descendants

With these subtleties in mind, we can make the first estimate. We define *genealogical adams* and *genealogical eves* as the people who each individually are UGAs of an entire group of *required descendants*; by definition, all "universal" ancestors must be genealogical ancestors of all the people in this group. After specifying the *required descendants*, we can estimate a range, which will stretch from the very distant past to a more recent date. Perhaps we can insist that Adam was a *Homo sapiens*, or in the *Homo* genus, or lived in a specific era in the past.

The recent end of the range is defined by three critical dates: (1) the *most recent universal genealogical ancestor* (MRUGA), (2) the *nearly identical ancestor point* (nearly IAP), and (3) the *identical ancestor point* (IAP). The most recent date is that of the MRUGA, the first point. Here, a single UGA appears somewhere in the globe. The most ancient date is that of the IAP, the third point. Here, each and every one that leaves ancestors is also a UGA. The only people at this point who are not UGA are those who, for example, do not have any children. Between these two dates is the nearly IAP, where *nearly* everyone alive (e.g., 95%, 98% or 99%) who leaves ancestors is also a UGA.[56] The "nearly" qualifier applies only to the number of UGAs, and does not diminish the universality.

Peer-reviewed estimates of these dates are available only in the scientific literature, when *required descendants* are chosen to be "those alive in the present day." Other estimates are nevertheless possible. Currently, only one study models migration, geographic barriers, and population structure to estimate dates for all humans alive today.[57] The same first author also released an unpublished and unreviewed report with expanded results using a variety of parameters. These two studies represent the most realistic simulations of UGA.[58] Building confidence in the estimates, simulation results were reasonably consistent, even though all models used very low migration levels. The outliers with the longest estimates use unrealistically low migration across the entire map. The "high" immigration rate models still use very low immigration rates, but a MRUGA can arise in as little as 2,000 years. Other simulations are less relevant because they neglect geographic constraints entirely[59] or assume only a few kilometers of migration.[60]

In the best simulations,[61] the MRUGA is estimated to arise 3,000 years earlier than the *required descendants*. The IAP is estimated at about 5,000 years earlier than the *required descendants*. The nearly IAP for Mesopotamia is likely closer to the MRUGA data than the IAP; a conservative number is 4,000 years.[62] For reference, this is approximately three times longer than analytic results assuming random mating.[63] The simulation increases estimates over the theoretical results, but not by much.

These estimates lead to surprising conclusions. For example, consider choosing all those alive in AD 1 (about 2,000 years ago) as the *required descendants*. An estimate of the IAP is about 7,000 years ago with a MRUGA at 5,000 years ago.[64] Therefore, all farmers in Mesopotamia 6,000 years ago who left any ancestors would each be universal ancestors of everyone alive in AD 1 (fig. 3). The reference to 6,000 years, to be clear, is merely a consequence of the math (4 + 2 = 6 kya) and should not be interpreted as a specific endorsement of somehow locating Adam here.

Moreover, these are cautious estimates. By AD 1, the most remote islands are not yet settled,[65] the population was smaller than present day,[66] and the simulation assumes very low levels of migration.

Descendants of Universal Ancestors

The central question can be asked the other way around. Consider a UGA in the distant past. How long is the "wait time" for this ancestor to become a universal ancestor of all those alive? How quickly does this individual's ancestry spread?

The estimates of the prior section guide us to the answer. It will take between 3,000 and 5,000 years for a specific ancestor to become a UGA (fig. 2). The quickest time, 3,000 years, corresponds to the time of the MRUGA and applies to very few, lucky, and ideally located individuals. The longest time, 5,000 years, corresponds to the time of the IAP and applies to very few, unlucky, and poorly located individuals, such as those in the Americas or Australia. More likely, especially for those in central locations such as the Middle East, the wait time is between 4,000 and 3,000 years (fig. 3). A cautious estimate, therefore, of the wait time for typical individuals is 4,000 years, even though a more accurate estimate might be 3,500 years (fig. 4).

The key point, however, is that UGAs do not arise by pure luck or miraculous intervention. They are not restricted to single lineages or rare individuals or a single location. Instead, UGAs arise everywhere. Typical locations accumulate many UGAs quickly, well before the nearly IAP date at 4,000 years.

Improving Estimates

How confident can we be that UGAs exist? With plausible scientific assumptions, we can be very confident. To make an analogy, we have no way of identifying or observing all my distant ancestors, but this does not reduce our confidence that they existed. Even though they are unobservable, we are entirely certain that they existed. With plausible assumptions, we can estimate approximately when my great-great-great grandparents lived. In the same way, we confidently infer the existence of universal ancestors and estimate when they arise.

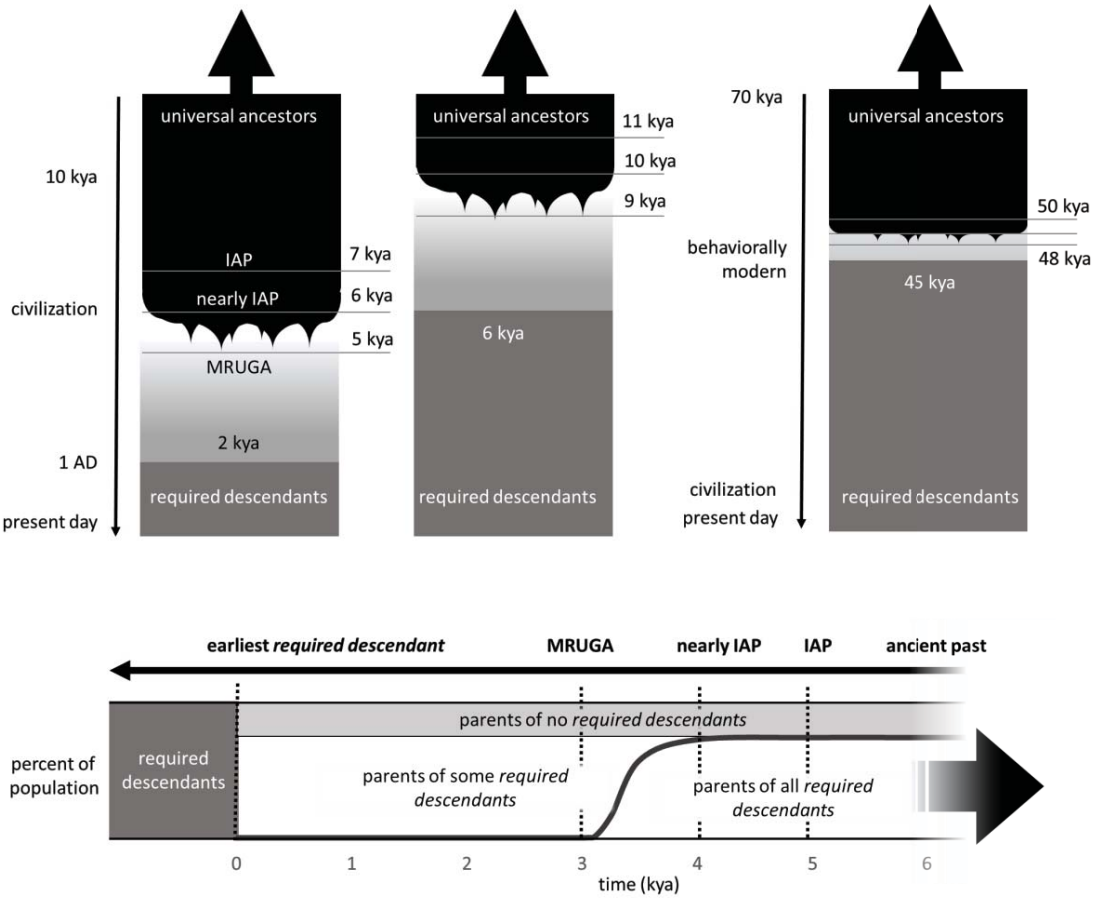

Figure 3. Estimating when universal ancestors arise. Universal genealogical ancestors (UGA) first arise in about 3,000 years before the *required descendants* and extend back into the distant past. The estimated UGAs of all those alive at AD 1, 6 kya, and 45 kya are displayed in cartooned pedigrees (top). The time axes are drawn approximately to scale but width does not correlate with population size. Three dates define the recent end of the range (bottom): (1) the *most recent universal genealogical ancestor* (MRUGA) date, (2) *nearly identical ancestor point* (nearly IAP), and (3) the *identical ancestor point* (IAP).

Smaller population sizes in the past could substantially reduce the wait times to UGAs. Quantitatively, wait time estimates should scale with log n/log m, where n is the population size at a time in the past, and m is seven billion, the approximate population at present day.[67] For example, at 5,000 years ago, there were about 18 million people in the world,[68] the scaling factor is about 0.8, and the corrected MRUGA estimate is about 2,400 years. At 10,000 years ago, there were about 2 million people in the world, the scaling factor is about 0.7, and the corrected MRUGA estimate is about 2,100 years.

A more rigorous approach uses improved simulations. Unfortunately, simulations at the level of detail in the 2004 *Nature* study are difficult to implement and run, so this hypothesis is not easily verified.[69] Perhaps increased interest in these results will stimulate scientists to embark on these efforts.

Until then, the estimates presented here are reasonable, and are based on the best simulation of common ancestry available. Building confidence, the simulation results correspond closely with theoretical analysis. Moreover, the results of this simulation have stood uncontested for more than a decade in the literature. Certainly, the results are surprising. The reason is that our intuition is calibrated by genetic ancestry, which works very differently than genealogies.

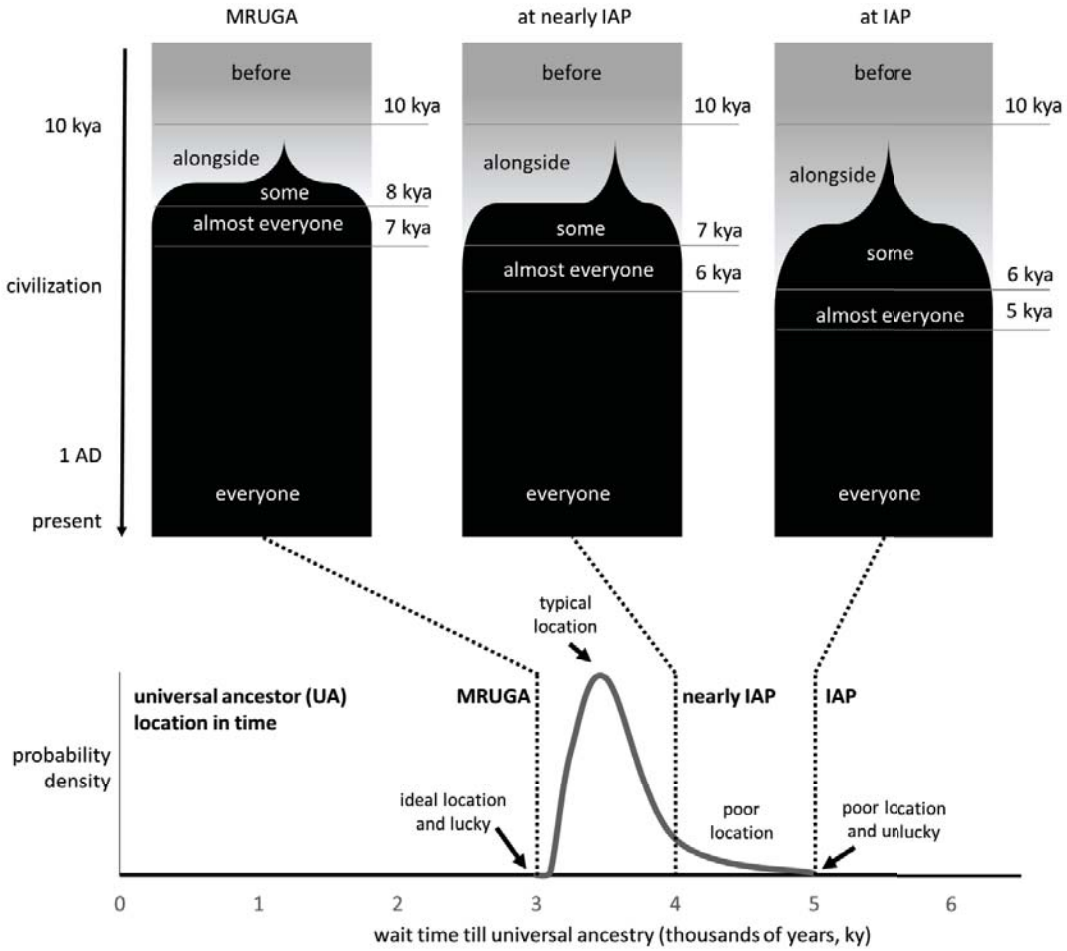

Figure 4. Estimating the descendants of universal ancestors. Cartooned pedigrees show the estimated ancestors at the MRUGA, nearly IAP, and IAP points (top). Universal ancestors usually become universal in less than 4,000 years, before the nearly IAP (bottom). The most likely time that UGAs first arise in a region is well before the nearly IAP, so most of the recent UGAs have pedigrees with dates about halfway between MRUGA (top left) and the nearly IAP (top middle) pedigrees. There are four eras to consider in relation to any specific UGA. In the first era, there are only those *before* the ancestor. In the second era, there are many living *alongside* the descendants of the ancestor. In the third era, *almost everyone* is a descendant of the ancestor. The non-descendants are those in the most isolated populations. In the fourth era, *everyone* alive is a descendant of the ancestor.

A Genealogical View of Origins

We now turn to scientifically assessing several models of Adam that have been proposed in the literature by others. In this analysis, citation or explication of a model does not in any way imply endorsement. There will be intractable disagreement about the theological and hermeneutical merit of each model, but that is entirely beside the point. Our intention is merely to clarify what science does and does not say in these cases in the light of science. Those who find these models theologically flawed or hermeneutically unwarranted can and should take up their concerns with the advocates of these models. We, however, are focused exclusively on the relationship of these models to genealogical and genetic science.

Ancient Adam Models

Several models have been constructed with the goal of preserving genealogical descent from a particular individual named Adam.[70] Usually, this includes placing such an Adam as far back as y-MRCA, 200,000 or 100,000 years ago.[71] This move requires either abandoning the Genesis setting and narrative, or maintaining that agriculture arises tens of thousands of years before it appears in the archeological record.

However, if the goal is to preserve universal genealogical ancestry, then choosing an ancient Adam is unnecessary (fig. 5). As we have seen, an Adam situated just 10,000 years ago is estimated, based on this analysis, to be the universal ancestor of all those in recorded history. Taking this as far as it can go, a couple, Adam and Eve, situated just 6,000 years ago could be estimated to be the UGAs of all those alive in AD 1, before the ministry of Jesus of Nazareth begins, and before Paul's writes Romans with reference to Adam. It is possible that this couple might even be UGAs when Genesis was compiled,

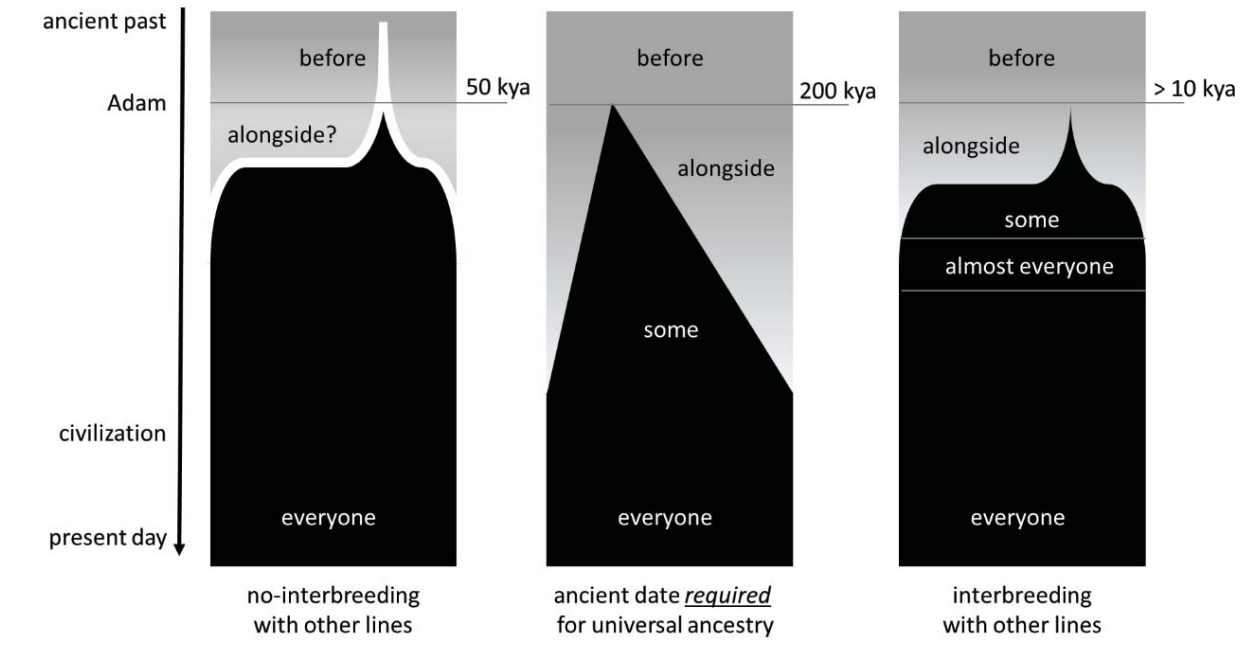

Figure 5: Ancient and recent ancestral models. Some models intend to include Adam as a universal ancestor and achieve this by placing him far back in time. In one model (left), Adam's descendants do not mix with other lines. In this case, the model is consistent with genealogical ancestry but is contradicted strongly by genetic evidence. Allowing for mixing with other lines fixes this problem. In another model (middle), Adam is placed about 200,000 years in the past to match with y-MRCA. However, it is unnecessary to place Adam so far back (right), because genealogical ancestry converges in just thousands of years.

about 3,000 years ago. Of course, they would also be UGAs if they are located in the distant past alongside y-MRCA.[72]

Whether or not these moves are warranted is a separate question, but the science itself does not force an *ancient* universal ancestor on those who think a genealogical relationship to Adam is important. All that must be accepted is that Adam's line did mix with others, and that the findings of population genetics are our most accurate view of those "outside the garden" who become our ancestors too.[73] This appears to be the only way that population genetics presses on our understanding of Adam.

How these adjustments affect theology is a separate question. Scientifically, however, it is not necessary to place Adam in the distant past to preserve universal genealogical descent from him.

Recent Adam Models

Some scholars identify Adam as a Paleolithic farmer about 10,000 years ago in Mesopotamia, alongside a larger population of *Homo sapiens*.[74] This model was offered by Derek Kidner and John Stott.[75] Their motivation for placing Adam here is to preserve the setting and chronology of the Genesis accounts.

This model is often coupled with the "representational" or "headship" model of original sin, in which sin spreads to all humankind independent of a genealogical connection to Adam.[76] It is asserted that a farmer situated 10,000 years ago could not be

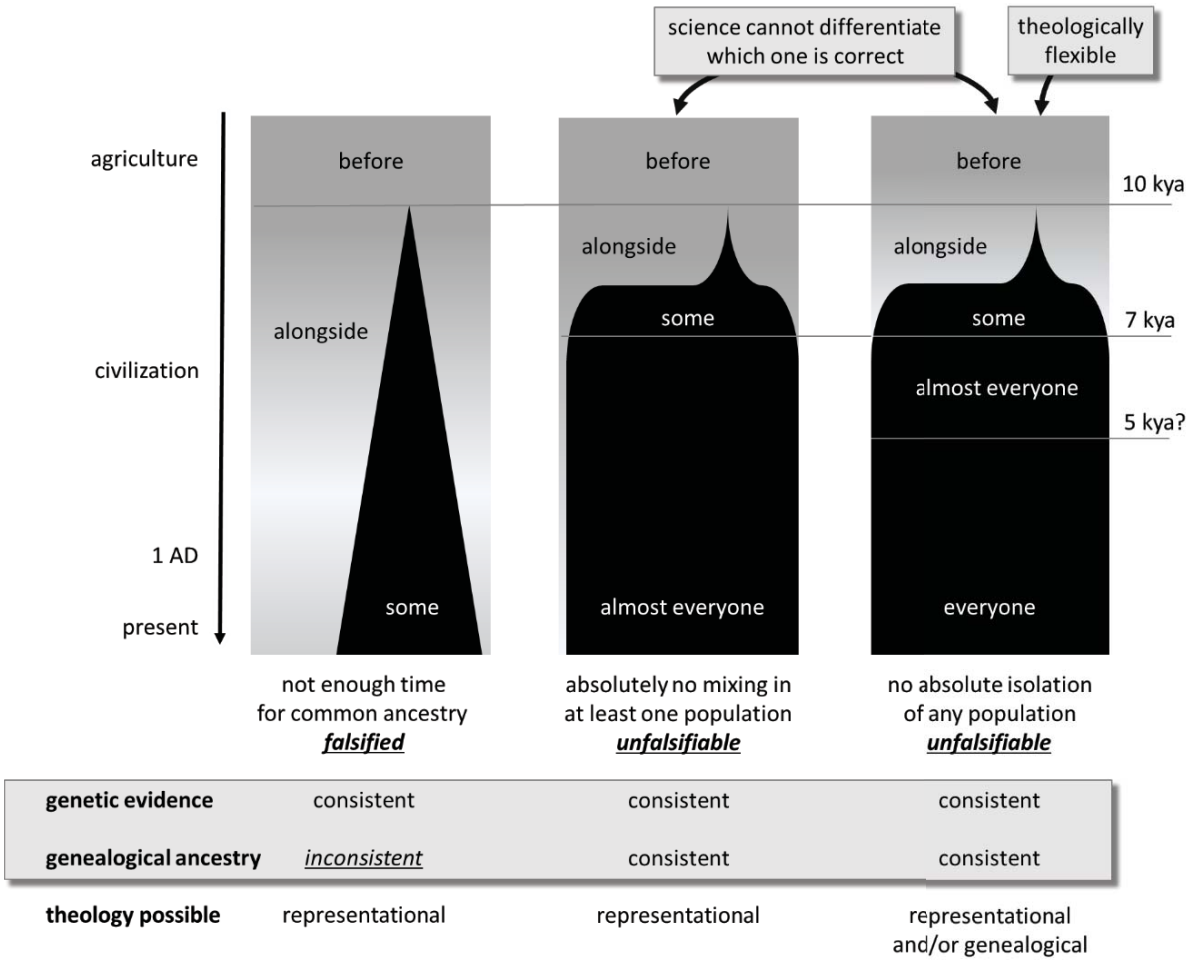

Figure 6. Recent representational models. It is commonly thought that, if a particular person named Adam lived 10,000 years ago, there was not enough time for him to be a UGA (left). Consequently, a genealogical relationship to such an Adam seems ruled out by science. Representational theologies circumvent this problem by passing original sin from Adam to all of us without a genealogical relationship. Whether or not a representational view of Adam is correct, the scientific reasoning is in error. Two alternate models are possible (middle and right); both are consistent with scientific knowledge, both are consistent with representational theology, but one (right) is consistent with genealogical theology. It appears impossible to scientifically differentiate between the two models; both depend on absolute negatives, which are very difficult or impossible to prove.

a universal ancestor.[77] Consequently, theology that includes descent from Adam seems inconsistent with this scenario. A commonly offered solution is a representational model of original sin, which does not depend on descent from Adam. As we have seen, however, it is a scientific error to maintain that recent Adam models are incompatible with a universal genealogical descent from Adam (fig. 6).

Mesopotamia is a location from which we might expect universal ancestors to arise quickly. From the birthplace of civilization, descendants of a particular Adam could have spread, by riding the population boom of the agricultural revolution, to the remote corners of Europe, Asia, Australia, Africa, and the Americas. When recorded history begins about 6,000 years ago, everyone alive might already have descended from him. Moreover, the date of 10,000 years ago is merely an estimate, and could be revised earlier. Adam might be placed in the Gulf Oasis at 12,000 years ago,[78] while keeping all the essential details of the model fixed. Placing him this far back would make universal ancestry even more certain. Only a population that is genealogically isolated for thousands of years would prevent universal ancestors, and genealogical isolation of this type is unobservable. Consequently, it is likely in this model, under plausible assumptions, that we could all have descended from a particular couple. Of course, whether this possibility is important theologically cannot be answered by science.

Conclusion

This newly found theological freedom in the scientific account is an invitation to science-engaged theology. New evolutionary scenarios are possible.

Those who find theological significance in a genealogical connection to Adam are invited to consider important questions. How should we think of beings "outside the garden," even if they remain in our distant past? A genealogical Adam affirms *monophylogeny* in the present day, but how theologically coherent is a history with other beings alongside Adam? It is also surprising that genealogical ancestors are not usually genetic ancestors. In what way, then, could genealogical relationships, nonetheless, be theologically meaningful for doctrines such as original sin?

These theological questions aside, more care is needed in stating the findings of science. Our ancestors arise as a population, not as a single couple, and they share ancestry with the great apes. However, at the same time, there are also many universal ancestors and potentially ancestral couples, each individually from whom we all descend.

Acknowledgments

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Notes

[1]F. J. Ayala et al., "Molecular Genetics of Speciation and Human Origins," *Proceedings of the National Academy of Sciences of the USA* 91, no. 15 (1994): 6787–94, https://doi.org/10.1073/pnas.91.15.6787; Scott McKnight and D. R. Venema, *Adam and the Genome: Reading Scripture after Genetic Science* (Grand Rapids, MI: Brazos Press, 2017); D. R. Venema, "Genesis and the Genome: Genomics Evidence for Human-Ape Common Ancestry and Ancestral Hominid Population Sizes," *Perspectives on Science and Christian Faith* 62, no. 3 (2010): 166–78, http://www.asa3.org/ASA/PSCF/2010/PSCF9-10Venema.pdf; S. Schiffels and R. Durbin, "Inferring Human Population Size and Separation History from Multiple Genome Sequences," *Nature Genetics* 46 (2014): 919–25, https://doi.org/10.1038/ng.3015; H. Li and R. Durbin, "Inference of Human Population History from Individual Whole-Genome Sequences," *Nature* 475 (2011): 493–96, https://www.nature.com/articles/nature10231; P. Soares et al., "Correcting for Purifying Selection: An Improved Human Mitochondrial Molecular Clock," *American Journal of Human Genetics* 84, no. 6 (2009): 740–59, https://doi.org/10.1016/j.ajhg.2009.05.001; D. L. Wilcox, "Genetic Insights for Human Origins in Africa and for Later Neanderthal Contact," *Perspectives on Science and Christian Faith* 66, no. 3 (2014): 140–53, http://www.asa3.org/ASA/PSCF/2014/PSCF9-14Wilcox.pdf.

[2]D. Alexander, *Creation or Evolution: Do We Have to Choose?* (Oxford, UK: Monarch Books, 2008); D. B. Haarsma and

L. D. Haarsma, *Origins: Christian Perspectives on Creation, Evolution, and Intelligent Design* (Grand Rapids, MI: Faith Alive Christian Resources, 2011); and C. J. Collins, *Did Adam and Eve Really Exist? Who They Were and Why You Should Care* (Wheaton, IL: Crossway, 2011).

[3]The terms are pluralized to emphasize that this is a large group of individuals. They are lowercase letters to emphasize that they are not all "Adam" and "Eve."

[4]Haarsma and Haarsma, *Origins;* Collins, *Did Adam and Eve Really Exist?*; J. H. Walton, *The Lost World of Adam and Eve: Genesis 2–3 and the Human Origins Debate* (Downers Grove, IL: InterVarsity Press, 2015); and J. B. Lumpkin, *The Books of Enoch: The Angels, the Watchers and the Nephilim* (Blountsville, AL: Fifth Estate Publishers, 2009).

[5]C. Wiuf and J. Hein, "On the Number of Ancestors to a DNA Sequence," *Genetics* 147 (1997): 1459–68; and S. Gravel and M. Steel, "The Existence and Abundance of Ghost Ancestors in Biparental Populations," *Theoretical Population Biology* 101 (2015): 47–53, https://doi.org/10.1016/j.tpb.2015.02.002.

[6]J. K. Pace II and C. Feschotte, "The Evolutionary History of Human DNA Transposons: Evidence for Intense Activity in the Primate Lineage," *Genome Research* 17 (2007): 422–32, https://doi.org/10.1101/gr.5826307.

[7]J. Lachance, "Inbreeding, Pedigree Size, and the Most Recent Common Ancestor of Humanity," *Journal of Theoretical Biology* 261, no. 2 (2009): 238–47, https://doi.org/10.1016/j.jtbi.2009.08.006; and Gravel and Steel, "The Existence and Abundance of Ghost Ancestors in Biparental Populations."

[8]This is an estimate of the *minimum* number of UGAs in a class of scenarios. The bias of almost every number chosen drives the estimate downward. Some of the terms here will be unclear at this point, but will be defined in later sections. If we expect Adam to be the common ancestor of all those alive at AD 1, a very ancient estimate of the identical ancestor point might be 20,000 years ago. If we want Adam to be a *Homo sapiens*, there is uncertainty in knowing when our species arises. To keep the math simple for illustrative purposes, we might assert that Adam appears sometime after 320,000 years ago. To produce a cautious estimate, we would use the effective population size of 10,000 individuals per generation and 30 years per generation; simple arithmetic brings us to 100 million UGAs: $10K\,(320K - 20K)\,/\,30$.

[9]D. L. T. Rohde, S. Olson, and J. T. Chang, "Modelling the Recent Common Ancestry of All Living Humans," *Nature* 431 (2004): 562–66, https://doi.org/10.1038/nature02842; and D. L. T. Rohde, "On the Common Ancestors of All Living Humans" (2003), https://tedlab.mit.edu/~dr/Papers/Rohde-MRCA-two.pdf. *Author's note:* This is a non-peer-reviewed web supplement.

[10]For example, there are approximately 160 generations between 10,000 and 5,000 years ago. Naïvely assuming that all ancestors are unique, we can compute the number of ancestors alive 10,000 years ago from the population at 5,000 years ago, 18 million people (see K. Klein Goldewijk, A. Beusen, and P. Janssen, "Long-Term Dynamic Modeling of Global Population and Built-Up Area in a Spatially Explicit Way: HYDE 3.1," *The Holocene* 20, no. 4 [2010]: 565–73, https://doi.org/10.1177/0959683609356587); we arrive at about 2×10^{55} ancestors, more than the number of stars in the universe. However, there were just 2 million people alive 10,000 years ago. The naïve calculation, therefore, double counts by a stunning 10^{49} times per ancestor. In a random mating model, this high degree of double counting gives rise to UGAs in less than 700 years.

[11]J. T. Chang, "Recent Common Ancestors of All Present-Day Individuals," *Advances in Applied Probability* 31, no. 4 (1999): 1002–26, https://doi.org/10.1017/S0001867800009587.

[12]Ibid. The *identical ancestor point* arises in about $1.77 \log_2 N$ generations.

[13]Rohde, Olson, and Chang, "Modelling the Recent Common Ancestry of All Living Humans"; Rohde, "On the Common Ancestors of All Living Humans."

[14]Lachance, "Inbreeding, Pedigree Size, and the Most Recent Common Ancestor of Humanity"; and Rohde, Olson, and Chang, "Modelling the Recent Common Ancestry of All Living Humans."

[15]Lachance, "Inbreeding, Pedigree Size, and the Most Recent Common Ancestor of Humanity."

[16]J. Kelleher et al., "Spread of Pedigree versus Genetic Ancestry in Spatially Distributed Populations," *Theoretical Population Biology* 108 (2016): 1–12, https://doi.org/10.1016/j.tpb.2015.10.008.

[17]Rohde, Olson, and Chang, "Modelling the Recent Common Ancestry of All Living Humans."

[18]J. Hein, "Human Evolution: Pedigrees for All Humanity," *Nature* 431 (2004): 518–19, https://doi.org/10.1038/431518a; P. Donnelly et al., "Discussion: Recent Common Ancestors of All Present-Day Individuals," *Advances in Applied Probability* 31 (1999): 1027–35, https://doi.org/10.1017/S0001867800009599; and J. T. Chang, "Reply to Discussants: Recent Common Ancestors of All Present-Day Individuals," *Advances in Applied Probability* 31 (1999): 1036–38, https://doi.org/10.1017/S0001867800009605.

[19]Wiuf and Hein, "On the Number of Ancestors to a DNA Sequence"; and Kelleher et al., "Spread of Pedigree versus Genetic Ancestry in Spatially Distributed Populations."

[20]Wiuf and Hein, "On the Number of Ancestors to a DNA Sequence"; and Gravel and Steel, "The Existence and Abundance of Ghost Ancestors in Biparental Populations."

[21]Gravel and Steel, "The Existence and Abundance of Ghost Ancestors in Biparental Populations."

[22]Kelleher et al., "Spread of Pedigree versus Genetic Ancestry in Spatially Distributed Populations"; and C. D. Huff et al., "Maximum-Likelihood Estimation of Recent Shared Ancestry (ERSA)," *Genome Research* 21 (2011): 768–74, https://doi.org/10.1101/gr.115972.110.

[23]M. C. Whitlock and D. E. McCauley, "Indirect Measures of Gene Flow and Migration: $F_{ST} \neq 1/(4Nm+1)$," *Heredity* 82 (1999): 117–25, https://doi.org/10.1038/sj.hdy.6884960; and J. Wang and M.C. Whitlock, "Estimating Effective Population Size and Migration Rates from Genetic Samples over Space and Time," *Genetics* 163, no. 1 (2003): 429–46, http://www.genetics.org/content/163/1/429.

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[25]This is a turn of phrase that does not require that Adam exist or that there be a garden. Instead, it refers to those outside a UGA's line.

[26]Lachance, "Inbreeding, Pedigree Size, and the Most Recent Common Ancestor of Humanity"; Chang, "Recent Common Ancestors of All Present-Day Individuals"; and Kelleher et al., "Spread of Pedigree versus Genetic Ancestry in Spatially Distributed Populations."

[27]Rohde, Olson, and Chang, "Modelling the Recent Common Ancestry of All Living Humans"; and Rohde, "On the Common Ancestors of All Living Humans."

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[43]Collins, *Did Adam and Eve Really Exist?*

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[56]In the simulations, these last 2 to 5% were people in Australia and the Americas (see Rohde, "On the Common Ancestors of All Living Humans"). At the nearly IAP, central locations like Mesopotamia have reached the IAP. Put another way, at the nearly IAP, essentially all individuals in Mesopotamia that left descendants are UGAs.

[57]Rohde, Olson, and Chang, "Modelling the Recent Common Ancestry of All Living Humans."

[58]Rohde, "On the Common Ancestors of All Living Humans."

[59]Chang, "Recent Common Ancestors of All Present-Day Individuals."

[60]Kelleher et al., "Spread of Pedigree versus Genetic Ancestry in Spatially Distributed Populations."

[61]Rohde, Olson, and Chang, "Modelling the Recent Common Ancestry of All Living Humans"; and Rohde, "On the Common Ancestors of All Living Humans."

[62]As the simulation author notes, "the [nearly IAP] and the [IAP] are separated by perhaps 1000 years" (see Rohde, "On the Common Ancestors of All Living Humans").
[63]The logarithm base 2 of 1 billion people computes to 30 generations; this number times 30 years per generation gives us about 900 years up to MRUGA.
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Luke Jeffrey Janssen

Article

"Fallen" and "Broken" Reinterpreted in the Light of Evolution Theory

Luke Jeffrey Janssen

The church has long discussed the nature of the human-divine relationship. A key point of contention has been what it might mean to say that humans are "fallen" or "broken" creatures, heirs of original sin. As science brought clarity and a new model to church leaders disputing the relationship between Earth and heaven (Copernicus, Galileo, and the heliocentric theory), might biological evolution and other naturalistic processes provide a new understanding of humans as "fallen" or "broken"?

Too often science and theology have been treated as being in conflict.[1] Many other people feel that they address completely distinct questions and use entirely different language and presuppositions. Both sides too often culture a hostile attitude to the other. But do we need to see things as a science-*versus*-faith debate? Can it not be a science-*and*-faith dialogue?

Many scholars are ardent Christians who use both science and theology to shape their worldview. Even certain prominent non-Christian scientists find value in both disciplines when addressing some of life's hardest questions. Stephen Jay Gould, for example, suggested that religion and science occupy "nonoverlapping magisteria" which

> bump right up against each other, interdigitating in wondrously complex ways along their joint border. Many of our deepest questions call upon aspects of both for different parts of a full answer.[2]

Likewise, Einstein saw religion and science as occupying two opposite poles of a spectrum, but nonetheless also said, "Science without religion is lame; religion without science is blind."[3]

The astrophysicist Robert Jastrow wrote:

> At this moment it seems as though science will never be able to raise the curtain on the mystery of creation. For the scientist who has lived by his faith in the power of reason, the story ends like a bad dream. He has scaled the mountains of ignorance; he is about to conquer the highest peak; as he pulls himself over the final rock, he is greeted by a band of theologians who have been sitting there for centuries.[4]

A key tenet in many strands of Christian theology holds that humans are "fallen creatures" and "broken image-bearers"; we have become separated from God. Here, I will explore how the modern theory of biological evolution might bring an insightful perspective to those ideas.

Were Humans Ever Perfect to Begin With?

The terms "fallen" and "broken" derive from a reading of the third chapter of Genesis. That event is said to have fundamentally changed humans—triggering some form of death within us (Rom. 5:12)—and unleashed a series of curses on all of nature (Gen. 3:14–19). Even "Old Earth" Christians who are able to embrace a much longer timeline

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for creation (theistic evolutionists or evolutionary creationists), with various forms and degrees of evolution over millions of years, will still frequently refer to our "fallen nature."

"Fallen" suggests that humans were once perfect or nearly so, and suddenly became much less than that. Something cannot be "fallen" if it was not first at a higher level; it cannot be "broken" unless it was once more whole or perfect. That implication may be consciously asserted and vigorously defended, or may be entirely subconscious, but it is still there nonetheless. And yet the facts staring us in the face inform us that *humans were never perfect to begin with*: an abundance of data documents a very protracted and gradual upward trajectory of evolution from very simple life forms eventually to a whole family of hominids, from which the human line became unique among our extant hominid cousins (chimpanzees; gorillas; orangutans) and extinct hominin cousins (Neanderthals; Denisovans; *Australopithecus*).[5]

It goes without saying that we were never perfect physically. Through comparative biology and genetics, we are able to trace many aspects of our biology and physiology which are improvements on previous designs, and yet, in some cases, are still far from perfect. Notwithstanding the Psalmist's claim that we are fearfully and wonderfully made (Ps. 139:14), certain aspects of our design are arguably flawed. Some interpret certain of these design flaws as corruptions which occurred following the Cosmic Fall: products of a "broken" design. These include proviral insertions, pseudogenes (such as olfactory receptors) and disrupted genes (L-gulono-γ-lactone oxidase for making vitamin C), or uncontrolled cell growth leading to cancer.[6]

Other design flaws, however, are much more difficult to attribute to the Fall event, such as the convergence of the trachea and the esophagus.[7] That design leads to increased morbidity for some people (for example, those with diseases which rob them of adequate control over their skeletal muscle forcing them to always struggle against accumulation of saliva in their airways, or those who have stomach acid spilling over into their airways producing various respiratory complications), and horrible mortality for others (those who drown at the beach, or choke on a piece of food lodged in their airway). That design cannot be easily explained by some kind of post-Fall modification, since we find it in every kind of animal right down to simple worms, and can explain it by simple coaptation:[8] primitive animals, many hundreds of millions of years ago, becoming sufficiently large and complex as to require a tubular system for bringing oxygen into the deeper parts of their bodies, modified an already-existing tubular system for ingesting foods and liquids, to that purpose. A similar argument can be made about the life-threatening manner in which babies are born, a process which could have been accomplished in many other ways than passage through the birth canal or inlet of the mother's pelvis, but which evolution solved by again coapting other existing structures.

It is also evident that we were never perfect intellectually. We have abundant evidence within archaeological artefacts of the development of human technology: stone tools, shelters, agriculture, jewelry, medicine.[9] Linguistics can shed light on the gradual development of speech and writing.[10]

We also have evidence that we were never perfect in a theological sense but, rather, evolved gradually in that respect as well. Humans, and possibly also Neanderthals, performed ritual burials as far back as one hundred thousand years ago in a manner that suggested a belief in an afterlife:[11] certain bodies either were carefully laid out with arms crossed, or were bound up in a fetal position, rather than being discarded haphazardly. They were buried together with tools, jewelry, food items, or, in some cases, with other individuals who would appear to be their loved ones.

In the more recent past, we find hand-crafted representations of what appear to be deities—Venus-like figurines, fertility gods, sky gods, gods of war—some of which have been dated as far back as sixty thousand years.[12] In Göbekli Tepe in Turkey, we have temple ruins which have been dated to twelve thousand years ago,[13] and other religious/temple structures nearly that old from ancient Babylon and Egypt as well as Stonehenge in Great Britain.[14] It is only *after* humans had developed these religious items and religious structures that we find the first evidence of writing and languages, and only *after* the appearance of polytheistic literature from the Akkadians, Sumerians, Egyptians, and others in the Ancient Near East that we see the first examples of the monotheistic literature of Judaism and Zoroastrianism, which, in turn, are followed quickly by

a dizzying array of Christian and Islamic theologies. During the same period of human history, we see the development of various mystic religious lines of thinking in the Far East—Confucianism, Taoism, Shintoism, Hinduism, and Buddhism—as well as countless versions of tribal and regional religions throughout the world wherever humans settled.

Finally, we were never morally perfect. We descended down a long line of ancestors whose core moral value was put-number-one-first. The recent discovery of a 430,000-year-old cranium bearing markings of localized blunt force trauma indicates that "lethal interpersonal violence is an ancient human behavior."[15] At what point along this millennia-long continuum could it be said that humans as a species were given a moral law and became morally culpable? Or did we gradually accumulate a moral code? We will return to these questions later in this article.

Given all this evidence that *we were never perfect to begin with*, how can we continue to hold to any tenet which is based upon the idea of humans as once perfect and now "fallen" or "broken" from that perfection? Below, I will argue that humans have not fallen from perfection, but from potential; not from the ideal, but from what could have been.[16]

Scientific Attempts to Reinterpret the Fall

Humans were never perfect anatomically, intellectually, theologically, or morally. On the contrary, we have been on an ascending trajectory in *all* these respects. The only possible sense in which we can claim that humans might once have been perfect would be spiritually, although here it might be better to use the word "alive" rather than "perfect." When and how could that important event have happened within our evolutionary history?

A common Christian answer has been that this occurred when God breathed life into his image-bearer six thousand years ago. As scientific evidence began to mount up against this timeline, some simply extended it to fifty or even one hundred thousand years while still maintaining that a primal pair were specially created and had not descended from a predecessor species.[17] That point in our past history may have been chosen, in part, to accommodate both the limitations of carbon-based radiometric dating (which becomes unreliable, and therefore is not used beyond that length of time) and the fact that humans seem to have experienced a form of "cultural big bang" at that time,[18] which some mistakenly equate with humans being granted the *imago Dei*. However, this does not account for the abundant scientific data indicating humans as a species never numbered less than several thousand[19] and are highly genetically related to the chimps, gorillas, orangutans, Neanderthals, and Denisovans.[20]

Others, therefore, will accept the standard evolutionary model, but will posit that God chose, approximately forty-five thousand years ago from those hominids, a primal pair whom he then "refurbished," endowing them with his image and a soul and thereby creating the first two true humans.[21] However, this is still quite problematic.

First, this accommodation is not founded on *any* scientific evidence whatsoever but, rather, on a concordist interpretation of the second chapter of Genesis (concordism is the view that biblical texts will reveal or contain certain elements of modern science[22]). Another reason some insist upon a primal pair is to preserve the theological concept of the federal headship of Adam: that is, that all humans inherit death and a sinful nature by virtue of having descended from an "Adam and Eve" who rebelled in some way against God. Once again, however, the genetic data strongly disconfirm the idea that all humans descended from a primal pair, and death has been with us for billions of years.

Second, this insistence on a "refurbished" primal pair raises considerable theological, missiological, and ethical problems, given that they would be surrounded by large numbers of their peers who would be quite able to interbreed and co-evolve with their non-"refurbished" cousins. This raises a particularly troubling conundrum if sin and spiritual death are inherited down familial lines:

> Missionary strategists would be put in the very uncomfortable position of identifying those groups of anatomically modern "people" who are not descendants of Adam and Eve and thus not really human … As non-image-bearers, such "peoples" are therefore not sinners and are ineligible for salvation. They do not need it. Missionary activity among such groups is unnecessary. We do not evangelize non-humans.[23]

Davis Young also rightly asks what might be the status of the descendants of the half-Adamites if interbreeding occurred between the chosen and not-chosen tribes. We already know humans interbred with Neanderthals and Denisovans.[24] We even have a specimen from a human male who lived forty thousand years ago and whose ancestors included a Neanderthal only four to six generations prior to his own birth.[25] Or what of those who were only one-quarter Adamites, or only one-eighth human? And so on? Would these be only partially spiritually alive? Would they be only partially culpable in Adam's sin of rebellion? Admittedly, all of these questions are valid only if our fallenness is inherited in some way akin to genetic inheritance. That quasi-genetic transmission of sin and guilt is exactly what Augustine and Calvin argued for, and some of their modern-day followers still maintain that concept without explaining precisely how that kind of inheritance might work; it is just assumed.

On the other hand, can one set aside the concept of a literal primal pair, and instead allegorize the Fall narrative even further to refer to all humans existing throughout all of time? At what point in human history do we draw a line between human and not human? There is no distinct point at which one can go back and define one generation as distinctly human and the previous generation as distinctly not human, so there would be a seemingly infinite regress as the line of inclusion blurred to also encompass Neanderthals, Denisovans, *Australopithecus*, and other hominins.

Third, when and where does one draw the line at which humans were collectively given a divine law, with a clear choice to obey or disobey—and collectively failed? Some might try to find the answer for this in natural or general revelation (Rom. 2:14–15). However, the latter can be quite imprecise. A beautiful starry night or an intricate ecosystem can certainly inspire awe and a strong sense that "there is a God." But they do not project the clear divine command that there is *only one* God, or that it would be wrong to envision and worship multiple gods. Likewise, thoughtful introspection of the influence our actions have on others and listening to our conscience will point us in the right direction(s) on certain decisions but not necessarily toward discrete commandments such as "do not bear false witness" (sometimes it seems that public peace is better kept by distorting the truth or even by blatant lying) or "keep the Sabbath holy," let alone the hundreds of other laws clearly given within the Pentateuch. Furthermore—to counter the Pauline passage quoted above—many "Gentile" societies have also condoned practices which are forbidden by the Law but *which seemed natural and appropriate to them,* such as infanticide, human sacrifice, polygamy, and revenge killing. So, can one say that natural revelation provides a clear commandment(s) that all humans have broken, and thereby justify the use of the terms "fallen" or "broken"?

Does the Bible Teach That Adam Was Perfect before the Fall?

While Genesis does teach that God's creation was "very good" (Gen. 1:31)—"*tov me'od*" in Hebrew[26]—this does not mean that it was all as good as it possibly could have been. For those who take *tov me'od* to mean perfect, beautiful, and blissful, Genesis also describes a garden which featured a prowling deceptive serpent determined to pit humans in rebellion against God, and humans who were capable of rebelling. For those who take *tov me'od* to mean "working the way it was created to be or to function," the Garden had an Adam who grew to be lonely and possibly jealous of the other animals since they had a partner but he did not: after deeming everything *tov me'od*, God later says it is "not *tov*" that "the adam" should be alone.

Also, Hebrew scripture does not emphasize the story of the Fall as the *source* of sin within the human race.[27] Other than in the first five chapters of Genesis, the Old Testament refers to "Adam" as a person only once (and does so merely as the opening line in a long genealogy; 1 Chron. 1:1), and as a geographical location two other times (Josh. 3:16; Hos. 6:7),[28] while Eve and the Fall in the Garden incident are never mentioned again (although some Apocryphal literature refers to them[29]). Jesus never mentioned Adam or Eve or the Fall as the root of the biggest problem facing humans. Jesus did indeed allude to the newly created humankind (Matt. 19:4–6), but the passages he quoted refer to humankind in general, not to two individuals: he referred to "an adam" leaving his father and mother and being united to his wife, but "Adam" did not have a mother, nor *leave* his father when he was joined to Eve. Jesus was instead speaking generally, and was addressing a sociological

matter—divorce and marriage. Those who apply this passage to Adamic genealogy, ancient human history, or original sin take his words out of context. Paul is the only biblical author who refers to the Fall-in-the-Garden story of Genesis 3.[30]

This scriptural silence would be a tremendous oversight if the biblical authors saw Adam and Eve as the source of "original sin" or a "fallen nature." According to the *Universal Jewish Encyclopedia*:

> Judaism rejects this idea of inherited depravity, and the idea of a "Fall" has never become current in Jewish theology … Judaism has no doctrine of original sin in the Christian sense … *The Apocrypha* and *Pseudepigrapha* are the first to cite the Fall of Adam and Eve as the cause of death and other human evils.[31]

This is not to say that the ancient Hebrews did not see humans as having any kind of sin at all. Nearly every Old Testament book refers in some way to sin or sinfulness, and many refer to sacrifices and practices which were prescribed to address those problems. But none link those prescriptions back to Adam or Eve or the Fall in the Garden. Some of the Psalms (Pss. 78; 95:7–11; 106:6–43) and the prophets (Neh. 9:7–37; Isa. 63:7–15; Ezek. 20:5–44) refer to the nation of Israel testing God after leaving Egypt, but none refer to the Garden story. They certainly saw human righteousness paling in comparison to that of YHWH, but they did not see humans as having once been perfect. Instead, Judaism traces sin back to Israel's rebellion at Mount Sinai.[32]

The Moral Influence Theory of Atonement

When astronomers led by Galileo presented to the church scientific evidence that contradicted their model of the universe, a model that was supported by their interpretation of numerous and diverse passages of scripture and by two millennia of church tradition,[33] Cardinal Robert Bellarmine acknowledged that it was necessary to revisit that aspect of theology and "proceed with great care in explaining the scriptures that appear contrary, and say rather that we do not understand them than that what is demonstrated is false."[34] Perhaps we can learn from this precedent and now apply it to another theological concept which is supported by numerous scriptural passages and two millennia of church tradition.

Given that neither scientific evidence nor ancient Hebrew theology support the view that humans are "fallen" or "broken" in the traditional theological sense of those terms, and given the theological variety of atonement models, perhaps it is time to emphasize a model that is compatible with the wider body of evidence now available to us. The moral influence theory is not a new idea: it is as old as Christianity itself. It was universally taught during the first three centuries,[35] and was the primary view of many influential theologians from the Patristic period, including Augustine.[36]

In essence, the moral influence theory teaches that God desires a positive moral change in the hearts of individuals, and he wants to transform human societies to become more loving. God nurtured this change in part by providing the Old Testament laws and the teachings of the prophets, and ultimately modelled it in the life example and teachings of Jesus Christ himself. Jesus, then, becomes the ultimate example to us: "the Way" to the Father (John 14:6).

This theological view is consistent with the arc of human history as seen through the lens of biological evolution. Consider the long-held view of a Fall, on the one hand, juxtaposed, on the other hand, against a modern view which combines moral influence theory (a very old idea) and evolution theory (a new idea). These two distinct views begin from the same starting point. Both agree that (1) God exists and embodies pure love, and for this reason desires relationship; (2) God created all things, including humans with whom he wants relationship; and (3) humans are currently imperfect beings. Despite these three general propositions in common, the two alternatives subsequently diverge radically.

The Fall viewpoint adds the proposition that humans have "fallen" from a more perfect state, and are simply unable to attain God's high expectations of perfection because of our inherent human faults and limitations. Some go on to emphasize that humans are therefore destined for eternal destruction—a few even add eternal conscious torment—but for God's compassion in the form of the saving act of Jesus Christ. God makes provision for our salvation, but it is up to us to accept his gift of grace (a few even insist that it needs to be a *verbal* acknowledgment). And yet God cloaks himself in nearly impenetrable obscurity, and we are incapable of relating to him directly, such that many feel compelled to conclude that there is

no God to begin with. Some who nonetheless choose to persist in theistic belief still struggle against their own human faults and limitations and continually experience failure, guilt, doubt, and a sense of separation; others give in to the seeming futility of resisting. All of these statements paint a frustrating scenario in which humans are doomed to fail.

In contrast, combining moral influence theory with biological evolution theory disputes that we were ever perfect to begin with, or that God condemns us for our innate imperfection. Instead, it takes for granted that we evolved from very simple and imperfect forms, and that God saw his own image beginning to form and beckoned us closer to his perfection. God created all things using natural mechanisms, including big bang cosmology, Newtonian mechanics, quantum physics, relativity, abiogenesis, and biological evolution. These processes are God ordained, and pregnant with the possibility of producing his image out of inanimate matter.

Our evolution was driven by instincts which were absolutely necessary to help us to survive the capricious forces of natural selection. Those forces were designed to push life forms from one level of complexity to the next. All life forms *needed* to be selfish. They (we) had to kill when threatened, had to hoard and steal resources (food, shelter, mates), had to view competitors in their ecological niche as "the enemy," and had to spread genes as far and wide as possible and as frequently as possible. Granted, conflict was not the only key to evolutionary success. In many cases, cooperation became a superior strategy. This is the idea behind the transition from prokaryotic life to eukaryotic life, in which certain cellular forms of life became incorporated into other forms of cellular life and ultimately produced organelles and a much more evolutionarily successful lifeform. It also explains social cooperation in insects (ants and bees), or between different species (certain fish and birds which clean parasites from other species, or consider also the powerful synergistic relationship between humans and dogs),[37] as well as altruism, empathy, and compassion.[38]

Life forms continued to become more complex biologically, intellectually, and behaviorally, eventually producing humans with cognitive abilities and instincts which drew us toward a Great Being: minds which always searched to find an Agent or an explanation behind every observation, and which possessed a theory of mind; the ability to ponder with abstract thought and to experience empathy and love; the use of rituals to solve problems; and the belief in an afterlife and a *sensus divinitatus*.[39]

These tools and abilities drew us toward the Divine. We can certainly consider how our ancestors gradually became aware of God, even if we cannot identify a punctiliar event in which we actually met God. As a species, we then embarked on a quest, stretched out over hundreds of thousands of years, in a driven search for God. We responded to an inner voice and searched to the best of our ability to understand the divine, and to make physical representations (statues and figurines) and structures (temples) dedicated to the Great Being. In the process, we began to perceive (and God revealed) his ideal: to stop being driven by the selfishness which was hammered into our psyches through millions of years of evolution, and to now culture a new driving force within ourselves: selflessness. He called for a complete course redirection—a "repentance"—to instead love, give, share, heal, and help. From this perspective, Romans 8:19–22 takes on a whole new meaning:

> For the creation waits in eager expectation for the children of God to be revealed. For the creation was subjected to frustration, not by its own choice, but by the will of the one who subjected it, in hope that the creation itself will be liberated from its bondage to decay and brought into the freedom and glory of the children of God. We know that the whole creation has been groaning as in the pains of childbirth right up to the present time.

That is, God created a primordial "cosmic egg" which exploded into a constantly evolving entity, exhibiting ever-increasing complexity despite the disruptive forces of entropy which short-circuited many changes (creation being "subject to frustration, not by its own choice, but by the will of the one who subjected it"). In this way, entropy constantly reshuffled the cards, removed dead ends, and cleared the slate for newer and greater increases in complexity, acting like a "Brownian ratchet." God intended/desired that ever-evolving creation to eventually produce beings which bear his image and with whom he would enjoy relationship. That is, creation would be "liberated from its bondage to decay (entropy) and brought into the freedom and glory of the children of God." Even creation itself seems to anticipate that end-goal: it "waits in eager expectation for the

children of God to be revealed." It was created for this purpose—*tov me'od*—a productive effort with which it has been engaged for millennia, "groaning as in the pains of childbirth right up to the present time."

It is at this point that we can introduce the Hebrew word *hata* and the Greek word *hamartia*, both of which are rendered by English translations of the Bible as "sin": both of those original biblical terms are metaphors borrowed from archery which literally mean "to miss the mark." Our human inheritance is not so much Adam's guilt, the Augustinian view, but rather the inability to fully achieve God's perfection, although God cherishes all our efforts to approach it. We were on an ever upward trajectory toward manifesting the image of God, only to "fall short" of our *full* potential and God's ideal for us.

Certainly we are inherently selfish, and we find it easy to ignore the less fortunate: that selfishness and indifference comes from millennia of simply competing and trying to survive. Likewise, our instinctive fear of "the other" produces racism, prejudice, xenophobia, and various forms of tribalism which are tearing apart our societies. A powerful inner procreative drive constantly seeds urges around which lustful thoughts crystallize. Humans do fall short of perfection in many ways. But according to the theory of evolution, we were never perfect to begin with—nor even nearly so. Nor did we originally have a perfect relationship with God from which we were suddenly separated and to which we need to be reconciled. Those faults, limitations, and undesirable characteristics are products of the mechanisms which were crucial to our development as a species, and which were put in place to bring us to this point in history. In that sense, those primitive characteristics and instincts were *tov me'od*: functioning as they were intended.

But God also showed us, through Jesus Christ, that it is possible to be free from the selfish driving force that we inherited from our evolutionary heritage. Jesus modelled for us a new driving force: perfect selflessness. Christ eschewed personal material wealth, the accumulation of personal property, and even personal security and comfort—even to the point of martyrdom. And we are called to do the same. He taught us to love supremely, to give, to heal, and to serve. When asked to define God's greatest commandment, Jesus answered simply:

> "Love the Lord your God with all your heart and with all your soul and with all your mind." This is the first and greatest commandment. And the second is like it: "Love your neighbor as yourself." All the Law and the Prophets hang on these two commandments. (Matt. 22:36–40)

Critics may challenge the idea that humans have been on an upward trajectory. They see the past century as the most violent ever, one in which hundreds of millions of people have been killed in violent conflict. Those numbers are not in dispute, but should be considered in the context of our population growth over the past few centuries: when the population size of the countries going to war increases, the numbers of fatalities will inevitably increase correspondingly. Also, our violent urges may not have changed over millions of years, but our ever-increasing technology enables us to do violence on bigger scales. More apropos, though, the critics should also consider the humanitarian efforts which are commonplace today—disaster-relief efforts, hospitals, education, peacekeeping missions—and which were rare just a few thousand years ago, and were arguably absent one hundred thousand years ago. Those recent humanitarian efforts are manifestations of the moral influence theory.

Recasting "the Fall" and "Fallenness"

Given the points above, one could challenge both the idea that humans were ever perfect to begin with, and the idea that we inherit the guilt of a rebellious act of a primal pair. And when one revises that latter claim by stating that we are all guilty of personal acts of rebellion against God, one might point to the fact that humans have actually, for millennia, been on a cosmic search to *find* the divine and therefore have not actually rebelled—*or have we?*

God gave prehistoric humans the cognitive tools to find him, as well as evidence that pointed to him in the heavens and in nature around them (Ps. 19:1–5; Rom. 1:20).[40] And as they began to sense the Great Being, they responded by creating images and temples. But did they do that to nurture a relationship with the divine, or to *contain* and *control* the divine? They made a sky god in order to ask it for rain, or sunshine, or other good conditions for growing crops; they wanted power over the weather. They made a god of war in order to gain superiority over

their enemies, a fertility god to give them children, and various other gods from which they could satisfy various needs and/or ward off various evils. God had begun to open their eyes and minds to a wonderful new relationship, and they turned it into a resource. Rather than humbly submit to the authority of the Great Being(s), they subverted the revelation and wrestled for control.

This is what we see metaphorically in Genesis: Adam and Eve were tempted to "be like God" and to gain something (wisdom) (Gen. 3:5–6). They were made in his image, to reflect him; instead, they chose to be in control.

The metaphor is repeated in the story of the Tower of Babel (Gen. 11:1–9). The people in the plain of Shinar endeavored to build "a tower that reaches to the heavens." They did this, not to meet with the divine, but to gain control over the chaotic dispersing forces (to "not be scattered over the face of the whole earth"), to create their own image ("make a name for ourselves"), and to gain something (prestige, honor, identity, national unity).

And we see it again in the Mount Sinai story in which the ancient Hebrews trace the origin of their *corporate* sinfulness. And what had they done? Only days after YHWH had led them out of Egypt, they made another god: the Golden Calf. In their minds, Moses and YHWH were taking too long and it was time to take control: Egypt was starting to look much better than Mount Sinai and the desert.

Even today, we, too, often turn God into a cosmic vending machine. Too many of our prayers ask God to change our circumstances ("God, please give us …" or "God, please help me to …"). In too many ways we try to hold God hostage to our own interpretation of his promises. When experiencing some kind of burden, we ask God to remove it rather than to give us stronger backs. When praying for someone in need, we ask *God* to do something rather than ask what *we* ourselves might do in his name and thereby manifest his image.

Certainly, as a species and as individuals, we have failed and continue to fail. We are well on the way to destroying each other and creation. And for that reason, we still need a Savior. Jesus represents a break in that pattern of human history: he was often tempted to take control, but chose submission and obedience instead (Luke 4:1–12; Matt. 26:39–42, 53; John 5:19; Heb. 5:8).

Our inheritance from Adam may not be so much the guilt of his "original sin"; rather, it may be the innate human tendency to be defiantly independent, selfish, and in control of our own circumstances and destiny. Our species has for many millennia been on an upward trajectory. However, we all continually fall short individually: sometimes by means of intentionally committed sin, but much more often through acts of omission—conscious or unconscious. Perhaps sin is not so much inherited or transmitted as it is echoed: we all resonate with Adam.

Science Coerces a Reconsideration of Fall Theology

For two millennia, the Western church has taught that humans are "fallen" or "broken" creatures, with an unhealthy emphasis placed upon a primal pair. Many found the focus upon sinfulness too oppressive, and the harsh picture of God painted by certain Christian theologies too difficult, such that they discard their faith. Meanwhile, the church is increasingly being confronted with evidence that humans evolved from a long line of hominid ancestors. Some may feel that the church today does not see tension between faith and science. However, as Roy Clouser wrote previously in this journal: "If these clergy and scholars have good reasons for thinking there is no such conflict, they have done an extremely poor job of communicating those reasons to the lay members of their churches."[41]

The data suggest that we have never been perfect by any definition: we never *became* "fallen" or "broken." Instead, they suggest that we have been on an upward trajectory, gradually evolving to a point from which we could embark on a spiritual search for God. As we pursued God, we perceived his ideals for perfection. When our thinking was still quite tribal, he showed us his ideal: a complete reversal of the fundamental driving force on which we base our thoughts and actions—from selfishness to selflessness. He modelled this ideal perfectly within the teachings and life example of Jesus Christ, who invited us to accept an internal change (Matt. 15:18–20, 23:25–26; Mark 7:20–23; Luke 11:39–41; Rom. 12:2): one aimed at our base instincts.

The scientific data now at hand pertaining to human evolution conflict with any theological worldview that is dependent upon the following:

(1) a "young earth," or a timeline of less than ten thousand years. This will be a minor point for some readers of this journal, but others do indeed still hold dogmatically to such a viewpoint;

(2) there being a primal pair. Again, many still attribute genetically transmissible qualities to sin and guilt without thinking through how that might work—or not work; and/or

(3) the human species receiving a discrete command regarding what God expects, and all humans having broken that command.

Instead, we should account for hard evidence, such as

(1) *Homo sapiens* appearing a couple hundred thousand years ago;

(2) humans being nearly genetically identical to other hominids who can be tied together on an evolutionary tree of life extending back millions of years;

(3) interbreeding between humans and other species (Neanderthals and Denisovans);

(4) the evolution of religious thinking and practices long predating the biblical texts; and

(5) a gradual evolution of morality and awareness of God.

Reframing Christian thinking may be difficult for some, even if they are convinced by the scientific data. In addition to centuries of church tradition, Paul's writings will likely be a barrier.[42] However, scripture itself gives abundant evidence for an evolution of Christian thinking. When Jesus began his ministry, he clearly announced that he was "sent only to the lost sheep of Israel" (Matt. 15:24), and he imposed the same limitation on his disciples (Matt. 10:6). So it is quite understandable that the early church might have acted as if the Gospel message were meant only for Jews. They continued to not understand (or not accept?) the Great Commission to preach the Gospel to all nations until Peter's vision of the blanket lowered down from heaven and the Council at Jerusalem, at which point they radically changed their theological worldview.

The early church continued to hold other firm convictions, some of them Pauline in origin or emphasis, which they began to relinquish by the end of the first century and which have long since been markedly revised. These include the Parousia and Eschaton occurring within their lifetime, prohibitions against meat offered to idols, stipulations about hair length that were thought to be blatantly evident within "the very nature of things," and the ecclesial role of women. Christianity continued to evolve beyond biblically recorded history. Paul's ideas were further developed during the Patristic era by Roman and Greek theologians who were thoroughly educated in Platonism, Stoicism, and Neoplatonism.[43] Their ideas were, in turn, reformulated during the Reformation by others having yet other motivations and worldviews. Clearly Christianity itself has been evolving, notwithstanding a central theological core which is unchanging and eternal.

Now there is a new impetus driving further change to our theology. None of the foregoing Christian thinkers had any information whatsoever about the evolution of humans. *But we do*, and therefore now we have the responsibility of finding a way to reconcile this knowledge with our theology. So, when Paul writes about sin and death entering the world through one man and of the trespass of that one man (Romans 5), or about a "first Adam" (1 Corinthians 15), or implies that Adam is guilty of a greater sin than "the woman" because she was only deceived but he willingly rebelled (1 Tim. 2:14), we have cause for reinterpretation of his teachings.

Believing scholars are increasingly taking up that challenge. The diversity and unanimity of their voices is important. Paradigm shifts are notoriously difficult to navigate, both within secular circles (the particle/wave nature of light, Newtonian versus quantum mechanics, epigenetics and biological evolution) and within theological circles (the birth of Christianity, the Reformation), as well as within the intersection between these two (heliocentric theory, human evolution). Many perspectives are needed to guide us safely through the rockier portions of the journey. This article is certainly not the first to appear within this journal addressing human evolution from a Christian perspective; the past two years alone have seen contributions within this journal from Lamoureux,[44] Clouser,[45] Wilcox,[46] Venema,[47] van den Toren,[48] Murphy,[49] Sollereder,[50] Berry,[51] and Davidson,[52] and there have been others in the more distant past.[53]

These contributions generally agree in certain respects: an emphasis on the starkly different worldview(s) of the human authors of scripture as compared to our own; caution regarding an overly literal reading of scripture and/or concordism; a call toward reconciling perceived tensions between science and faith; and a reassurance that accepting biological evolution does not require rejecting faith or the Bible. But each also focuses particularly upon different aspects and finer details of this critical and difficult discussion. Some weighed in much more heavily upon the biological mechanisms per se,[54] while others explored theological issues such as the *imago Dei*,[55] natural evil,[56] moral evil,[57] original sin,[58] suffering and redemption,[59] the historicity of Adam,[60] and "the Nephilim."[61] This article focuses specifically on the terms "fallen" and "broken," both of which are used ubiquitously in Christian discussions at both the lay level and within the academy.

In addition to such points of general agreement and other finer points of unique but complementary perspective, this multiplicity of papers also offers up striking differences. For example, Lamoureux sees Romans 8:19–22 as describing the Cosmic Fall and the subsequent appearance of natural evil (a downward trajectory and cataclysmic event), while I suggest that it can also refer to the process of human evolution itself prior to any putative Cosmic Fall (an upward trajectory and gradual process); Berry presents his own interpretation of this Pauline passage while quoting from several other theologians speaking specifically on the same passage, each with their own unique nuances.[62] This separation of views can be positive: it creates a safe space which is conducive to discussion and contemplation, and illustrates how a given passage can be understood in radically different ways. Lamoureux provides an amusing pictorial representation of this in his 2015 paper: Is it a rabbit or a duck?—or both![63] This is a characteristic of rabbinical Judaism, and was a technique employed by Jesus himself: "You have heard it said … but now I say …" It was also used by his apostles.

The many strands of agreement strengthen our discussion of human evolution from a Christian perspective, while the nuances/differences give it depth. This is essential whenever we explore new theological territory as scholars have been doing ever since the theory of evolution came up against Fall theology.

Conclusion

Humans are indeed "fallen," but not in the common sense of that theological term. We have not fallen from perfection, but from potential; not from the ideal, but from what could have been. We are called toward wholeness in right relationship with God and one another, and have been given the perfect example to follow. The scientific idea of biological evolution helps us to better see what God is doing.

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Notes

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[39]Justin L. Barrett, "Cognitive Science of Religion and Christian Faith: How May They Be Brought Together?," *Perspectives on Science and Christian Faith* 69, no. 1 (2017): 3–12, http://www.asa3.org/ASA/PSCF/2017/PSCF3-17Barrett.pdf.

[40]Many theologians refer to this as "General Revelation," in contrast to the "Special Revelation" given by Jesus and within scripture.

[41]Clouser, "Reading Genesis," 238.

[42]Romans 5, Romans 8, and 1 Corinthians 15.

[43]James B. Torrance, "Introduction," in J. McLeod Campbell, *The Nature of the Atonement* (Grand Rapids, MI: Eerdmans, 1996), 16.

[44]Denis Lamoureux, "Beyond Original Sin: Is a Theological Paradigm Shift Inevitable?," *Perspectives on Science and Christian Faith* 67, no. 1 (2015): 35–49, http://www.asa3.org/ASA/PSCF/2015/PSCF3-15Lamoureux.pdf; ___, "Beyond the Cosmic Fall and Natural Evil," *Perspectives on Science and Christian Faith* 68, no. 1 (2016): 44–59, http://www.asa3.org/ASA/PSCF/2016/PSCF3-16Lamoureux.pdf.

[45]Clouser, "Reading Genesis," 237–61.

[46]David L. Wilcox, "A Proposed Model for the Evolutionary Creation of Human Beings: From the Image of God to the Origin of Sin," *Perspectives on Science and Christian Faith* 68, no. 1 (2016): 22–43, http://www.asa3.org/ASA/PSCF/2016/PSCF3-16Wilcox.pdf.

[47]Venema and McKnight, "Adam's Last Stand?," 31–66.

[48]Benno van den Toren, "Human Evolution and a Cultural Understanding of Original Sin," *Perspectives on Science and Christian Faith* 68, no. 1 (2016): 12–21, http://www.asa3.org/ASA/PSCF/2016/PSCF3-16Toren.pdf.

[49]George L. Murphy, "Necessary Natural Evil and Inevitable Moral Evil," *Perspectives on Science and Christian Faith* 68, no. 2 (2016): 111–18, http://www.asa3.org/ASA/PSCF/2016/PSCF6-16Murphy.pdf.

[50]Bethany Sollereder, "Evolution, Suffering and the Creative Love of God," *Perspectives on Science and Christian Faith* 68, no. 2 (2016): 99–110, http://www.asa3.org/ASA/PSCF/2016/PSCF6-16Sollereder.pdf.

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[52]Gregg Davidson, "Genetics, the Nephilim, and the Historicity of Adam," *Perspectives on Science and Christian Faith* 67, no. 1 (2015): 24–34, http://www.asa3.org/ASA/PSCF/2015/PSCF3-15Davidson.pdf.

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[55]Wilcox, "A Proposed Model for the Evolutionary Creation of Human Beings," 2–43; Jeeves, "Neuroscience, Evolutionary Psychology, and the Image of God," 170–86; Garte, "Evolution and *Imago Dei*," 242–44; Berry, "Natural Evil," 87–98.

[56]Lamoureux, "Beyond the Cosmic Fall and Natural Evil," 44–59; Murphy, "Necessary Natural Evil and Inevitable Moral Evil," 111–18; Sollereder, "Evolution, Suffering and the Creative Love of God," 99–110; Berry, "Natural Evil," 87–98.

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[61]Davidson, "Genetics, the Nephilim, and the Historicity of Adam," 24–34.

[62]Berry, "Natural Evil," 87–98.

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George L. Murphy

Article

The Nuts and Bolts of Creation

George L. Murphy

The Christian doctrine of creation is discussed in connection with scientific knowledge of the universe, primary attention being given to God's ongoing activity in the world. We consider first the reason for Christian belief in such activity and the Trinitarian character of the Creator, using Irenaeus's picture of Word and Spirit as two "hands" through which God works. The traditional view that God cooperates with creatures in their actions is presented, with consideration of the idea of a "causal joint." This divine work is kenotic, with God always present and active, but limiting action to the capacities of creatures.

Having described God's creative work in our local space-time neighborhood, we follow the example of science and extrapolate our theological understanding out in space and back in time to see what God has been doing since the beginning of cosmic expansion. While this does not describe creatio ex nihilo, *it does enable us to understand the origins of entities such as the earth and living things that are included in the traditional "six days of creation." The origin of the universe "from nothing" is then considered, and we conclude with reflections on God's freedom to act in creation.*[1]

In 1980, this journal published my paper "A Positive Approach to Creation."[2] This focused on belief in God's origination of the universe and its relationships with scientific cosmology, and briefly discussed God's ongoing activity in the world. Its positive feature was a focus on contributions that the doctrine of creation could make to the science-theology dialogue rather than a reconciliation of science with traditional views.

As the present title suggests, the emphasis of that earlier paper is reversed here, with God's ongoing creative activity receiving the greatest attention. It will, however, explore connections between that ongoing activity and cosmic origins. Reference to "nuts and bolts" does not mean treatment of God's work as a matter of mechanics, something we will touch on in connection with the question of a causal joint. But I will say something specific about what God does locally, in individual phenomena, as well as globally.

The Hebrew bara`, translated "created" in Genesis 1:1, has only God as its subject in the Old Testament but does not always imply strict *creatio ex nihilo* and is not limited to the origin of the universe.[3] In the Christian theological tradition, God's ongoing work in the world has been discussed in connection with the first articles of the creeds that deal with God as Creator. Divine action can be called continuing creation without suggesting that the world is constantly remade from nothing.

God's ongoing creative activity is often referred to as "providence." The word has its origin in a phrase of Genesis 22:14, traditionally translated as "the LORD will provide."[4] As in that story of God

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providing a sacrifice to take the place of Isaac, attention to a doctrine of providence often concentrates on God's care for human beings. Examples are existentialist theologies, in which belief in creation is understood to simply mean faith that God is *my* Creator.[5] But scripture speaks of God's care for wild creatures quite apart from humanity (e.g., Job 39–41), and to speak of God as my creator I must be able to say that God acts in the world both to provide me with food and to empower a supernova billions of years ago to make the carbon atoms in my body. God's activity has cosmic scope.

We will begin with a fundamental question: What is the justification for speaking about divine action? We also need to ask, "Who is this 'God' who acts?" Until recently, the one who does so, in many discussions, could have been the deity of philosophical theism rather than the God revealed in Jesus Christ. Attention to a Trinitarian understanding of creation both globally, in the overall picture of God's work, and locally, in individual events, helps to clarify not only *who* acts, but *how* God acts in the world.

Why Should We Say That God Acts?

Since the work of Newton, the successes of science have led many people to think that discussion about divine action is superfluous. Science has not yet explained things such as dark matter and the origin of life. But there is no reason or principle for thinking that any phenomena in the natural world cannot be explained in terms of natural processes obeying rational laws. In a phrase popularized by Bonhoeffer, it seems possible to understand the world "though God were not given."[6]

But there is an old principle of Christian thought, *lex orandi, lex credendi* – "the law of praying is the law of believing." The way we pray, and more generally, what we do in worship, should inform what we believe. For example, the practice from an early period of baptizing people in the name of the Father, and of the Son, and of the Holy Spirit, as in Matthew 28:19, helped to lead Christians to understand that the one God is triune.

Jesus taught a pattern for prayer that includes the petition "Give us this day our daily bread." We ask God to give us food and other necessities of life and acknowledge that God does provide for us. The Lord's Prayer is hardly unique in that regard. For example, Israel's "historical credo" (Deut. 26:5–9) is set in the context of a liturgy of thanks for God's provision of first fruits (vv. 1–11), Psalm 145:15–16 is often adapted as a table prayer today, and 1 Timothy 4:5 specifies that food is to be "received with thanksgiving."

If the law of praying is the law of believing, then we are to believe that God is involved in providing our food and other needs. But Jesus and his hearers knew that our supply of bread depends on the growth of grain and requires seeds, good soil, good weather, and human labor. It does not appear out of nowhere but is "bread which earth has given and human hands have made."[7] A faith-seeking understanding must think about God's activity in conjunction with natural processes.

Similar things can be said about prayers for healing, which should not be understood as alternatives to medical care. God may heal as God chooses, but, in most cases, it will be through drugs, surgery, radiation, and other means applied by skilled humans. In biblical times, olive oil was used as a medicine (Isa. 1:6, Luke 10:34), and today, in the anointing of the sick (Mark 6:13, James 5:14–15), it can be seen as a symbol of all medical treatments through which we ask God to heal.

That God acts in the world is a statement of faith, not the result of scientific observations. But it is also not an arbitrary assertion. It is an expression of trust in the God revealed in Jesus Christ, the crucified one.[8] Though it will not always be explicit here, this article is part of a long-term project of pursuing an understanding of the scientific picture of the world in the context of a theology of the cross.[9]

Who Is the God Who Acts?

Ideas about how God acts in the world have a long history.[10] The influential views of Aquinas were developed by early Lutheran and Reformed theologians.[11] While all of them believed in God as the Holy Trinity, none of the discussions of providence in the sources I have cited refers explicitly to the activities of Father, Son, and Holy Spirit in this providential work. The first volume of Barbour's *Gifford Lectures* and its later revision, together discussed ten different views of divine action with little reference to the Trinitarian character of God's work in creation.[12]

Failure to allow the doctrine of the Trinity to inform other aspects of theology was, for a long time, widespread in the western church, and can be seen as a result of emphasis on the divine unity at the expense of God's triune character. Fortunately, that situation has changed over the past century.[13] Many of those concerned with theology-science issues, as well as systematic theologians with broader interests, have given attention to specifically Trinitarian features of God's work on ongoing creation. A few of these may be noted, and specific references will be given in appropriate places.[14]

"By the word of the LORD the heavens were made; and all their host by the breath of his mouth" (Ps. 33:6). This pairing of God's "word" and "breath" is an example of the parallelism common in Hebrew poetry, one that comes naturally in this case because our speech is accompanied by our breath. In the Old Testament, God's word and spirit are not pictured as persons of a triune God, a concept to which early Christians were brought by God's revelation in Christ. But, in the context of all of scripture, it is natural to see this verse as a pairing of the activity of the divine Word and Spirit, the second and third persons of the Trinity, in God's creative work.

It does not stand alone in that regard. In the first creation account of Genesis, God speaks the world into being, successive acts of creation being preceded by the spirit of God sweeping over the face of the waters (Gen. 1:2, following NRSV margin). God's creating word is often accompanied by spirit, as when Ezekiel prophesies "'Hear the word of the LORD'" to the dry bones, and the wind/spirit/breath comes upon them to give them life (Ezek. 37:1–14). (Hebrew *ruach* can be translated as "wind," "breath," or "spirit." Sometimes it is misleading to focus on only one of these English words.)

Discussions of God's activity directed toward the world have often "appropriated" the work of creation to God the Father, redemption to the Son, and sanctification to the Holy Spirit.[15] This provides a convenient way to organize important theological topics, but appropriation should not be imagined as a naive "division of labor."

In the late second century, Irenaeus, the first great theologian of the post-apostolic church, suggested a vivid image of the Trinitarian work of creation. He pictured the Word and Holy Spirit as the two "hands" by which God creates the world and acts within it.[16] They work together but in distinctive ways that we will consider in the next section. This is seen, for example, in the Nicene Creed, which says that the Holy Spirit "has spoken through the prophets," and in Cranmer's *Eucharistic Prayer* in which God is asked to "vouchsafe to bless and sanctify, with thy Word and Holy Spirit, these thy gifts and creatures of bread and wine."[17]

Irenaeus's image or analogy is not a literal description of the Trinity, but it is quite helpful in discussing divine action and its relationships with scientific descriptions of phenomena. For other purposes, some other analogy may be more helpful. Dorothy Sayers's comparison of the creative work of the Trinity with the work of a literary artist is an example.[18]

The Work of Word and Spirit

Our first step is to consider the role of the Word, the *Logos*, in John's prologue, where we are told that "all things" were made by the Word who was "in the beginning" (John 1:1–3). The resonance of the gospel's opening verses with the beginning of the first creation account in Genesis strongly suggests that John's "Word" has its roots in the way the Word of God is pictured in the Old Testament.[19] God's creative speech in Genesis 1 is important, as is the word of the LORD that came to the prophets—"Is not my word like fire, says the LORD, and like a hammer that breaks a rock in pieces?" (Jer. 23:29). Goethe's Faust, who wanted to change the beginning of John's gospel to "In the beginning was the deed," missed this active sense of the word. God's word is deed, doing what it says (Isa. 55:10–11).

The author of the fourth Gospel may also have been aware of the *logos* concept in Greek philosophy, and perhaps its use to interpret the Jewish tradition by Philo.[20] Greek *logos* had a wide range of meanings, from counting and reckoning through "word" to human reason. For the Stoics, *logos* could have a sense of the ordered nature of the universe, and thus be equated with God. Whether these ideas influenced the evangelist, early Christians soon saw connections between the creativity of the Johannine *Logos* and the rationality of Hellenistic philosophy.[21] The universe is logical because it is the work of the divine *Logos*. The regularities science discerns can be connected with the creative role of the *Logos*.

In the past, it was often assumed that before the conception of Jesus the pre-incarnate or "unfleshed" Word (*logos asarkos*) was the agent of creation through whom all things were made. But, in the past century, a number of theologians, following Barth, have argued—correctly, I believe—that the incarnation was not simply God's "Plan B" to solve a problem that arose with human sin. God intended it before creation. Nevertheless, Jesus did not exist as a physical entity in the universe until about 2,000 years ago, and it is difficult to see what might be meant by speaking of the activity of that entity prior to his birth.

Between the beginning of the universe and Jesus's birth, Jenson suggests that we should speak of "the narrative pattern of being going to be born of Mary."[22] The Word who was active in creation before his coming in the flesh, was also the Word who was on the way to suffering under Pontius Pilate, dying on the cross, and rising on the third day. As Bonhoeffer said, "The world exists from the beginning in the sign of the resurrection of Christ from the dead."[23]

The laws, or patterns, of nature are themselves God's creation, the work of the divine Reason, the Son of God who became human as Jesus of Nazareth. We may think first of mathematically expressed laws of basic physical processes, but we cannot be certain that all the patterns of living things and the interactions of intelligent creatures can be reduced to physics. Whether such reduction is possible, the Word brings about "the distinctiveness of each creaturely form as opposed to others and to God the Creator."[24] Pannenberg's phrase "creaturely form" should not be understood in a static sense. The rational patterns of the world include patterns of temporal change.

The *Logos* is not merely the pattern of this world but the personal source of patterns of all possible worlds. God could have created different universes with different rational laws, so that we can speak, with Torrance, of a doctrine of the contingent rationality of the universe.[25] That explains why observation as well as rational thought is essential for the possibility of scientific understanding of the world. The contingency of mathematical patterns for worlds was shown by the discoveries of consistent non-Euclidean geometries in the nineteenth century, something that eventually led to Einstein's use of Riemannian geometry in his successful theory of gravitation, general relativity.

In recent years, there has also been renewed interest in the role of the Holy Spirit in the creative work of the Trinity and its significance for science-theology dialogue.[26] Johnson speaks of birthing and restoring life, healing what is broken, moving people to proclaim and do God's will, and creating community as works with which the Spirit is especially associated.[27] Psalm 104, a hymn of praise to the Creator, tells of the variety of the living things that inhabit the world, and then says (vv. 29–30),

> When you hide your face, they are dismayed;
> when you take away their breath (*rucham*)
> they die and return to their dust.
> When you send forth your spirit (*ruchakha*), they are created;
> and you renew the face of the ground.

We are reminded of Genesis 2:7, in which God "breathed … the breath of life" into the first human. The Spirit, the Nicene Creed says, is "the Lord and giver of life"—all life.[28]

The Spirit is often associated with unpredictable behavior. When the Spirit comes upon people such as Samson or the apostles at Pentecost, they behave in wild and unexpected ways (Judges 14:6, 19; 15:14; Acts 2:1–21). In his conversation with Nicodemus, Jesus compares the Spirit's work with the unpredictability of the wind. That may remind modern readers of the butterfly effect of chaos theory, that the flapping of an insect's wings in Asia today could change the weather in New York two weeks from now. The Holy Spirit is involved with novelty and spontaneity, with phenomena that our experience of the past has not led us to expect.[29] Thus, "the powers of the Spirit" can be said to be "the powers of the new creation."[30]

In the heyday of the mechanical worldview, strict determinism was often thought to rule out freedom for divine action, while today the probabilistic character of quantum theory and aspects of biological evolution are sometimes claimed to prohibit purposeful divine action. In reality, spontaneity and regularity, "chance and necessity," are both essential features of natural phenomena.[31] Individual quantum events cannot be predicted, but their statistical distribution is governed by the deterministic Schrödinger equation. Genetic variations that

contribute to evolution are random but they are embodied in DNA, which obeys the rules of quantum chemistry.

Polkinghorne summarizes this Trinitarian work with reference to Irenaeus's image of the divine hands. "The Father is the fundamental ground of creation's being, while the Word is the source of creation's deep order and the Spirit is ceaselessly at work within the contingencies of open history."[32] Again, we need to emphasize that the order given by the Word is dynamic. Word and Spirit work together in the unfolding of creation's history, the spontaneity granted by the Spirit making possible the emergence of that which is genuinely new.

God's Word and Spirit work together. Chance and necessity, lawlike behaviors and spontaneity, go together as the mutual creative activity of the two hands of God. We cannot, however, derive physics or biology from the doctrine of the Trinity. Here we are considering what we know about the world in the context of Christian faith.

Divine and Creaturely Energies[33]

How should we speak theologically about God or creatures acting? Early Christian theologians made use of the Greek philosophical term *energeia*, "operation," the activity appropriate to any nature. The English word "energy," derived from *energeia*, is used in both the physical sciences and theology, but, in the latter discipline, it cannot be expressed with a formula such as $E = mc^2$. Our word "operation," from Latin *operari*, "to work," is more to the point there. In elementary physics, energy is defined as the capacity to do work. In quantum theory, the Hamiltonian operator of a system (its energy expressed in terms of canonical coordinates and momenta), acting on the state of the system, gives the rate of change of the state with time, and thus can be said to be responsible for the temporal evolution of a physical system.

The Fourth Ecumenical Council (Chalcedon, AD 451) attempted to settle christological debates by declaring that in Christ there were two natures, divine and human, united in one person of the divine Son. This did not resolve all differences, and it was proposed that while there are two natures in Christ, there is only one operation (and will). The Sixth Ecumenical Council (III Constantinople, AD 680–681) rejected that position and said that both natures in Christ, human and divine, have their appropriate operations. "For each form (μορφὴ) does in communion with the other what pertains properly to it, the Word, namely, doing that which pertains to the Word, and the flesh that which pertains to the flesh."[34] The relevance of this will become clear in the next section.

Divine action can be discussed as relating, in some way, divine energy and the energies of creatures.[35] But this cannot be seen as God simply pouring energy, in the physical sense, into the world, for that would violate a well-established conservation law.

We can refer simply to "God" acting in the world because there is a single divine operation. The classic statement of this is "The external works of the Trinity are undivided." But a qualification needs to be added to that—"preserving, of course, the properties of each person."[36] The need for such a qualification is clear from the way different things are ascribed to different persons in scripture and the way we have delineated their roles. They work together but some activities display the character of one person more than others. (This is the point of the idea of appropriation.)

Jesus says that he does the will of the Father who sent him (John 4:34; 5:30; 6:38–39), and we can speak of the Father willing the creative work.[37] Word and Spirit contribute lawlike pattern and spontaneity in varying degrees in each act, the former most prominently in phenomena described well by classical physics and the latter most prominently in living things. This should be borne in mind in the following sections.

How Does God Act?

How are we then to speak of God acting in a world that is described quite well in terms of entities and processes conforming to patterns that we call laws of nature? Our purpose here is not to review all ten of the theologies of divine action discussed by Barbour,[38] but to use three of them (Existentialist, Neo-Thomist, and Kenotic) that seem, with modifications, most helpful. We have already expanded upon the role of faith that is central to the first idea, that belief in creation means trusting in God as our Creator.

Some authors have sought a "causal joint where God's action joins nature's actions."[39] At first glance

this may seem reasonable. There is a standard procedure for studying the interaction of two physical systems, such as an electromagnetic field and charged particles. We know the Hamiltonians for fields and particles separately. We then look for an interaction Hamiltonian, involving variables for both systems, to describe the causal joint between them. The total Hamiltonian, the sum of the parts for field, particles, and interaction, then describes how the field and particles affect one another.[40]

But divine action is not that of an entity within the world, and what God does in the world is not just one more cause along with the causes with which physics deals. Though there is, as we have noted, a theological concept of energy, there is no "Hamiltonian for God," and we cannot write an interaction Hamiltonian for the way God influences creatures. The idea of a God-creature causal joint thus seems questionable.[41]

The claim that God does not act as an entity within the world has been challenged by Sollereder, who gives the incarnation as a counterexample.[42] But this is not convincing. First, the divine Word was not "an entity within the world" for the first 13.8 Gyr of the world's existence and did not act as such an entity. Secondly, we noted the decision of the Sixth Ecumenical Council that the incarnate Word has not one but two natural operations. In Jesus, the Second Person of the Trinity did act as an entity within the world, his human operation accomplishing human things. But it was the divine operation that continued to sustain creation. It is the sustenance of creation that is at issue here.

I suggest that instead of searching for a causal joint, we will be better occupied with a traditional picture of divine action which is frankly analogical, that of cooperation. God works with creatures as humans work with tools. An analogy is not an exact description of a thing, and there is not a one-to-one mapping of features between them. That there is a causal joint between a human and a wrench does not require that we be able to find such a joint between God and a creature.

All models of divine action use analogy to some extent, and this should not be seen as an embarrassment. It expresses the fact that the Creator is not a creature, as any theology must acknowledge. As Jesus Ben Sirach said some 2,100 years ago, "Where can we find the strength to praise [God]? For he is greater than all his works" (Sirach 43:28).

The term "cooperation" seems preferable to another that is often used in this connection, "concurrence." The etymology of the latter word implies "running together," while the meaning of the former, "working together," indicates that creatures as well as the creator are actually doing something. Cooperation can illustrate a neo-Thomist theology in which God is the first cause (with the qualification noted above) operating through secondary causes.[43] But we need not commit ourselves to Aquinas's metaphysics.

It is important to note that the analogy of cooperation is teachable. Theology ought to be useful for preaching to, and teaching of, ordinary people. The picture of God working with created things requires no complex philosophical explanation. It can be illustrated with familiar pictures, such as a person using a computer or a carpenter sawing a board (an appropriate image for Christians). The tools do not do the jobs by themselves, but neither do the humans' hands. They cooperate.

This also emphasizes that God is at work at every stage of a network of events, and does not just "intervene" at some point or points. There is not one special place in that network where divine input occurs. God is active along with all the activities of created things. In providing daily bread, God works with nuclei fusing in the core of the sun, radiation transporting energy to the earth, molecules involved in photosynthesis, farmers and their equipment, millers, and so on.

This picture is not a deistic one in which God created in the beginning but does not act in the world today. Nor does divine action precede the actions of creatures. God does not preoperate but cooperates.[44] Things in the world owe their existence to God, but God grants them their own integrity and a relative autonomy. Creatures are not extensions of, or emanations from, God.[45]

Things in the world with which God cooperates are those that God has brought into being, as we will discuss later. Traditional doctrines of providence also spoke about God's preservation of creatures. That cannot mean keeping static entities in existence, for nothing in creation is static. In quantum field theory, a "bare" particle is an unobservable abstraction,

and real particles from which matter is built up are "dressed" because of their interactions. Thus God's cooperation with them in their interactions is essential for preservation of them as they actually are.[46] The traditional doctrine also dealt with the divine governance of creation, which is directed ultimately to God's eschatological goal. Our final section will be germane to that topic.

A distinction between "causation" and "agency" should be borne in mind. We can say that the impact of an asteroid was a cause of the extinction of the dinosaurs, but the asteroid was not an agent that brought this about. Agency is exercised by personal entities. Thus the personal (or tri-personal) God was the agent of the universe's creation.

The distinction is especially significant when we come to talk about the way in which God acts with human beings. It is relatively easy to think of what God does with electrons, DNA molecules, or stars in analogy with our use of tools such as screwdrivers or smart phones, and humans too can be pictured as God's instruments, as in the prayer attributed to St. Francis that begins, "Lord, make us instruments of your peace."[47] But God acting with a human should be pictured as the cooperation of two personal agents, like a ruler with a subject or one friend with another, not like a mechanic using some inanimate tool. Helpful analogies suggested by Settle for double agency, such as horse and rider or ballroom dancers, may be seen as examples of concurrence, two agents moving together. But the agents also cooperate, in that they work together even though they are not in physical contact.[48]

And because we possess some free will in worldly affairs and are sinners, we tend in varying degrees to be faulty instruments, refusing to cooperate with God. Recognition of this reality helps in understanding some issues of theodicy. If we wonder why God did not stop the holocaust sooner, the failure of the people of the world to resist and to attempt strongly enough to end genocide is at least part of the answer.

How Does God Not Act?

We could imagine God dealing with creatures in arbitrary ways, but long before the development of modern science, people recognized that there are regularities in natural phenomena, "seed time and harvest, cold and heat, summer and winter, day and night" (Gen. 8:22). Near the beginning of the scientific revolution a distinction was developed between God's "absolute" and "ordained" powers. God could exercise absolute power and do anything not involving self-contradiction, but God has ordained certain rational patterns to which divine action conforms. The ability of scientists to formulate laws describing phenomena strengthened belief that God exercises an ordained power and that the patterns to which many phenomena conform are mathematical.[49] This means that they can be understood without reference to God.

This philosophical distinction is helpful, but it is not distinctively Christian. We are concerned not with the activity of a generic deity but with the God of Israel who has made himself known in Jesus Christ. Already in Isaiah we read, "Truly, you are a God who hides himself, O God of Israel, the Savior" (Isa. 45:15). Pascal had that verse in mind when he wrote: "What meets our eyes denotes neither a total absence nor a manifest presence of the divine, but the presence of a God who conceals Himself. Everything bears this stamp."[50] We return to the point made earlier: Saying that God acts in the world is a confession of faith, not a result of scientific observation.

In the Incarnation, "Christ Jesus, who, though he was in the form of God, did not regard equality with God as something to be exploited, but emptied himself, taking the form of a slave, being born in human likeness" (Phil. 2:6–7). The Greek verb "empty," *kenóō*, gives us English "kenosis." In this passage, it means that the Son of God chose to be limited to the human condition.

Some authors have argued that the concept of kenosis should be used only in connection with the Incarnation, and not with creation.[51] But if Jesus Christ is the fullest revelation of God, if "true theology and recognition of God are in the crucified Christ,"[52] then there is no reason to insist on that limitation. Gordon Fee comments on the hymn that contains those verses from Philippians that state, "in 'pouring himself out' and 'humbling himself to death on the cross' Christ Jesus has revealed the character of God himself."[53] The works of the Trinity, in creation and inspiration as well as in redemption, are kenotic.[54]

Kenosis, self-limitation, was not just a temporary tactic but also is the divine *modus operandi*. A number

of authors have used this concept in discussions of divine action.[55] But because different writers use the idea differently, I need to be clear about what I mean by it.[56] The kenotic aspect of divine action is that God constrains his cooperation with creatures to the capacities of created entities, limiting it in accord with rational laws which themselves are God's creation. God does not do things that "violate" those laws.

Authors who have emphasized kenosis in discussing divine action have not always given adequate attention to the fact that kenosis cannot by itself be a theology of divine action. In the collection of essays on this theme that he edited, Polkinghorne is the only contributor who addresses this point at any length, saying that "kenotic creation and divine action are opposite sides of the same theological coin."[57] Kenosis is not a statement about what God does in the world but about what God does not do, and must be combined with some positive statement about how God does act, such as the model of divine cooperation. God is never absent or inactive. Bonhoeffer overstated the matter when he wrote that God "is weak and powerless in the world."[58] It is in what humans may judge as weakness that God's power is seen (1 Cor. 1:25). God is always present and working (John 5:17), but with self-imposed limitations.

God's limitation to what can be done in accord with what we call "the laws of nature" means that we can understand the world in terms of things within the world that interact through natural processes. What we observe are the "tools" with which God works and not the worker who uses them. Created things play a double role: they are instruments with which God works and, in Luther's phrase, "masks of God" which hide the worker from our observation.[59] God is hidden in the divine work of continuing creation, as God is hidden in his saving work on Golgotha.

Toward the Beginning and Back Again[60]

The present tense in previous sections was deliberate. We naturally try first to understand our immediate space-time neighborhood, and our prayers for divine action, such as that for daily bread, show the same concern. But what about the past? What was God doing then?

Later we will consider God's act of bringing the universe into being and the sometimes controversial concept of *creatio ex nihilo*. But it is also important to realize that all the divine works of the traditional "six days"—everything in Genesis 1 after the first verse—can be understood in the way we have described. What God has been doing between the initial act of creation and the present can be described with the model of divine action that has just been sketched.

It is instructive to consider first how science has proceeded in understanding the universe. Scientific knowledge about the remote past of the universe was not gained by grand speculation. Knowledge of gravitation, dynamics, and properties of light and matter gained on Earth and from observations of the moon and planets made it possible to move gradually outward from the solar system. Distances to nearby stars were measured, their spectra studied, and masses of some in binary systems determined. Distances to more and more remote stars, and eventually to other galaxies, were found in stepwise fashion so that, because of the finite speed of light, we could also see farther and farther back in time.[61] A large statistical sample of stars with known properties made it possible to understand stellar evolution, and advances in nuclear physics explained the source of stellar energy.

Eventually the limits of our galaxy were determined, and it was found to be one of billions of such systems. The relationship between distances and spectral redshifts of galaxies pointed to a general expansion of the universe. One theory—that expansion began from a hot, dense state—predicted that redshifted "relic radiation" should still pervade the universe. (When a mixture of gas and radiation is slowly compressed, the radiation heats up faster than the gas.) This prediction has been verified from observations of the cosmic microwave background. Abundances of light nuclei from fusion reactions during the first minutes of expansion provide further confirmation of the basic big bang scenario.

The point of this brief survey is that science enables us to understand cosmic history back to very early stages in terms of the same well-established laws that prevail on Earth today. We still do not understand the nature of dark energy and dark matter, which make themselves known only on cosmic scales, but we observe their effects.

Insights of the biological sciences into the past cannot be described so simply. Here we have to rely on signals from the past in the form of "time capsules" such as fossils, which require more complex interpretation than electromagnetic waves. (All data is theory laden, but some data are more laden than others.) In addition, biological phenomena cannot be described by precise quantitative laws to the extent that physical phenomena can. This is not to disparage the life sciences but to recognize that the phenomena with which they deal are very complicated.

In spite of these difficulties, workers in the life sciences have learned a great deal. Recognition that earlier forms of life had become extinct influenced the development of evolutionary theories,[62] but patterns of current geographical distributions of species and anatomical similarities between species were also important. The way in which Darwin presented his theory of natural selection by analogy with artificial selection shows the connection of that theory with experience of today's world.[63] With the rediscovery of Mendel's work in genetics, evolutionary science was on its way to our present understanding of the history of terrestrial life. Here too there are unsolved problems, chief among them the origin of life on Earth.

Well-established theories, general relativity, and the standard model of particle physics can, as a conservative estimate, take us back to within about 10^{-11} seconds of the beginning of expansion.[64] We can be confident that we know, in broad outline, what has taken place in the observable universe during the 13.8 Gyr since that time.

A theological description of divine action is not the same as a scientific description of physical processes. But our theological model of divine action by means of God's kenotic cooperation with creatures links the two descriptions. Since we have treated divine action in the present in that way, it makes sense to pursue the same course that we did with a scientific description of the past, extrapolating our theological understanding back toward the beginning.

Now we can return to the present. What has God been doing during this 13.8 Gyr? In broad outline, the answer is simple. In the first minutes of expansion, God was making the present particle content of the cosmos by means of the strong and electroweak interactions while governing cosmic expansion gravitationally. As the universe continued to expand in accord with the laws of these interactions (whose source is the Word of God), atoms formed and the relic radiation propagated freely. Galaxies, stars, and planetary systems came into being as God worked with gravitation and forces governing the structure of materials. Cooperating with hydrogen and helium nuclei in their interactions, God ignited stars and made heavier elements, spreading them out in supernova explosions to become part of new generations of stars and planetary systems.

On at least one planet of one system, the Word of God and "the Lord and giver of life" somehow brought life into being. Over billions of years, new lifeforms evolved as God worked with complex biochemical processes and the forces that shape environments to come to the present day. Denis Edwards discusses this evolution of life as an aspect of cosmic evolution, with some attention to the issues of theodicy to which the evolutionary process gives rise.[65] On this planet, God has created a creature able to understand its world, to reflect on its own existence, to hear God's address, and to trust and obey that address—or to turn away. This is a universe in which flesh could come into being in order for the Word to become flesh.[66]

The Origin of the Universe

What, if anything, can science say about an absolute beginning of the universe? Theories have been proposed that would take us even closer to the beginning of expansion than 10–11 seconds, or before that beginning to a contracting phase, or that would eliminate a beginning altogether.[67] There is not room here to discuss these ideas further. But we do need to deal with claims that science can explain the origin of the universe from "nothing," and thus make the idea of a creator superfluous.

Such claims, made most prominently by Krauss and Hawking,[68] are based on the idea that in conditions like those very early in cosmic expansion, particles could be pulled from the quantum vacuum to become the material content of the universe. While a detailed treatment of this idea requires the machineries of general relativity and quantum field theory, a simple model suggests how basic ideas of special relativity, gravitation, and quantum theory allow the possibility. Massive particles could make quantum jumps from a state of zero energy if their negative

gravitational potential energy just cancelled their rest mass and kinetic energies.[69]

Making the material content of the universe from a quantum vacuum that is itself God's creation would be another illustration of ideas that we have already considered. We see again the divine kenosis in which God wills and allows something other than Godself to exist. "The κένωσις, which reaches its paradoxical climax in the Cross of Christ, began with the Creation of the world."[70]

But the quantum vacuum is not "nothing." Krauss's book begins with that fact and then uses a "bait and switch" trick to say that origination from a quantum vacuum would be "creation out of nothing." But the argument requires the reality of quantum fields as instantiations of certain laws. *Creatio ex nihilo,* in the theological sense, means creation in spite of absolute nothingness, the "*nihil negativum*."[71] It is not creation from some "nothing" that has the potential to be "something." Claims that somehow the universe can create its own laws "from nothing" are futile. There is always "something" smuggled in. It is sometimes said that one implication of quantum theory is that "whatever is not forbidden is allowed." But "nothing," in the sense of the theological tradition, means forbidding.

The Christian doctrine of *creatio ex nihilo* is only secondarily about the universe, and primarily about the God for whom nothing is impossible.[72] It is a claim that the Father, working through the Son of God and the Holy Spirit together, established basic patterns of a universe and, in Hawking's phrase, "breathes fire into the equations."[73]

An Open Creation

If God were constrained to act within the limits of deterministic laws of physics, then God would be locked into one particular course of action. It would be hard to see how there could be divine guidance of the course of evolution beyond hardwiring the entire course of it at the beginning, which is implausible. There would be no room for miracles in the sense of phenomena which are not predictable by science.

It can be only an act of faith, and not a matter of knowledge, to hold that the laws of nature are reducible to the laws of physics. Polkinghorne, for example, has argued that we should not be dogmatic about this.[74] If the laws of nature, and of life in particular, are not thus reducible, there might be more flexibility for kenotic divine action than quantum and chaos theories suggest. But having said that, we should consider what our current understanding of physics can say about God's freedom to act in the world.

Both sensitivity to initial conditions of some nonlinear systems (chaos theory) and to quantum mechanics have been suggested as loci for such freedom.[75] There is, strictly speaking, no quantum chaos because quantum dynamics are described by the linear Schrödinger equation. But the uncertainty principle places a limitation on how precisely the initial conditions for any system can be known. That may lead to a practical impossibility of prediction of the system's behavior after a short time even though that behavior is theoretically determined by the initial conditions. God's use of this effect to determine, for example, the effect on weather of a butterfly's wings flapping would be an undetectable interference with the laws of physics.[76]

While the Schrödinger equation determines the evolution of a system's state (wave function) between measurements, it does not give the result of a measurement. Thus the fundamental laws of quantum mechanics do not determine completely the future configuration and motions of the world.

This may point not only to a limitation of present-day quantum theory but also to a basic feature of the world, ontological indeterminacy. If so, God, without violating the laws of physics, could act to determine the final quantum state of systems that have interacted as long as the statistical laws for an ensemble of such systems were respected. The laws of physics would not completely determine the future of the universe.

Russell has argued, as part of an overall picture of divine action in the cosmos, that God could act at the quantum level and influence interactions involving DNA to produce mutations, and thus guide the evolutionary process.[77] The idea that God could give some direction to evolution will be criticized by evolutionary biologists who insist that evolution is unguided. While their voices must be heard, it is important to remember that the branch of science relevant to biological systems at the quantum level is physics.

The proposal that God is the final "determiner of indeterminacies" is potentially important but raises problems. If God does this in every interaction, we are back to Barbour's "monarchical" model of a divine ruler who determines absolutely everything and gives creatures no freedom. The opposite idea, that all final states "just happen" with no special divine influence, makes one wonder if God could have any control of creation at all. A suggestion that God determines some, but not all, final states, would be clumsy. It seems appropriate to end discussion of divine action at the quantum level with some uncertainty. ✯

Notes

[1]This an expanded version of a paper given at the annual meeting of the American Scientific Affiliation at Oral Roberts University in 2015. Biblical citations are from the NRSV.

[2]George L. Murphy, "A Positive Approach to Creation," *Journal of the American Scientific Affiliation* 32, no. 4 (1980): 230–36.

[3]See John H. Walton, "Hebrew Corner 3: 'create (*bara'*),'" Zondervan Academic, September 12, 2008, http://zondervanacademic.com/blog/we-have-been-di/, for occurrences in the Old Testament.

[4]Benjamin Wirt Farley, *The Providence of God* (Grand Rapids, MI: Baker Book House, 1988), 16.

[5]Rudolf Bultmann, *Jesus Christ and Mythology* (New York: Charles Scribner's Sons, 1958), 69; Ian Barbour, *Religion in an Age of Science* (New York: HarperCollins, 1990), 254–56.

[6]Dietrich Bonhoeffer, *Letters and Papers from Prison*, enlarged ed. (New York: Macmillan, 1972), 360.

[7]*The Sacramentary* (New York: Catholic Book Publishing, 1972), 370–71.

[8]Eberhard Jüngel, *God as the Mystery of the World* (Grand Rapids, MI: Eerdmans, 1983), 218.

[9]George L. Murphy, "Chiasmic Cosmology: An Approach to the Science-Theology Dialogue," *Trinity Seminary Review* 13, no. 2 (1991): 83–92; ___, "The Theology of the Cross and God's Work in the World," *Zygon* 33, no. 2 (1998): 221–31; ___, "Chiasmic Cosmology and Creation's Functional Integrity," *Perspectives on Science and Christian Faith* 53, no. 1 (2001): 7–13, http://www.asa3.org/ASA/PSCF/2001/PSCF3-01Murphy.html; ___, *The Cosmos in the Light of the Cross* (Harrisburg, PA: Trinity Press International, 2003); ___, "Divine Action and Divine Purpose," *Currents in Theology and Mission* 36, no. 1 (2009): 32–38.

[10]Farley, *The Providence of God*.

[11]Thomas Aquinas, *The Summa Theologica of Saint Thomas Aquinas*, vol. 1 (Chicago, IL: Encyclopaedia Britannica, 1952), pt. 1, QQ 104–106, 535–49; Heinrich Schmid, *The Doctrinal Theology of the Evangelical Lutheran Church*, 3rd ed. rev. (Minneapolis, MN: Augsburg, 1961), 170–94; Heinrich Heppe, *Reformed Dogmatics* (Grand Rapids, MI: Baker Book House, 1978), 251–80.

[12]Ian Barbour, *Religion in an Age of Science*, chap. 9; ___, *Religion and Science: Historical and Contemporary Issues* (New York: HarperCollins, 1997), chap. 12.

[13]Jürgen Moltmann, *The Trinity and the Kingdom*, trans. Margaret Kohl (New York: Harper & Row, 1981), 1–20; Ted Peters, *God as Trinity: Relationality and Temporality in Divine Life* (Louisville, KY: Westminster/John Knox, 1989), 81–90.

[14]Jürgen Moltmann, *God in Creation* (San Francisco, CA: Harper & Row, 1985); Colin E. Gunton, *The Triune Creator: A Historical and Systematic Study* (Grand Rapids, MI: Wm. B. Eerdmans, 1998); Christopher Southgate, ed., *God, Humanity and the Cosmos* (Harrisburg, PA: Trinity Press International, 1999), especially chap. 7; John Polkinghorne, *Science and the Trinity: The Christian Encounter with Reality* (New Haven, CT: Yale University Press, 2004); Denis Edwards, *How God Acts: Creation, Redemption, and Special Divine Action* (Minneapolis, MN: Fortress Press, 2010); Ian A. McFarland, *From Nothing: A Theology of Creation* (Louisville, KY: Westminster John Knox Press, 2014).

[15]Alan Richardson and John Bowden, eds., *The Westminster Dictionary of Christian Theology* (Louisville, KY: Westminster John Knox Press, 1983), s.v. "Appropriation," H. E. W. Turner.

[16]"Irenaeus against Heresies," in *The Ante-Nicene Fathers*, vol. 1 (reprint; Grand Rapids, MI: Eerdmans, 1979), 4.20.1 (p. 487) and 5.6.1 (p. 531).

[17]The Episcopal Church, *The Book of Common Prayer* (New York: Church Publishing, 1986), 327, 335.

[18]Dorothy L. Sayers, *The Mind of the Maker* (London: Methuen, 1941).

[19]Raymond E. Brown, S.S., *The Gospel According to John I–XII* (Garden City, NY: Doubleday, 1966), 4–6, 23–27. Some commentators suggest that the Greek philosophical logos idea may have influenced the evangelist. For the concept throughout scripture, see, e.g., Burton H. Throckmorton, *Creation by the Word* (Boston, MA: United Church Press, 1968).

[20]Geoffrey W. Bromiley, trans. and ed., *Theological Dictionary of the New Testament*, vol. 4 (Grand Rapids, MI: Eerdmans, 1967), s.v. "λέγω, λόγος κτλ," section B, Kleinknecht.

[21]E.g., Justin Martyr, "The First Apology of Justin," in *The Ante-Nicene Fathers*, vol. 1, 163–87.

[22]Robert W. Jenson, *Systematic Theology*, vol. 1, *The Triune God* (New York: Oxford, 1997), 141.

[23]K. R. Hagenbach, *Compendium of the History of Doctrine*, vol. 2 (Edinburgh: T&T Clark, 1852), 320; Dietrich Bonhoeffer, *Creation and Fall: A Theological Exposition of Genesis 1–3* (Minneapolis, MN: Fortress, 1997), 34.

[24]Wolfhart Pannenberg, *Systematic Theology*, vol. 2, trans. Geoffrey W. Bromiley (Grand Rapids, MI: Eerdmans, 1994), 109.

[25]Thomas F. Torrance, *Divine and Contingent Order* (New York: Oxford, 1981), especially chap. 1.

[26]Amos Yong, *The Spirit of Creation* (Grand Rapids, MI: Wm. B. Eerdmans, 2011).

[27]Elizabeth A. Johnson, *Women, Earth and Creator Spirit* (Mahwah, NJ: Paulist Press, 1993), especially chap. 5.

[28]George L. Murphy, "The Third Article in the Science-Theology Dialogue," *Perspectives on Science and Christian Faith* 45, no. 3 (1993): 162–68.

[29]Robert W. Jenson, "The Holy Spirit," in *Christian Dogmatics*, vol. 2, ed. Carl E. Braaten and Robert W. Jenson (Philadelphia, PA: Fortress, 1984), 170–73.

[30]Moltmann, *God in Creation*, 96.

[31]Jacques Monod, *Chance and Necessity* (London: Collins, 1972); Arthur Peacocke, *Theology for a Scientific Age*, enlarged ed. (Minneapolis, MN: Fortress, 1993), 115–21.

[32]Polkinghorne, *Science and the Trinity*, 81.
[33]For more detailed discussion, see George L. Murphy, "Energy and the Generation of the World," *Zygon* 29, no. 3 (1994): 259–74, https://doi.org/10.1111/j.1467-9744.1994.tb00666.x.
[34]For the relevant part of the council's definition of faith in which this statement of Pope Leo I is endorsed, see *The Nicene and Post-Nicene Fathers*, 2nd series, vol. 14 (reprint; Grand Rapids, MI: Wm. B. Eerdmans, 1979), 345.
[35]Murphy, "Energy and the Generation of the World"; Gunton, *The Triune Creator*, 175–76.
[36]Fred Sanders, "Preserving, of Course, the Properties of Each" (Beckwith), *The Scriptorium Daily*, November 2, 2016, http://scriptoriumdaily.com/preserving-of-course-the-properties-of-each-beckwith/.
[37]Cf. the way Sayers, *The Mind of the Maker*, associates the Father with the idea of the work.
[38]Barbour, *Religion in an Age of Science*, chap. 9; ___, *Religion and Science*, chap. 12.
[39]John Polkinghorne, "Natural Science, Temporality, and Divine Action," *Theology Today* 55, no. 3 (1998): 334.
[40]W. Heitler, *The Quantum Theory of Radiation*, 3rd ed. (London: Oxford Clarendon Press, 1954).
[41]Austin Farrer, *Faith and Speculation* (New York: New York University Press, 1967), especially chaps. 4 and 5. On the concept of cause, see, e.g., Zachary Hayes, O.F.M., *What Are They Saying about Creation?* (New York: Paulist Press, 1980), 35–36.
[42]Bethany Sollereder, "A Modest Objection: Neo-Thomism and God as a Cause among Causes," *Theology and Science* 13, no. 3 (2015): 345–53, https://doi.org/10.1080/14746700.2015.1053762.
[43]Barbour, *Religion and Science*, 305–12.
[44]E.g., David Hollaz, quoted in Schmid, *The Doctrinal Theology of the Evangelical Lutheran Church*, 187.
[45]Cf. Athanasius, "On the Incarnation of the Word," in *Nicene and Post-Nicene Fathers*, 2nd series, vol. 4 (Grand Rapids, MI: Wm. B. Eerdmans, 1978), 37.
[46]Murphy, *The Cosmos in the Light of the Cross*, 77.
[47]The Episcopal Church, *The Book of Common Prayer*, 833.
[48]Tom Settle, "The Dressage Ring and the Ballroom: Loci of Double Agency," in *Facets of Faith and Science*, vol. 4, ed. Jitse M. van der Meer (Lanham, MD: University Press of America, 1996), 17–40.
[49]Margaret J. Osler, *Divine Will and the Mechanical Philosophy* (Cambridge, UK: Cambridge University Press, 1994).
[50]Blaise Pascal, *The Pensées* (Harmondsworth, UK: Penguin, 1961), 222, #602.
[51]E.g., Colin Gunton, *Christ and Creation* (Grand Rapids, MI: Wm. B. Eerdmans, 1992), 85.
[52]Luther, "Heidelberg Disputation 1518," in *Luther's Works*, vol. 31 (Philadelphia, PA: Fortress, 1957), 53.
[53]Gordon D. Fee, *Paul's Letter to the Philippians* (Grand Rapids, MI: Wm. B. Eerdmans, 1995), 196.
[54]George L. Murphy, "Kenosis and the Biblical Picture of the World," *Perspectives on Science and Christian Faith* 64, no. 3 (2012): 157–65.
[55]E.g., Nancey Murphy and George F. R. Ellis, *On the Moral Nature of the Universe* (Minneapolis, MN: Augsburg Fortress, 1996); John Polkinghorne, ed., *The Work of Love: Creation as Kenosis* (Grand Rapids, MI: Wm. B. Eerdmans, 2001).
[56]Murphy, *The Cosmos in the Light of the Cross*, 30, 80–85; George L. Murphy, "Kenosis and Divine Action," *Dialog* 52, no. 4 (2013): 280.
[57]John Polkinghorne, "Kenotic Creation and Divine Action," in *The Work of Love*, ed. Polkinghorne, 96. Paul Fiddes and Sarah Coakley touch on the point in their essays.
[58]Bonhoeffer, *Letters and Papers from Prison*, 360–61.
[59]Martin Luther, "Psalm 147" in *Luther's Works*, vol. 14 (St. Louis, MO: Concordia, 1958), 114.
[60]George L. Murphy, "From the Small Catechism to the Big Bang," *Glaube und Denken* 10 (1997): 29–46.
[61]Steven Weinberg, "The Cosmic Distance Ladder," in *Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity* (New York: John Wiley & Sons, 1972), 427–40. More recent methods are described in Saul Perlmutter, "Supernovae, Dark Energy and the Accelerating Universe," *Physics Today* 56, no. 4 (2003): 53–60, https://doi.org/10.1063/1.1580050.
[62]Loren Eiseley, "How Death Became Natural," in *The Firmament of Time* (New York: Atheneum, 1962).
[63]Charles Darwin, *On the Origin of Species* (London: J. M. Dent & Sons, 1972), chapters 1 and 2.
[64]"Thermal History of the Early Universe," http://www.helsinki.fi/~hkurkisu/cosmology/Cosmo6.pdf, p. 71.
[65]Denis Edwards, *How God Acts* (Minneapolis, MN: Fortress, 2010). On the theodicy question, see also George L. Murphy, "Necessary Natural Evil and Inevitable Moral Evil," *Perspectives on Science and Christian Faith* 68, no. 2 (2016): 111–18, particularly 111–14.
[66]George L. Murphy, "The Incarnation as a Theanthropic Principle," *Word & World* 13, no. 3 (1993): 256–62.
[67]Aquinas, *The Summa Theologica*, vol. 1, pt.1, Q 46, Art. 2, 253–55, argued that it is an article of faith, not a conclusion of reason, that the world had a beginning.
[68]Lawrence M. Krauss, *A Universe from Nothing* (New York: Free Press, 2012). My review of this book is in *Perspectives on Science and Christian Faith* 65, no. 2 (2013): 137–38; Stephen Hawking and Leonard Mlodinow, *The Grand Design* (New York: Bantam, 2012), chap. 8.
[69]George L. Murphy, "Einstein + Newton + Bohr = Quantum Cosmology," *The Physics Teacher* 35 (1997): 480–81, https://doi.org/10.1119/1.2344773.
[70]Emil Brunner, *Dogmatics* II (Philadelphia, PA: Westminster, 1952), 20.
[71]Dietrich Bonhoeffer, *Creation and Fall* (Minneapolis, MN: Fortress, 1997), 33–34.
[72]McFarland, *From Nothing*, is an exposition of this doctrine.
[73]Stephen Hawking, *A Brief History of Time* (New York: Bantam, 1988), 174.
[74]John Polkinghorne, "The Laws of Nature and the Laws of Physics," in *Quantum Cosmology and the Laws of Nature*, 2nd ed., ed. Robert John Russell et al. (Berkeley, CA: The Center for Theology and the Natural Sciences, 1999), 429–40. Other contributions to this volume are also relevant to our topic.
[75]Robert John Russell, Nancey Murphy, and Arthur R. Peacocke, eds., *Chaos and Complexity*, 2nd ed. (Berkeley, CA: The Center for Theology and the Natural Sciences, 1997).
[76]Nicholas Saunders, *Divine Action and Modern Science* (Cambridge, UK: Cambridge University Press, 2002), 87–90 and chap. 7, discusses relationships and distinctions between predictability and determinism.
[77]Robert John Russell, *Cosmology from Alpha to Omega* (Minneapolis, MN: Fortress, 2008), chapters 5 and 6.

Ethics

THE SCIENCE OF VIRTUE: Why Positive Psychology Matters to the Church by Mark R. McMinn. Grand Rapids, MI: Brazos Press, 2017. 208 pages. Paperback; $18.99. ISBN: 9781587434099.

Christianity and psychology have a checkered history. Despite the systematic scientific review work of David Larson, Dale Matthews, and others, who have demonstrated over the last forty years that sincere Christian faith promotes physical and mental health, antagonistic psychiatrists have continued to look upon the faith community as delusional or mentally unbalanced. Some faith leaders consider psychology as a concoction of the devil and antithetical to a Christian worldview. In this work, Mark McMinn, George Fox psychology professor, Templeton-funded researcher, and clinical psychologist, assures the faith community that it has nothing to fear from positive psychology. Indeed, serious discipleship leads to a fuller expression of the six virtues highlighted in this short book: wisdom, forgiveness, gratitude, humility, hope, and grace.

Each chapter of the book has four purposes: (1) to help Christians understand positive psychology; (2) to illustrate how Christian thought can change positive psychology for the better; (3) to encourage the church to embrace the science of positive psychology; and (4) to consider the implications for Christian counseling.

The first virtue parsed is wisdom, which the secular Berlin Wisdom Project defines as "expert-level knowledge in the pragmatics of life" (p. 15). While this terse definition is helpful, additional criteria are necessary to make wisdom a measurable characteristic: factual knowledge, procedural knowledge, life-span contextualization, values relativism, and managing uncertainty. Scientific wisdom is then contrasted with the conventional wisdom of the wisdom books of the Bible and Jesus's critical wisdom. McMinn describes a PhD student's project on wisdom mentoring in which the study group had six meetings over twelve weeks. Since wisdom formation is greatest in young adulthood, this study paired older mature believers with young adults from 18 to 25. The results, as assessed by surveys before and after, showed improvement in several measures of wisdom that were not seen in the control group.

The second virtue, forgiveness, has been studied more extensively by secular psychology. Prior to the "discovery" of the scientific benefits of forgiveness and the explosion of articles written about the topic in the literature (from zero in 1980 to over one hundred per year from 2007–2014), forgiveness was demonized as wrongfully dismissing the pain of past wrongs. But since science has documented the benefits of forgiveness—lower blood pressure, less low back pain, reduced anxiety and depression, increased hope—the value of helping clients achieve forgiveness can no longer be ignored. For the Christian, forgiveness is not just a mechanism to achieve better mental and physical health but a command of Christ to forgive as we have been forgiven. Positive psychology can help by providing useful exercises, realizing that real forgiveness will take time. Beyond the forgiveness of others, there is the need for the Christian to seek to be forgiven by those they have offended. Although not always possible, reconciliation can sometimes result from seeking and granting forgiveness.

Gratitude is another of the virtues well studied by positive psychology. The book acknowledges the seminal work of Robert Emmons in this field, including his randomized trials demonstrating the value of gratitude journaling. Gratitude, like forgiveness, is associated with many physical and emotional health markers. McMinn is less certain that secular tools such as gratitude journaling can make the ungrateful thankful. For believing Christians, gratitude should come naturally since believers have received the blessing of salvation, a relationship with their Creator, and a hope for life beyond death. In his graduate student's crossover study, which sought to demonstrate that a formal program of gratitude enhancement would improve the psychological health of church members, a "ceiling effect" was encountered. Active church members were already highly grateful, satisfied with life, psychologically well, and spiritually attuned.

Humility represents a more difficult character trait to study. There is often a disparity between self-assessment of humility and the assessment of others. A simple definition of humility by psychologists entails three traits: (1) views self accurately (neither too high nor too low); (2) considers the other and not just oneself; and (3) is teachable, open to the possibility of being wrong (p. 101). One also needs to distinguish between "state humility," which refers to an individual who is humble in a given situation, and "trait humility," which is reserved for people who characteristically demonstrate humility. Scientific studies of humility, while limited, show that

> humble people experience more positive romantic relationships than others, form and repair social bonds more readily … are less anxious about death, are more compassionate, and experience less spiritual struggle. (p. 104)

For the Christian, humility follows logically from our relationship with the Almighty God and should translate into our relationships with people and our view of nature. It is still unclear whether humility can be increased in a measurable way by exercises. Mark believes that humility might be learned through example rather than cognitive exercises.

Hope as defined by positive psychology has three elements (p. 121): (1) feeling optimistic that one's future can be better than the present; (2) identifying pathways to help one move from where one is now to where one wants to be; and (3) having a sense of motivation to make it so. Scientific studies of hopeful people demonstrate that they have many positive health outcomes. They are more likely to engage in disease-preventive activities, less prone to high-risk sex, less prone to self-injury, and better able to cope with illness (p. 125). Although this secular view of hope is positive, it fails to give a rationale for that hope. For the Christian, hope is grounded in the sovereignty of God. The Christian worldview understands suffering within the context of sin and the fall. The individual striving inherent in the above secular definition fails to capture the role of community: hope for the believer comes in part from the faith community where hope is received and given.

Grace is the final virtue covered. While grace has not been well researched, the Templeton Foundation is currently sponsoring grants to study this virtue. There are preliminary studies that suggest that grace between couples "results in increased empathy, forgiveness, and reconciliation," and that a gracious orientation "is related to decreased levels of depression and anxiety and increased general mental health" (p. 144). This virtue has elements of the other virtues, especially gratitude, forgiveness, and hope. There are scales which empirically seek to quantify grace. For the Christian and the Christian community, the concept is rooted in God's grace to us while we were yet sinners. God's grace makes it possible to accept responsibility for our shortcomings and move to self-forgiveness. This then frees us to be more gracious to others and to enjoy the many gifts of people and the natural world.

This book is not a critical review of positive psychology; such a book would be much longer and I would not be qualified, as a practicing cardiologist and medical ethicist, to review it. I am struck by the parallels between virtue ethics and virtue psychology: both have grown in influence over the last fifty years. In virtue ethics, good ethical decisions result from positive character traits (truthfulness, temperance, modesty, courage, etc.) matured through years of practice. In positive psychology, by developing one's wisdom, forgiveness, gratitude, humility, hope, and grace, one becomes better able to withstand life's challenges, resist anxiety and depression, and enjoy better physical health (p. 165).

The book represents the reflections of a Christian psychologist who has contributed to the field of positive psychology. He is writing for fellow believers in the pews who wish to integrate the science of virtue with what we know about these virtues from scripture. There are applications to the church life and to Christian counseling. The book would be useful to ASA members who are always looking for a means to see their faith as a part of rational science. Because it is short, it can be read fairly quickly. If you have the luxury of being able to spend forty minutes to an hour in quiet time, you might use the book as a devotional, reading and meditating on a chapter every day for a week. McMinn's ambitious hope is that

> positive psychology and the church could be partners in promoting a new understanding of the good life in contemporary society, one that focuses more on virtue than pleasure, more on being good than on feeling good. (p. 165)

Reviewed by Jay Hollman, MD, MA, LSU Healthcare Network, Baton Rouge, LA 70806.

THE NATURE OF ENVIRONMENTAL STEWARDSHIP: Understanding Creation Care Solutions to Environmental Problems by Johnny Wei-Bing Lin. Eugene, OR: Pickwick, 2016. 326 pages. Paperback; $38.00. ISBN: 9781610976206.

Why can't we agree on what excellent climate action looks like? This question drives *The Nature of Environmental Stewardship* by Johnny Wei-Bing Lin (BS and MS, Stanford University; PhD, UCLA; Senior Lecturer and Director of Undergraduate Computing Education at University of Washington Bothell). Lin weaves an allegorical story about a pastor struggling to mediate a disagreement over environmental stewardship. While doing so, he provides a useful taxonomy for discussing environmental stewardship and a structure to use when debates and conflicts inevitably arise.

Lin begins with clear biblical support for the existence of a creation care command before arguing that the creation care command lacks the clarity of other commands, such as "do not steal." This recognition sets the book apart from many others which may argue the opposite. However, this also makes the book particularly useful for those trying to understand what creation care looks like. He explains that, due to its complexity, obedience does not flow directly from the command. He enumerates criteria that are used to evaluate what obedience looks like. Finally, he sets

forth four "determinants" that influence the criteria. Lin spends most of the book breaking down these "determinants" into their component parts.

The four determinants for the creation care command, he argues, are worldview, ethical theories, science, and society. In the first, Lin explores a range of worldviews, both religious and nonreligious, before examining how worldviews affect the criteria for evaluating the creation care command. In the following chapters, Lin examines a massive range of ethical theories, understandings of science, political ideologies, and economic theories with a careful and analytical eye. He critiques and lauds each fairly, while often providing compelling alternatives to common ideologies. His goal in doing so is to bring to light these foundational beliefs with an understanding that all of them have much to say about environmental stewardship.

An immediate concern for some readers may be that Lin begins to fall into moral relativism or that he accepts any belief regarding creation care as legitimate. However, Lin does an excellent job of reiterating the goal of the book. Rather than placing a value judgment on beliefs, Lin understands that in order for effective dialogue to take place, all views must be presented fairly and entirely. A quick glance at the acknowledgments and citations shows a wide variety of individuals with passionately held beliefs, and Lin certainly holds his own. However, by bringing together a sizable breadth of topics, he emphasizes "that the path from principles to practice is often incredibly complex and multi-faceted, not simple, and requires the highest levels of creativity to bring together many different fields of study—with different kinds of authority and expertise" (p. 17).

Lin does not resolve this uneasy tension. He ends his book with guidelines for synthesizing a comprehensive understanding of environmental stewardship rather than presenting his own complete synthesis. As a reader, I was forced to accept his critiques of my own fundamental beliefs while better understanding the beliefs of someone with whom I may disagree. A voice like this is sorely needed today and his strategy for understanding issues can be broadly applied to issues other than environmental stewardship.

The book is a challenging read and heavily references outside texts. For a reader to fully grasp Lin's ideas, they should already be familiar with some of the philosophical, theological, and environmental literature. The book is also very dense and should be read with a focused eye and a pen to take notes. At times, Lin uses large words and complex sentence structure when simpler prose would suffice. For someone who is trying to improve conversations about environmental stewardship at their church, campus community, or neighborhood, this is an excellent resource. However, while there are discussion questions at the end of each chapter, it would still be a frustrating book for the average church or small group that is casually interested.

Some may see the word "stewardship" in the title and assume the book is outdated; while terms such as "reconciliation" may be more in vogue, this book is very timely. The end of the book draws heavily on reconciliation themes and helps address the concern that creation care discussions often lead to damaged relationships and division. Lin references familiar social psychology and Christian peacemaking sources to provide strategies for effective conflict resolution. Lin earnestly seeks peaceful living between individuals and groups, and this book provides strategies for the development of that peace. The ability to articulate effectively *why* a certain belief is held allows for people to find common ground and develop more stable policy solutions. He argues this effectively and provides the taxonomy for this to take place.

This book both made me think and changed how I think. If Lin's goal is to help us understand how we think about environmental stewardship, he achieved it. Lin's book is an effective solution to a common problem: we have forgotten how to talk about issues such as environmental stewardship with those with whom we disagree. Lin reopens the dialogue.

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History of Science

SCIENCE WITHOUT FRONTIERS: Cosmopolitanism and National Interests in the World of Learning, 1870–1940 by Robert Fox. Corvallis, OR: Oregon State University Press, 2016. 168 pages, 24 B&W illustrations and photographs, notes, bibliographic essay, index. Paperback; $22.95. ISBN: 9780870718670.

Begin with a truism about an earlier century: "… truth was indeed open to all. Yet it was only fully open to those who knew how to get at it" (p. 13). When Ben Jonson appealed to Seneca's adage (*Patet omnibus veritas*) in his seventeenth-century commonplace book, the sheer volume of printed material was already making one's access to truth increasingly difficult. How the sharing of knowledge across international and linguistic boundaries developed in the late nineteenth and first half of the twentieth century is the historical question that Robert Fox, Emeritus Professor of the History of Science at the University

of Oxford, tackles in this book. Initially delivered as a series of lectures at Oregon State University, they are now published in a highly polished and documented form. Fox, a well-known scholar in the history of the physical sciences in the eighteenth and nineteenth centuries, has now turned from an examination of science as practice to science as a model for society with international aspirations, a society in which real harmony, peace, and understanding set the tone.

Fox's thesis, in short, is

> that shared research goals and scientists' readiness to take advantage of the dramatically improved provision for communication across national and linguistic boundaries had much in common with contemporary internationalist movements extending far beyond the realms of science and technology. (pp. 2–3)

If you have ever wanted to learn how collaborative efforts and improved mechanisms of communication and information retrieval came into existence, this is the book for you. To Fox's credit this is not a mere cataloging of efforts, but a hard-won academic search for the cultural contexts that made such a retrieval of knowledge both invigoratingly delightful and, at times, frustratingly difficult. Political and cultural contexts matter. *Science without Frontiers* is a testament to that fact in the arena of knowledge acquisition and sharing.

Besides a brief introduction and epilogue, *Science without Frontiers* has three major chapters. The first, "Knowledge, the Cement of Nations," traces advances in scientific collaboration across linguistic and national boundaries from the mid-nineteenth century up to the First World War. This collaboration was fostered by the accelerated growth in international congresses and scientific societies. Such efforts also were funded by a search for a universal language (Esperanto), cataloging innovations such as the Melvil Dewey decimal system of classification, the creation in Brussels in 1895 of an Institut international de bibliographie (IIB), and the formation of international institutes and societies for geodesy, astronomy, chemistry, et cetera. It was a revelation to this reviewer to fathom how widespread these efforts actually were. The role that Belgium played in these endeavors, as a neutral country and as an assumed facilitator of knowledge between the Latin and Germanic worlds, was remarkable. These efforts to build and elaborate a "scientific internationalism" gave support to those focused on creating a global society in which information and values were shared.

The jarring reality of WWI as national governments increasingly sought to control the uses of science and technology brought a challenge to these international efforts. This is detailed in the second chapter, entitled "War as Watershed." Perhaps the most egregious event occurred early in the First World War. On October 4, 1914, ninety-three German intellectuals signed a patriotic manifesto, "A Call to the Civilized World," claiming the allies had stained German honor by suggesting that the German kaiser had wanted to go to war and that Germany had violated Belgium's sovereignty. About one fifth of the signatories were scientists, many of them Nobel Prize winners. Albert Einstein, ever the internationalist and pacifist, was the leading scientific holdout. The war, later hostilities, and latent prejudices brought a near halt to any cooperative endeavors.

In chapter 3, "The Legacy of a Fractured World," Fox advances the story up to 1940. Once the idealistic vision of an "all-embracing internationalism" was so savagely called into question, it would indeed take an extreme effort to reestablish international scientific cooperation. The agenda was set by a "national turn." Pride of place was given to national museums and exhibitions, as well as the number of Nobel Prize winners a nation had won. To be sure, there were still countervailing efforts to normalize relations between countries. The International Research Council (IRC), through its organs such as the International Astronomical Union (IAU) and the International Union for Pure and Applied Chemistry (IUPAC), sought to reestablish relations with the Central Powers, despite the prevailing French/German rivalry and the reluctance of Belgian academics to participate with Germans. Also, the increasing "totalitarian tide" in Germany and Russia in the 1930s made cooperation difficult. Just think, for instance, of the four-volume manual, *Deutsche Physik* (published in 1936–1937), by German Nobel Prize winner Philipp Lenard, as well as the pavilions celebrating and glorifying national contributions at the 1937 International Exposition in Paris.

A short epilogue highlights some of the more hopeful post-1940 developments, such as the resuscitation of the International Committee on Intellectual Co-operation in 1945. This was soon followed by UNESCO, the United Nations agency for educational, scientific, and cultural affairs. In our own century we have seen such ventures as the Google Books Library project, the Digital Public Library of America (DPLA), and global brain emerge. The question remains whether they will succeed in making truth open to all.

Who should read this book? Anyone interested in learning more about the social and cultural embeddedness of scientific international communication endeavors. And, equally, those interested in reflecting critically on the human hope that science and

scientific knowledge sharing and acquisition will lead to a promised land in which peace reigns unadulterated.

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ORIGINS

SAVING THE ORIGINAL SINNER: How Christians Have Used the Bible's First Man to Oppress, Inspire, and Make Sense of the World by Karl W. Giberson. Boston, MA: Beacon, 2015. 212 pages. Hardcover; $27.95. ISBN: 9780807012512.

In his latest endeavor to make a case for the coherence of evolutionary science and religion, Karl Giberson uses the biblical story of Adam as both a starting point and a framework for exploring the alleged "conflict" between religion and evolution in American culture. Giberson is a physicist who, in an earlier book (*Saving Darwin: How to Be a Christian and Believe in Evolution*) gives "a deeply personal account" of how he was raised as a fundamentalist whose ambition was originally to study science and to become an advocate for creationism, but who, in his scientific studies, discovered young-earth creationism to be indefensible. Yet, still a Protestant Christian, he felt compelled to justify his belief that one can both accept evolutionary science and remain Christian. Largely because of the rather negative reception of the *Saving Darwin* book in evangelical circles, he spent much time defending his views to critics and to the administration of his own evangelical college. Eventually, he quit his job (where he had taught for 27 years); he now teaches at a Catholic school that "welcomes examination of its own traditions." It was within this environment that Giberson was able to write the current book under review. He notes that several other scientists and friends at evangelical schools, who had also written books or articles about evolution as God's creative process or about how Christianity need not believe in a literal Adam, have been driven out of their teaching positions. Clearly, within the environment of an evangelical college or university, delving too deeply into this topic is a potentially risky task, although the scientists at many of these colleges have been trained at first-rate and elite universities.

The Adam of the Old Testament is only rarely mentioned in the biblical texts after Genesis. Christians, however, have focused on Adam as the ultimate source of sin, death, and evil among humans. Furthermore, says Giberson, Adam is seen as establishing the social order regarding heterosexual marriage, free will, observation of the Sabbath, use of the earth's resources, condemnation of nudity, and the assigning of subordinate roles to women and non-whites in modern society, as well as influencing people's views of evolution and big bang cosmology. However, Adam would probably have remained a relatively minor character had it not been for the Apostle Paul, whose theology cast Christ as the "Second Adam" and whose role is to undo the damage done by the first one. Giberson next recounts the roles of early Christian apologists in developing this viewpoint. The question arose: Did Adam's sin stain all of humanity and make it impossible for any of us to avoid sin, or was Adam simply an example for each of us, that we all have the free will to either sin or to avoid sin? The Pelagian heresy, advanced by the early Christian ascetic Pelagius, took the second view. According to Pelagius, Adam was merely an example of each of us. Adam's sin was his own; infants are born into a state of innocence and Christians need not be overly concerned with Adam's sin to the point of hopelessness.

The definitive Christian answer to this question was put forth by the early theologian Augustine of Hippo (St. Augustine) who, says Giberson, was the most influential Christian in the Western church after Paul. Augustine argued for "original sin" with which we are all born due to Adam's sin, and for Christ as the "Second Adam." This arises from his affirmation that salvation can only come from the church through the sacrament of baptism. Any other path claimed for salvation, such as through good works, would suggest that Christ had died in vain. Therefore, seeing Adam as simply an example of the temptations faced by "Everyman" is insufficient to explain the passion of Christ. But, if all are born inheriting Adam's transgression, then infants must be baptized as well. It made sense to Augustine that the suffering of innocent infants who have disease and deformities is the result of the sins they inherited, not any they had as yet committed. Furthermore, as babies mature, he noted, they always commit sins in their actions as if they are actually unable to choose the good over sin. As such, Augustine established the role of Adam as the source of original sin and Christ as the only path to salvation. Thus, Christ himself became the only character in the entire Bible that is more significant than Adam.

From here, Giberson brings in the medieval topic of dualism. As Christianity moved into the late Middle Ages, Thomas Aquinas argued that while Adam's fall had indeed impaired the ability to resist sin, it had not affected human reason. Thus, through the study of natural philosophy, humankind can learn to understand God's grand design on a cosmic scale. Aquinas taught the centrality of the unmov-

ing earth as the locus of God's great acts of creation and redemption, but that the earth was surrounded by moving heavenly spheres which reflect God's untainted mathematical perfection of creation. This "Christianized cosmos" led to the search for Adam's language as the common source of all other human tongues and for the location of the Garden of Eden. Furthermore, if Adam was indeed the first man, then European histories were necessarily extensions of Old Testament chronologies which were thought to extend back to around 4000 BC to Noah, who descended from the first man, Adam. This meant that no national history could extend back before that time and that all humans of all nationalities must have diverged from Noah's (and Adam's) lineage.

The birth of modern science began to challenge these views. In the mid-1500s, Nicholaus Copernicus postulated that the corrupted earth actually moves through the uncorrupted heavens, an idea which was later advocated by Galileo. Anatomists Andreas Vesalius and Paracelsus challenged the long-established teachings of the Greek physician Galen, practicing in the Roman Empire, whose ideas of anatomy had stood for over one thousand years. These new scientists met with strong resistance because the general opinion was that God had imbued Adam with complete knowledge and that ancient texts (especially the Bible), being closer in time to Adam, were wiser, closer to God, and therefore more accurate. Giberson notes that it took centuries to dislodge these old ideas. New sciences that challenged the old biblical accounts were suppressed, denounced, and viewed as unorthodox.

Giberson argues forcefully that a person can be a Christian without believing in a literal Adam and Eve. Since anthropologists find it impossible to trace all humans back to a single pair of ancestors in the Middle East some six thousand years ago, this indicates that humans are *theologically*, not *biologically*, descended from Adam. The biblical accounts of creation and the flood are clearly retellings of Babylonian creation and flood myths, *Enuma Elish* and the *Epic of Gilgamesh* (based on an even earlier myth of *Atrahasis*), which were written centuries before the two different creation and flood stories in Genesis.

The "Book of Nature," however, clearly has no Adam, as the process of natural selection and the fossil record documenting evolution do not require it. Although Darwinian evolution was initially challenged by other hypotheses, modern evidence clearly indicates that Darwin was correct in his description of evolution by natural selection. The fact that evolution has been firmly established within the scientific community triggered three modern responses in the twentieth century. The *Modernists* saw evolution and modern biblical scholarship as undermining older Christian views, indicating a need for a new post-Enlightenment Christianity. The *Fundamentalists*, on the other hand, insisted that a literal reading of the Genesis accounts, including Adam and Eve as real persons, was necessary, and that any scholarship that uproots this is to be rejected. A third group, which Giberson calls *Traditionalists*, tried to make small theological adjustments to accommodate the discoveries of science without calling for a new understanding of Christianity. Over time, the fundamentalist view evolved into the pseudoscience of "scientific creationism" that is still popular among conservative Christians. However, this triggered another extreme cultural backlash; the "anti-religious culture warriors," such as Richard Dawkins, began using evolution as an argument against religion. The above disagreements are the source of the current conflict.

Saving the Original Sinner is a well-written, well-researched, readable history of the origins of the conflict between religion and evolution in contemporary society. And certainly, other scholars have written about this topic from scientific and religious viewpoints. But the uniqueness and the heart of this book (where I can, from experience, empathize with the author), lie in the *introduction*, in *chapter 11*, and in the *conclusion*. Here, Giberson discusses his own struggles: first, as a Christian academic who left fundamentalism to accept evolution, and secondly, as a faculty member at an evangelical college, struggling to teach that there is, in fact, no conflict. He met constant resistance both from the college administration and from the "gatekeepers"—the outspoken individuals who were not associated with the college, but insisted that any concession to accepting evolution is a reason to steer Christian students away from that college.

A Christian can accept modern science, Giberson insists, including evolution. But the task is difficult. Giberson notes that, in contemporary America, the anti-evolution movement has grown stronger and more conservative over the past century, whereas in the scientific world, evolution has become firmly established. Evolution is no longer just a chapter in the back of a biology book, but has become the central, organizing principle of biology. Therefore, the challenge remains: to resolve the problem of how to take "God's Two Books" (Divine Revelation and the Book of Nature) seriously. Says Giberson, "The task is beginning to look impossible from any perspective." A historical Adam has become an essential component of Christian theology—as a part of creation, the Fall, and Christ's redemption. And no

Christian scholar has found a more satisfactory resolution to the origin of sin. Yet, the physical evidence clearly indicates that the human body evolved from an earlier form. But he argues that "the Book of Nature (science) need not bow down every time they disagree" and that "Christianity does not need an inerrant Bible."

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Science and Religion

REASON AND WONDER: Why Science and Faith Need Each Other by Eric Priest, ed. West Conshohocken, PA: Templeton Press, 2017. 224 pages. Paperback; $14.95. ISBN: 9781599475264.

The book *Reason and Wonder* consists of thirteen chapters, each of which arose for the most part out of the James Gregory public lectures on science and religion at the University of St. Andrews, Scotland, funded by the John Templeton Foundation. The chapters are on diverse subjects relating science and religion. The topics in the book address the question: Do science and religion need each other? Of course, being a Templeton-funded project, the answer in every case is, in some sense, yes.

The first chapter, by Eric Priest, the editor of the volume, is an introduction to the general problem of relating science and religion. It stresses that science and religion are not at war, invoking Ian Barbour's taxonomy of the relation between the two. After that, there are chapters on the New Atheism (by Keith Ward), natural law and reductionism (Eleonore Stump), the origin and end of the universe (David Wilkinson), the universe of wonder (Jennifer Wiseman), evolution, faith and science (Kenneth R. Miller), evolution and evil (Michael J. Murray and Jeff Schloss), "Is there more to life than genes?" (Pauline Rudd), psychology and science (David G. Myers), being a person and neuroscience (John Wyatt), science, spirituality and health (John Swinton), miracles in science (Mark Harris), and "Can a scientist trust the New Testament?" (N. T. Wright). For readers of *PSCF*, many of the authors and much of the ground covered will be familiar, even if written from a slightly different slant.

Given the breadth of the book, this review will focus on a few of the essays, and respond critically to two others.

In his chapter, Keith Ward questions how plausible it is for the New Atheists to believe that the universe started from a quantum fluctuation in a preexisting quantum vacuum. If true, it would seem to suggest that the quantum vacuum must be eternal. This would mean that the universe depends upon a timeless reality beyond itself. But how could this possibly fit within scientific explanation? It would seem that this is no more scientific than asserting that a timeless God created the universe. Furthermore, to quote Ward, "Belief in God is rational, because it is based on our knowledge that consciousness and intentional agency are fundamental features of reality" (p. 45). In other words, not all relevant evidence is testable in the scientific sense. Ward points out three basic problems with the arguments of Richard Dawkins. First, it is sheer dogma to deny that consciousness could arise in any other way than through a long evolutionary process. Second, Dawkins argues that the universe of simple elements is more probable than the complex mind that God represents. But, again, this is a dogmatic assertion with no scientific foundation. Third, the idea that there needs to be an explanation for God is no greater a problem than the need to explain a universe that exists in and of itself. In summary, Ward suggests that

> the final irony is that it is belief in a rational God that makes science possible, whereas in an atheistic universe it is a complete surprise that there is any rational structure to the universe, or that human reason can make any sense of it. (p. 53)

Eleonore Stump provides a critique of the "secularist scientific picture" (SSP), which, she says, is a reductionism of everything to the laws of physics. Her claim is that "research in various areas is making inroads against some parts of this view" (p. 54). While noting that it is highly counterintuitive that such things as love, fidelity, creativity, and the progress of science could come out of such a reductionist view, she contrasts that view with the scholastic view of natural law. In the latter view, "natural law is a participation on the part of a human person in the eternal law in the mind of God" (p. 56). She goes on to say that the challenge for SSP is "the construction of the personal out of the impersonal" (p. 58). Some examples illustrate further problems, for instance, protein folding (the function of which depends on structure), and the dependence of an infant on a caregiver to allow for proper development. The essay concludes, "The rejection of reductionism leaves room for the place ordinary intuition accords persons in the world" (p. 63).

Perhaps my favorite essay was the one by Murray and Schloss entitled "Evolution and Evil." This chapter offered an argument on the problem of evil, borrowing a page from the book of skeptical theism. The first step is to recognize that one does not need evolutionary theory in order to observe that

there is apparent evil in nature—as this would have been evident before Darwin. The claim the authors wish to challenge is that since evil in nature exists for no good reason, therefore God does not exist. Rather than apply a direct argument, the authors suggest that all we really need is a good explanation of evil that is true "for all we know" (p. 101). A good explanation "makes it clear that the evil that is permitted is a necessary condition for the occurrence of an outweighing good" (p. 101). After dismissing some popular explanations they regard as weak, the authors offer two explanations that comport well with the scientific story. One relates to our lack of understanding of animal consciousness; the other reasons that the possibility of law-like regularity, producing beings such as us, would necessarily require the kind of history that we see from remnants past.

Space does not permit me to summarize the book further, but I do want to raise a couple of questions about a few of the other essays in the volume. To start with, Myers's article raises a number of issues related to religiosity and psychology, with several of the points not well supported by the data. For example, with little evidential support, Myers states that sexual orientation is "natural," that is, largely biologically influenced. The problem is what is meant here by "natural." Conditions such as substance abuse can have genetic components as well. Would we then say that they are "natural" too, and therefore acceptable, or would we recognize that the world is broken because of the Fall and interpret them in light of that? This is reminiscent of Abraham Kuyper and his "two sciences." If creation is fallen, then we must take that into account in our explanations. It follows that there is no such thing as a category called "natural" that allows us to conclude that what appears in nature can be judged simply as part of the "good." Myers tells us he comes out of the "Reformed and ever reforming" tradition, but perhaps his "ever reforming" in this case has gone too far.

Swinton's essay also suffers from some surprising misunderstandings. When I read that he thought his methods for studying spirituality and health ("randomized control variables, statistical analyses and modes of research that follow the principles of falsifiability, generalization and replicability") were the measure of why he thought the research should be considered "hard science," I was taken aback. As anyone who does research in the hard sciences knows, it is not that the methods make the conclusions reliable. It is rather the constricted subject matter of the investigation that is so constraining as to qualify as "hard science." This does not lend confidence to the conclusions Swinton draws from his investigation.

In light of the criticisms noted above, the reader should realize that the quality of the book's essays is variable; some are more substantial, others less so. Who would find the book of interest? Anyone who is following the writings of particular authors in this collection might like to pursue their essays. Beyond that, those who do not have a substantial background in the issues involved may find the essays as a whole an interesting introductory read. However, as many of the edited Templeton volumes seem to be, I would suggest that there is little here that one cannot find in more depth elsewhere.

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MY SEARCH FOR RAMANUJAN: How I Learned to Count by Ken Ono and Amir D. Aczel. Switzerland: Springer, 2016. 238 pages. Hardcover; $29.99. ISBN: 9783319255668.

"But what does a mathematician actually *do*?" It is still as likely as not that the lay person who asks this question will be pointed, first of all, to G. H. Hardy's *A Mathematician's Apology*, first published in 1940. In the third paragraph of that elegant but elegiac work,

the author describes himself and his literary task thus: "A man who sets out to justify his existence and activities."

No sensitive Christian reader can pass over those words without a profound sense of sadness. True, Hardy's "justification" is not exactly the δικαιοσυνη of the Epistle to the Romans. Yet, true also, Hardy does not welcome the idea that the real justification at the heart of life is received as an unmerited gift. Indeed, *A Mathematician's Apology* is poignant precisely because it combines the defense of mathematical fame (for those few who are capable of achieving it) with the fear that even this "safest and soundest of investments" may not endure. "How painful it is to feel that, with all these advantages, one may fail …"

Ken Ono's heart-wrenching autobiography bears a subtitle with a double meaning: "How I Learned to Count." On one level, this is a capsule description of the combinatorial aspect of Ono's mathematical work. "Combinatorial" refers to counting patterns or arrangements of some kind, such as the *partitions* which are frequently mentioned in the text: a partition of an integer (such as 6) is simply a way of writing it as a sum of smaller integers (such as 1+2+3). The number of different ways of partitioning a given integer, like 6 in our example, is called $p(6)$, and the behavior of p, the *partition function*, has many surprises and unexpected depths. On another level, this is the story of how the author learns that he himself counts as a human being, and that (contrary to what a reading of Hardy might perhaps suggest) his significance is not measured simply by the abundance of his mathematical achievements. These stories are interwoven with one another and with a third one: Ono's interaction with the work of the enigmatic genius Srinivasa Ramanujan, who was "discovered" by European mathematicians when he wrote to Hardy in 1913 and who, upon his early death from tuberculosis, left for posterity a huge collection of mysterious formulae (most without a sketch of a proof, most subsequently turning out to be both true and profound) which he believed had been revealed to him by the goddess Namagiri. (Ramanujan's story was recently dramatized in the movie *The Man Who Knew Infinity*, and the story of Ono's work as mathematical consultant to this movie serves as a kind of coda to his autobiography.)

Ono shares with us that he was raised by Japanese-American "tiger parents" determined that their son follow the path they had marked out to the goal they had determined was best for him: that of becoming a distinguished professional mathematician. He writes:

> They wanted their boys to be hungry for success, so they starved us of praise … At school, I was a star student; at home, nothing I did was good enough. [My parents] saw no point in acknowledging such insignificant achievements as straight A's on a report card … I awoke each day with painful thoughts. I will never be good enough. I am an impostor. My parents will never love me because I can never live up to their expectations … And so I dropped out. (p. 11)

Today, Ono is indeed a distinguished professional mathematician, although he did not arrive by the path his parents had mapped for him. His book contains heartfelt tributes to friends, family, and professional mentors who helped him recover his life's purpose. Behind all of these stands the figure of Ramanujan, whose story Ono retells in this book: a story which deeply influenced his father's life and subsequently his own. "Ramanujan's story showed me that there might be a way to earn my parent's respect that didn't require following the rigid script that they had written for me" (p. 49). In fact, Ramanujan's story opened his heart, and perhaps his family's heart, to the possibility of grace.

How do I count? How do I *know* that I count? I suggest that in the parables of Luke 15, Jesus shows us that to count is to be embraced by the love of Abba, the Father who runs to welcome the strayed one home. Jesus warns us also, through the figure of the elder son in the story, that we can misperceive this love; we may regard it as something to be earned or "slaved for," and as a result live with a sense of hollowness, of never having done enough. Ono courageously describes his own journey from this hollowness to this grace, and he (raised agnostic from the cradle) chooses to conclude the story with his request to receive baptism and join a church community in 2004, in his middle thirties. This is a brave and passionate autobiography, combining the academic and the deeply personal. Strongly recommended.

Reviewed by John Roe, Professor of Mathematics, Pennsylvania State University, University Park, PA 16802.

THEOLOGY AND SCIENCE FICTION by James F. McGrath. Eugene, OR: Cascade, 2016. viii + 113 pages, bibliography, no index. Paperback; $17.00. ISBN: 9781498204514.

Is there a Creator God who made all that exists out of nothing? Has God evolved along with the cosmos? Are godlike beings actually advanced aliens whose science and technology appear supernatural? Will humans develop godlike power? Will we be superseded by artificial super-intelligences? Will robots develop souls? Will Christianity survive encounters with extraterrestrial cultures in the spacefaring

future? How will earthly religions change in centuries to come? What if some alien worlds never fell from grace? Such big questions have long been raised by philosophers and scientists, as well as by theologians and science fiction writers.

That science fiction and theology intersect in many ways may surprise, but it shouldn't. Both often express a sense of wonder, and even awe. Both seek self-understanding and awareness of our place in the cosmos. Both are fascinated with the Other and the New, with intimations of the sacred, the transcendent, the divine—with the Mystery beyond human knowing and imagining. Both are curious about life and death, origins and endings, the deep past and far future. Both address changes and continuities in ideas, beliefs, values, and practices. Both address our hopes and fears, anxieties and dreams. When science fiction writers wrestle with moral questions, with the search for "forbidden knowledge" or the powerful possibilities and pitfalls of "playing God," with utopias or dystopias, with vivid apocalypses or epic, multigenerational journeys, with demons or messiahs from the heavens, they signal a deep debt to the Bible as an ancient and continuing source of images, characters, plots, tropes, and themes for storytelling. I have long used my training in biblical exegesis in the analysis and interpretation of science fiction (and scientific) texts; this is but one reason why I found the background of the author of this brief but stimulating discussion so appropriate.

James McGrath is a New Testament scholar and science fiction enthusiast who previously edited a wonderful collection of scholarly essays, *Religion and Science Fiction* (2011), as well as *Religion and Doctor Who* (2013). The slim volume under review (there are only 92 pages of text, with the first and last pages of each chapter filling only a half-page or less—not counting a short preface and three concluding, very short fictions) is full of interest and insight. Each chapter ends with questions for reflection. Mary Shelley completed her incredibly influential novel *Frankenstein* in 1817; it at once established science fiction as *the* literature of the modern age of science and technology and set it upon a century-spanning trajectory of engagement with the world of myth and religion. Sadly, there was no space for McGrath to reflect on this, nor to provide much context or description of texts the reader might not be familiar with.

In his helpful introduction, McGrath defines his terms and the limits of his study. He regards Ian Barbour's famous four-fold typology of science-religion relations as useful for his purposes. I would agree that it makes a good starting point for analysis,

although the model is quite problematic from a history of science perspective. In his second chapter, McGrath offers a good introduction to the nature of canonicity with respect to the Bible, *Star Wars*, and *Dr. Who*. Also included are practices such as pilgrimages and ritual clothing, which cut across the worlds of religion and science fiction/comic book fandom. "Science Fiction against Theology and as Theology," the focus of chapter three, is a fine discussion deserving of a book-length analysis. Antireligious science fiction is not really addressed, nor satires such as John Kessel's *Good News from Outer Space* (1989) and Marcos Donnelly's *Letters from the Flesh* (2004). A few quibbles: it was shocking to find no account of Olaf Stapledon's mind-blowing 1937 masterpiece, *Star Maker* (see the 2004 scholarly edition, edited by Patrick McCarthy). On p. 45, Christmas is mentioned, but no classic science fiction stories are cited. On p. 46, McGrath quite rightly states that Christians have many ways of incorporating the discovery of extraterrestrial intelligences into their theologies. But he cites none of the theological literature produced by Ted Peters and others; for a recent example, see *Theology and Science*, vol. 15 (May 2017). In a comprehensive treatment of this subject, one would learn about D. G. Compton's *The Missionaries* (1972), Philip José Farmer's *Father to the Stars* (1981), and many other examples.

Chapter four, "Theology against Science Fiction and as Science Fiction," is another brief but illuminating angle on the relationship, addressing such questions as apocalypse, afterlife, miracles, and how theological ideas can be expressed in science fiction. The discussion, given the publisher's constraints on the author, is good, but is neither specific nor detailed enough. The fifth chapter, on philosophical/ethical issues (e.g., soul/mind/sentience/personhood, the Golden Rule, eternal life, digital immortality) is also very interesting—if too general for my taste. The scholarly literature is ignored, as are countless primary texts (to be fair, the author's modest aims are made explicit, e.g., p. 80). The sixth and last nonfiction chapter, on how science fiction can inform theology, and how theological science fiction can critique scientism and dogmatism, was my favorite. McGrath's message of treating "the alien" with hospitality, love, justice, and humility is—given the global refugee crisis—both timely and biblical.

McGrath's bibliography has eighty-three items, with curious omissions. The short story occupies a central place in the field, so it is quite right that *Other Worlds, Other Gods: Adventures in Religious Science Fiction*, edited by Mayo Mohs (1971), is mentioned. But it is a shame that there was no room to cite Roger Elwood's anthologies *Flame Tree Planet* (1973) and *Strange Gods* (1974); or Harlan Ellison's *Dangerous Visions* collections (1969–1972); or *Wrestling with Gods* (2015), edited by Liana Kerzner and Jerome Stueart, to name a few. Apocalyptic/post-Apocalyptic stories cut a huge swath in the literature of religious science fiction. Examples are legion: perhaps the classic atomic-age text is *A Canticle for Leibowitz* (1959) by the Catholic writer Walter M. Miller Jr. It is missing from McGrath's book, but I would recommend it highly, along with Rose Secrest's scholarly study *Glorificemus* (2002). C. S. Lewis's *Out of the Silent Planet* (1938) makes the bibliography, but not the rest of his *Space Trilogy: Perelandra* (1943) and *That Hideous Strength* (1945), nor his story collection *The Dark Tower* (1977), nor his essays *Of This and Other Worlds* (1982). McGrath cites Dan Simmons's *Hyperion* (1980) but not the rest of the saga: *The Fall of Hyperion* (1990), *Endymion* (1995), and *The Rise of Endymion* (1997). Mary Doria Russel's brilliant first-contact-with-intelligent-extraterrestrials meditation on faith, science, and theodicy, *The Sparrow* (1996), is included but not its perspective-shifting sequel, *Children of God* (1999). Robert J. Sawyer's *Calculating God* (2000) is listed, but none of his many other books wrestling with moral and theological questions. Although the idiosyncratic beliefs of science fiction giant Philip Dick receive scant attention, McGrath does cite Gabriel Mckee's *Pink Beams of Light from the God of the Gutter: The Science-Fictional Religion of Philip K. Dick* (2004); another scholarly source is the annotated tome, *The Exegesis of Philip K. Dick*, edited by Pamela Jackson and Jonathan Lethem (2011).

McGrath references Frederick A. Kreuziger's *The Religion of Science Fiction* (1986) but neglects his equally pioneering *Apocalypse and Science Fiction* (1982). Also missing are *The Intersection of Science Fiction and Philosophy: Critical Studies,* edited by Robert E. Myers (1983); Stephen May's *Stardust and Ashes: Science Fiction in Christian Perspective* (1998); and Richard A. Burridge, *Faith Odyssey* (rev. ed. 2003), which is a nice companion to George Murphy's 2005 *Pulpit Science Fiction*. Greg Garrett's *Holy Superheroes!* is cited, but not the revised and expanded edition of 2008.

Jewish science fiction, an important subgenre, gets a nod with the citation of *Wandering Stars*, edited by Jack Dann (1974), but not *More Wandering Stars* (1981, also edited by Dann), or *People of the Book*, edited by Rachel Swirsky and Sean Wallace (2010). Among the many missing are Phyllis Gotlieb's collection *Blue Apes* (1995), which begins with the death of the last Jew in the universe; and Paul Levinson's *Borrowed Tides* (2001), which depicts what I believe is the first Passover seder in space.

There is a significant subgenre one might call either acidic satire, anti-religious, or even anti-Christian science fiction. Well-known examples of this challenge to McGrath's creative interaction thesis include Michael Moorcock's *Behold the Man* (1969); James Morrow's linked series *Only Begotten Daughter* (1990), *Towing Jehovah* (1994), *Blameless in Abadon* (1996), and *Bible Stories for Adults* (1996); Gardner Dozois, ed., *Galileo's Children: Tales of Science vs. Superstition* (2005); and Thomas Disch, *The Word of God* (2008).

A few typos appear in McGrath's text, but they are easy to spot. For instance, carbon monoxide (p. 89) should be carbon dioxide. As I have suggested, the author was operating under tight publisher's constraints, limiting his discussion of significant stories and his ability to provide a more comprehensive list of relevant references. The multidisciplinary literature on the complex relations of theology and science fiction is huge, to match the deep and wide primary literature (and filmography). For a brief, sound, interesting introduction to the field, I can certainly recommend this book.

Reviewed by Paul Fayter, a retired pastor and historian of science, theology, and science fiction. He taught at the University of Toronto and at York University in Toronto for thirty years. He lives in Hamilton, ON.

Technology

THINKING MACHINES: The Quest for Artificial Intelligence and Where It's Taking Us Next by Luke Dormehl. New York: TarcherPerigee, 2017. 275 pages, including bibliographic references and index. Paperback; $16.00. ISBN: 9780143130581.

Thinking Machines is a book that gives you the facts about artificial intelligence (AI) in a well-written and enjoyable way. The book is a good read for those who know little about AI and want to see what all the fuss is about. In this small volume, author Luke Dormehl (author of *The Formula: How Algorithms Solve All Our Problems … and Create More*, and contributor to *Fast Company*, *Wired*, etc.) introduces the reader to the history of AI, where AI can be found today, and where AI seems to be going in the future.

Chapters 1 and 2 are about the history of AI. AI has had a somewhat "on again, off again" past, with many early attempts to build systems that seemed promising, but ultimately were disappointing. The chapters explain this history and how, ultimately, advances in neural networks led us to where we are today, and the development of tools like Siri, self-driving cars, and Roombas.

Chapter 3 talks about the rise of cognitive agents all around us—in our phones, cars, houses, watches, stores, and work. The author has a brief discussion of the ethics of information collection. What kind of data should we allow others to gather about us? Who owns that data? Will the information collected about us be used to serve us or to serve the companies that collect it? The author ask many questions, but gives no answers.

In chapter 4, Dormehl discusses the rise of service-oriented AIs, such as virtual assistants, Microsoft's Clippy, and others. The chapter contains many entertaining stories and then ends with a discussion of therapeutic, childcare, and eldercare robots. Dormehl makes no mention of the ethics of using these robots or the effects they might have on society and relationships between humans.

What will be the impact of AIs and robots on occupations? Chapter 5 speculates about how AIs and robots will revolutionize the job market, eliminating jobs that are dangerous (mining) and tedious (assembling smartphones), but also those that require a high level of knowledge in a limited domain, such as the practice of law. The author argues, however, that new kinds of jobs are on the rise, especially in the creation of content. The number of jobs is growing by nearly 10% per year in some areas such as vlogging, answering online queries that an AI cannot interpret, and game design. Dormehl argues that jobs like these, jobs that require creativity and social intelligence, will always be what humans are good at and computers are not. Finally, the author notes the rise of products made by humans, such as pottery, that are not all identical and have an artisanal touch.

Chapter 6 contains many fascinating stories about attempts to program computers, robots, and AIs to create. It briefly explores the definition of creativity. One fascinating question is whether a computer can create an invention that can be patented, as a patent requires an "illogical step" from existing invention, and making illogical steps is not a computer's forte.

Chapter 7, "Mindclones," follows, with information about attempts to duplicate a person's mind in a computer. The goal of various projects is to cheat death by storing a person's experiences, through personality capture, lifelogging, and neural networks, to duplicate the human brain. Again, the author describes how these efforts are being done, but never questions whether they could or should be done.

The final chapter of *Thinking Machines* looks at the future, and future risks, of AI. Dormehl notes that visionaries in the field of AI have begun to emphasize the need for safety protocols and ethics panels to guide AI scientists. The author states, "The threat

comes from AI that is smart enough to work with other connected devices, but not smart enough to question its own motivations" (p. 223). He then goes on to speculate about who is responsible when an AI goes wrong and breaks the law, and whether an AI has any rights.

Is Luke Dormehl's book one that you should have on your shelf? If you are looking for a book to introduce you to the past, present, and future of AI in an entertaining way, this is a quick and worthwhile read. If you are looking for a book that struggles with the hard questions surrounding AI, you will be disappointed. Dormehl only dips his toes into the ocean of questions that AI begs us to ask. In most cases, he is giving us "just the facts," without analysis of the ethical or sociological implications of the technology. For Christians, many of these are important questions. What does it mean to be made in God's image? What effects will AI have on relationships and community? What does God say about the importance of work and service, and which occupations and vocations should we give to AIs to handle? To get answers to these and other questions, one has to go elsewhere.

Reviewed by Victor T. Norman, Associate Professor of Computer Science, Calvin College, Grand Rapids, MI 49546. ✭

Call for Papers

Artificial Intelligence: Discerning a Christian Response

Derek C. Schuurman (PhD, McMaster University) is a professor of computer science at Calvin College where he holds the William Spoelhof Chair. *Shaping a Digital World: Faith, Culture and Computer Technology* (InterVarsity Press, 2013) is his most recent book. He describes for us, on the ASA and CSCA web sites, the latest developments and challenges in artificial intelligence. That focus calls for our attention to the promise and threat, at hand and in the near future, for issues such as job enhancement and displacement, building in guidance for systems that will then act autonomously, and what it is to be a person.

Schuurman's essay is intended as an invitation. 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 Schuurman at dschuurman@calvin.edu. He will send the best essays on to peer review and then we will select from those for publication in an Artificial Intelligence 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.

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Looking forward to your contributions,

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

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"Upholding the Universe by His Word of Power" Hebrews 1:3

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