PERSPECTIVES on Science and Christian Faith

JOURNAL OF THE AMERICAN SCIENTIFIC AFFILIATION

In This Theme Issue on Artificial Intelligence …

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

VOLUME 71, NUMBER 2 **JUNE 2019**

(US ISSN 0892-2675) (CPM #40927506)

Perspectives on Science and Christian Faith

Perspectives on Science and Christian Faith (USPS 28-3740, ISSN 0892-2675) is published quarterly by American Scientific Affiliation, 218 Boston Street Suite 208, Topsfield, MA 01983. Periodicals postage paid at Topsfield, MA, and additional mailing office. POSTMASTER: Send address changes to: Perspectives on Science and Christian Faith, 218 Boston Street Suite 208, Topsfield, MA 01983.

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Worth the Steep Price

James C. Peterson

Whether looking in this issue at the near future of artificial intelligence or at the distant past of origins, how we frame the discussion in time affects our evaluation of it. Let's take a moment to look at the bigger picture, the full context that affects our understanding of origins, life now, and what is in store for us in the future.

The Christian tradition describes the one God as a trinity of persons characterized by love in relationship even before creation. God has generously created a world in which other sentient creatures can come to be and love. But along with the consciousness that makes love possible comes the potential for suffering. Siddhartha Gautama thought that the very essence of sentience is suffering. That has often been the human experience. However, the current consensus, that the universe began about 13.8 billon years ago, means that consciousness and suffering are relatively recent. At least on our planet, there would be no suffering for a barren rock or for a primordial soup. Creatures that are sentient enough to suffer at all have been around for perhaps only the last half a billion years, hominids for a hundredth of that, *Homo sapiens sapiens* for less than a twentieth of the time of hominids, and recorded history for a twentieth of that. If the age of the universe were a book, the portion of its existence with conscious suffering, particularly human suffering, is on the last pages.

The Christian tradition proclaims that God's plan is to extend the life of his people with him forever. So, miles of library shelves could not contain the books to come, with always just as many more miles to go. The promise is that in the life to come, God will be so close as to wipe away every tear (Rev. 21:4). Might it be that conscious suffering on our brief page might be worth what it enables for those years to come? God could have created a world with no suffering by having no sentience; hence, there would be no choice for evil, no possibility of self-destruction, no opportunity to choose or reject relationship. Making possible the best gifts of life may require consciousness and, for a time, the possibility of the worst tragedies of life. Living on the page that contains these decisions and suffering, is a steep price for the moment, but only for the moment.

Jesus delayed his return to Mary and Martha so that there would be time for their brother Lazarus to die (John 11:6–7, 15). When Jesus did arrive, he saw their tears and wept with them (John 11:33–35). He felt their sorrow, even though he knew that his plan was to bring Lazarus back to life. The sisters' tears grieved Jesus, even though he knew their suffering was temporary and would be relieved to a better end (John 11:43–44). Suffering matters in its moment, but it can be reframed by its broader context.

It is amazing what one can endure if one knows that it is temporary and meeting a purpose. Jesus saw this in the Garden of Gethsemane and the cross that followed, as he directed his disciples to Psalm 22 that begins "My God, My God, Why have you forsaken me?" but continues, "For God has not despised or scorned the suffering of the afflicted one; he has not hidden his face from him, but has listened to his cry for help … They will proclaim his righteousness, declaring to a people yet unborn: He has done it!" (Ps. 22:1, 24, 31).

The Apostle Paul did not know what we now see as the evident age of the universe. Yet he did write,

> We know that the whole creation has been groaning as in the pains of childbirth right up to the present time. Not only so, but we ourselves, who have the first fruits of the Spirit, groan inwardly as we wait eagerly for our adoption to sonship, the redemption of our bodies. (Rom. 8:22–23)

The metaphor is one of a painful transition to the decades of life to come. The womb provides an extended start with no suffering. Then there is a transition with pain for all involved, but it results in a new life. It is understandable to fear the sharp pain of childbirth, yet it comes mixed with the excitement of the expectation of the new life to come that is worth the pain it requires.

Living in the brief time that we do, can seem like all that life is when we are immersed in it, but it may be that our genuine suffering now is both a crucial and an exceptional one-off. ⌂

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

Artificial Intelligence: Discerning a Christian Response

Derek C. Schuurman

Derek C. Schuurman

Artificial Intelligence (AI) techniques employing deep learning have recently achieved remarkable strides in tackling difficult problems and spurring applications in many new areas. Responses to these developments have ranged from existential fear to unbridled optimism. This technology opens up a plethora of ethical considerations and ontological questions about what it means to be human. The approach one takes to questions arising in AI is largely shaped by our philosophical presuppositions and our worldview. This article sketches some of the implications and important questions that arise surrounding AI. The article concludes by urging Christians to join this conversation, bringing insights from scripture and from Christian philosophy and theology to inform a responsible approach that contributes to the common good.

The movie *Wall-E* is an entertaining tale of a dystopian future of robots, automation, and humanity. A polluted earth is left abandoned except for robots like the charming title character *Wall-E,* who are left to clean up the mess. Humans have fled the planet, coddled aboard a massive ark-like spaceship where automated systems take care of their every need. It is striking that the most human-like characters in the movie are the two main robot characters while the human characters are portrayed as obese, feeble, and passive, shuttled about in reclining chairs, and consuming beverages while perpetually entertained by personal screens. At the climax of the movie, the ship's captain valiantly struggles to stand and, unaccustomed to walking, waddles over to the main control panel to wrestle control back from the automated ship. The tension in this climactic moment is driven by one question: will humanity take back control from technology?

For many decades, there have been many optimistic predictions about the capabilities of Artificial Intelligence (AI) which have consistently fallen short of expectations. In 1958 Frank Rosenblatt pioneered modeling neurons using simple networks called "perceptrons" which could be trained to classify data. Later, the pioneering AI researchers Marvin Minsky and Seymour Papert published an influential book titled *Perceptrons* which identified challenges with single-layer perceptrons and expressed skepticism about multilayer perceptrons. They wrote,

> Perceptrons have been widely publicized as "pattern recognition" or "learning machines" and as such have been discussed in a large number of books, journal articles, and voluminous "reports." Most of this writing ... is without scientific value.[1]

As a result, work in this area diminished greatly through the 1970s, during an era

Please note: A draft of this article was originally posted online in January 2018 as an invitational essay with a Call for Papers for a special issue on Artificial Intelligence. The two articles which follow were subsequently submitted and reviewed in response to this invitational essay.

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sometimes referred to as an "AI winter." However, interest in multilayer perceptrons was reignited in the mid-1980s after various breakthrough papers were published demonstrating how they could be made effective by employing specialized training algorithms.[2] These techniques have since been further refined, and, combined with advances in computing power, have led to so-called "deep-learning" methods.[3]

Deep learning uses many layers of perceptrons which can be trained using special techniques such as backpropagation or gradient descent. Deep learning is an approach to machine learning, a field which involves training computers to "learn" patterns without being explicitly programmed for those patterns. The training process will typically employ a labeled set of example training data in a process called "supervised learning." Alternately, training can also be performed using a set of unlabeled input data which is then processed to uncover patterns and structures. That process is referred to as "unsupervised learning."

AI techniques employing deep learning have recently achieved remarkable strides in tackling more difficult problems. A research team at Google demonstrated these techniques by developing a system that was trained to play the game Go by playing games against itself, eventually surpassing even the best human players.[4] Google has recently released its machine learning library, TensorFlow, under an open source license, spurring applications in many new areas.[5] These tools are not just solving puzzles in the laboratory. They are now being directed toward a plethora of difficult practical problems that traditionally have been beyond the capabilities of prior AI systems. For instance, these systems are showing great promise in diagnosing certain diseases and analyzing medical images, even outperforming human doctors in some tasks.[6] AI is also making advances in diverse areas such as legal work, image recognition, and language translation. The rise of autonomous vehicles is another emerging area in which deep learning has made remarkable progress.

As a book review editor for *PSCF* on topics relating to technology, I have been astounded at the sheer number of books that have been released in recent years about issues surrounding AI and robotics (several of which have been reviewed in these pages). These books include titles such as *Technology vs. Humanity: The Coming Clash between Man and Machine*; *In Our Own Image: Savior or Destroyer? The History and Future of Artificial Intelligence*; and *The Glass Cage: Automation and Us*. Some of these books take an optimistic stance, some are more circumspect, while others paint a darker picture.

Some have suggested that the advance of technology and AI will eventually solve all our problems. The term *technicism* is a word that has been coined to refer to the faith in technology as savior or rescuer of the human condition.[7] A recent book titled *Infinite Progress* includes the subtitle: "How the Internet and Technology Will End Ignorance, Disease, Poverty, Hunger, and War."[8] This is essentially a form of idolatry, replacing a trust in the Creator with technology. In fact, this trust in technology becomes explicit in the case of the "Way of the Future," a religious group founded by Anthony Levandowski, a former Google and Uber engineer who is working to "develop and promote the realization of a Godhead based on Artificial Intelligence" and that "through understanding and worship of the Godhead, [to] contribute to the betterment of society."[9] The transhumanist Zoltan Istvan suggests that this new AI deity "will actually exist and hopefully will do things for us."[10] These sentiments are explicit examples of an observation made by the writer David Noble that "the technological enterprise has been and remains suffused with religious belief."[11]

Everyone has a worldview which informs a set of beliefs that shape our conception of reality. Nicholas Wolterstorff suggests it is these "control beliefs" that enable us to commit to a particular theory.[12] These beliefs are also active in our technical work, including the theories related to research in AI, whether explicitly stated or not.

Some engineers and computer scientists believe that technology will even solve the problem of death. According to David Pearce, co-founder of an organization called Humanity+:

> If we want to live in paradise, we will have to engineer it ourselves. If we want eternal life, then we'll need to rewrite our bug-ridden genetic code and become god-like … only hi-tech solutions can ever eradicate suffering from the living world.[13]

Ray Kurzweil, an accomplished computer scientist and author of *The Age of Spiritual Machines*, has sug-

gested that within the present century we will be able to upload our brain into a computer and live forever, free from the limitations of our mortal bodies. This idea has been coined the "rapture of the geeks," and Kurzweil writes, "We don't always need real bodies. If we happen to be in a virtual environment, then a virtual body will do just fine."[14]

David F. Noble observes,

> Artificial Intelligence advocates wax eloquent about the possibilities of machine-based immortality and resurrection, and their disciples, the architects of virtual reality and cyberspace, exult in their expectation of God-like omnipresence and disembodied perfection.[15]

Psalm 115 states that the makers of idols will become like them, and in the case of the "rapture of the geeks," the end goal is to literally become software in a computer.

But not everyone shares an optimistic view of the future of AI, and warnings about the dark side of AI can be found in the recent headlines. Stephen Hawking warned that "the development of full artificial intelligence could spell the end of the human race," and Elon Musk has called AI "our biggest existential threat." In 2015, an open letter signed by many AI researchers, along with Musk and Hawking, urged that research priorities be made to ensure the beneficial use of AI.[16] The concerns over AI range from the short-term risks of putting people out of work to the more dystopian visions of a world in which machines turn on their human creators.

The pessimistic view of a dystopian future is frequently portrayed in sci-fi movies. Movies such as *The Matrix*, *Terminator,* and *Battlestar Gallactica* paint a picture of a dark future in which technology turns on humanity. Other movies and TV shows that have narratives based on the existential threat of AI and robotics include *Ex Machina*, *Westworld*, *Blade Runner*, and *I,Robot*. These stories portray different variations on the "Frankenstein narrative" in which technology turns on its human creators and threatens their existence. Many of these shows and movies, including the more recent sequel, *Blade Runner 2049*, raise profound questions about what it means to be human, exploring questions of identity, existence, free will, and how we are distinct from our machines. These cultural stories contribute to a social imaginary about the role and future of technology in our society.

While these threats may seem far-fetched, the more immediate concern is the loss of jobs due to AI, robots, and automation. In the early 2000s, I was doing my graduate studies in the area of computer vision. At the time, I recall thinking that self-driving cars were unlikely to be feasible due to the challenges of real-time vision systems in unstructured environments. However, within a short decade, autonomous vehicles were successfully demonstrated. In the near term, autonomous vehicles are likely to disrupt the labor market, potentially displacing millions of jobs in driving professions.

One paper published by researchers from the University of Oxford predicts that 47 percent of U.S. jobs are at risk of being replaced by AI technologies and computerization.[17] Other sources, such as the Organization for Economic Cooperation and Development (OECD), predict that only 9 percent of jobs are at high risk of being completely displaced, while many others will change significantly due to automation.[18] The issue of job losses due to robots and automation was also the topic of a recent *Christianity Today* article titled "How to Find Hope in the Humanless Economy."[19]

Still, some dismiss the threats of a "jobless future," pointing back to automation in the early nineteenth century when the "Luddites," fearful of losing their jobs, smashed automated weaving machines. They point to the advance of technology throughout the twentieth century, and how employment continued to grow. But a growing number of voices are warning that the remarkable success of AI and deep learning threatens to automate many tasks, including many white-collar jobs.

Some might suggest that these technological changes are inevitable, and we must accept the mantra of the Borg on *Star Trek*: "resistance is futile." However, we must reject a sense of technological determinism, the notion that technology is an autonomous force beyond our control. The famous media theorist Marshall McLuhan suggested that the way to begin is to stand back and scrutinize what technology and media are doing. He likened the forces of media and technology to the swirling storm depicted in Edgar Allen Poe's "A Descent into the Maelstrom." In this story, a sailor caught in the swirling vortex of a storm saves himself by carefully observing the behavior of the winds and currents around him. Like the sailor,

McLuhan suggests that we need to observe and discern the forces of a changing world to ponder its effects and wisely chart a safe course. "Nothing is inevitable if we are willing to contemplate what is happening."[20]

In one of his talks, Neil Postman suggested six helpful questions one might ask when thinking about the impact of technology.[21] Adapting these questions to the area of AI yields the following questions:

1. What is the problem to which AI is a solution?
2. Whose problem is AI solving?
3. What problems will AI create even as it solves a problem?
4. What people or institutions will be hurt by AI?
5. What changes in language are being forced by AI?
6. What sort of people and institutions gain special economic and political power through AI?

These six questions are helpful because they force us to consider more issues than just technical ones, helping us uncover some of the biases embedded in a particular technology. By answering these questions, it becomes abundantly clear that AI is not just changing the economics of the labor market. The reality is that technology is not neutral: it has a bias and it changes things.[22] In his book, *Technopoly*, Postman argues that "embedded in every tool is an ideological bias, a predisposition to construct the world as one thing rather than another, to value one thing over another, to amplify one sense or skill or attitude more loudly than another."[23] A recent book titled *Weapons of Math Destruction* (previously reviewed in *PSCF*) makes the case that even our mathematical algorithms are not neutral.[24] As we develop AI, we must recognize that "we shape our tools and thereafter they shape us."[25]

One helpful way to contemplate what is happening is to carefully consider the philosophical issues. Many of the basic philosophical questions that arise in AI occupied the minds of philosophers long ago. In the seventeenth century, Thomas Hobbes suggested that "cognition is computation," and later Descartes described human beings as "thinking things." In the mid-twentieth century, the pioneering computer scientist, Alan Turing, thought about the notion of "thinking machines" and even proposed a test for them, now referred to as the "Turing test."[26] The questions that frequently arise in AI cover the range of philosophical questions: what is really real? (ontology), how do I know it? (epistemology), what is right and good? (ethics), and what does it mean to be human? (philosophical anthropology).

The approach one takes to questions in AI is largely shaped by our philosophical presuppositions and our worldview. For instance, it has been suggested that Japan's enthusiastic embrace of robotics can be traced to a culture influenced by Shintoism, a religion that accepts that all things, including inanimate objects, can possess living spirits.[27] Another worldview is materialism, the belief that the physical world is all there is. This worldview leads to physicalism, "the philosophy that the human mind is fully explainable with reference only to the biological brain and the laws of physics and chemistry."[28] A physicalist view of what it means to be human has a variety of significant implications. Matthew Dickerson has provided an insightful and comprehensive critique of a physicalist view in his book, *The Mind and the Machine.* In this book, he pushes physicalism to its logical conclusions and shows the troubling implications for free will, creativity, environmental care, and reason.[29]

Some materialists suggest that everything in the real world can be described in terms of computation. Stephen Wolfram, a computer scientist and mathematician, does this in a book titled *A New Kind of Science*. Wolfram introduces the "Principle of Computational Equivalence" which suggests that "all processes, whether they are produced by human effort or occur spontaneously in nature, can be viewed as computation."[30] Some have conjectured about the possibility of machine consciousness using neurocomputational models and high-level cognitive algorithms.[31] Others have gone even further, musing that the world is a simulation like the one portrayed in the movie *The Matrix*. In his article "God is the Machine," Kevin Kelly explores the idea that everything is essentially a simulation, citing those who would suggest that the universe is a computer and we are the "killer app."[32] Gnosticism, a heresy that once plagued the early church, becomes more fashionable as physical reality is reduced to information.

It has also been suggested that developments in AI will disrupt religions, including Christianity. *The*

Atlantic recently published an article with the provocative title, "Is AI a Threat to Christianity?"[33] The article brings up a variety of challenges posed by AI by presupposing that intelligent artificial persons are, in fact, possible. Various questions are raised: Will machines have the ability to pray (and would God hear those prayers)? Would an AI have a soul? and Should Christians seek to evangelize this new technology?

This leads to the question of how a Christian philosophical perspective and worldview might help inform and guide us as we navigate the world of AI. There are many epistemological issues relating to how knowledge is represented in a computer and to the techniques for machine learning. But perhaps it would be better to start with the ontological issues. In the words of theologian Craig Bartholomew,

> We *should* start with ontology—this is our Father's world, and we are creatures made in his image—and then move on to epistemology—as his creatures, how do we go about knowing this world truly?[34]

I think this is helpful advice as we start to explore AI, since it is the ontological questions that will help us discern what separates humans from machines.[35] We are often captivated by what things can *do*, rather than asking what things *are*. A common tendency is to anthropomorphize our machines, thereby elevating the status of our machines and, in doing so, reducing the distinctiveness of human beings. Once we have established the ontological question of who we are and what machines are, we can start asking the questions about the best way to move forward, including questions about the appropriate use of AI.

A Christian worldview recognizes the ontological reality of creation and the value of physical reality. Christ who is "the Word who became flesh" (1 John 3:2) reveals the value God places on physicality and humanity. In the new heavens and earth, we will not be disembodied spirits floating in the ether, but, in the words of the Apostles' Creed, we look forward to the "resurrection of the body and the life everlasting."[36] A Christian perspective recognizes that reality extends beyond the physical world to include a spiritual realm. This ontological starting point will reject the reductionistic notion that humans are simply complex biochemical machines, while still affirming the value of the physical world.

The implications of AI have been raised in previous issues of *PSCF*. In 2008, Russell Bjork wrote an article in this same journal titled "Artificial Intelligence and the Soul" in which he identified three key issues:[37]

1. Is there a conflict between AI and biblical teaching about the origin of the human soul?
2. Is there a conflict between AI and biblical teaching about human worth and our being created in the image of God?
3. Does biblical teaching about personhood have any implications for our work in AI?

These are ontological questions that are just as relevant ten years after that article was written. Without a biblically informed ontological grounding, we are susceptible to all kinds of philosophical pitfalls such as physicalism, functionalism, reductionism, and gnosticism. But much more work remains to be done, exploring what 2,000 years of Christian social thought have to say about the responsible development of AI.

Once the ontological questions are addressed, we will be better equipped to wrestle with the vast array of ethical issues that arise. These include questions about appropriate applications of AI and and its use in robotics. A small sample of these issues include the following:

- When an autonomous vehicle crashes, who is responsible? This harkens to the "trolley problem," a classic thought experiment in philosophy.[38]
- Should lethal autonomous robots be permitted in warfare?[39]
- How do we approach automation and possible job loss?[40]
- Should we support efforts to develop "artificial persons" or machines that mimic humans or animals?
- Are social robots appropriate, and if so, how ought they to be used?[41]
- Should we use robots for child and elder care?[42]
- How do we navigate the privacy, transparency, and justice issues that arise as AI is applied to big data?[43]
- How do we show care for those whose jobs are threatened by automation?[44]

These are just some of the areas in which ethical issues arise in the use of AI. We will find a responsible way forward not by asking what AI can do, but rather by starting with ontological questions and then determining what role AI ought to play. In the words of the early AI pioneer, Joseph Weizenbaum, "There are limits to what computers ought to be put to do."[45] In his book, *Humans Are Underrated*, Geoff Colvin suggests asking the following question: "What are the activities that we humans, driven by our deepest nature or by the realities of daily life, will simply insist be performed by other humans, regardless of what computers can do?"[46]

On the other side of the coin, can we imagine some possibilities that AI might open up which can lead to further flourishing? As a part of creation AI can, in principle, be directed in God-honoring ways despite the possibility for sinful distortions. How can we employ AI responsibly in medicine, in research, and in environmental monitoring? In what ways can AI be harnessed to assist in Bible translation, to help in humanitarian relief, and to aid in search and rescue operations? What new assistive technologies might be possible to help people with disabilities? How might AI be directed toward helping the poor?[47] What other creational possibilities might be uncovered and applied in normative ways?

Fred Brooks, a respected computer scientist, wrote, "It is time to recognize that the original goals of AI were not merely extremely difficult, they were goals that, although glamorous and motivating, *sent the discipline off in the wrong direction*."[48] Our call is to help point the discipline in the right direction and to help discern a responsible road forward in obedience to God. Left on its own, AI will likely veer in the wrong direction, putting efficiency ahead of people. This approach is what Jacques Ellul called *technique*, the mindset that seeks "absolute efficiency in every field of human activity."[49] A related tendency is for technology and automation to concentrate power in the hands of fewer people, corporations, and nations. We should heed the warning of C. S. Lewis in *The Abolition of Man* in which he warns that "Man's power over Nature" can become "a power exercised by some men over other men with Nature as its instrument."[50]

In response to the many ethical issues that arise in AI, several organizations have been established to engage them. The Future of Humanity Institute at the University of Oxford is an example of one secular organization whose mission is to wrestle with some of the existential threats of machine intelligence.[51] Another group called the AI Now Institute was established "to explore how AI is affecting society at large … bridging the gap between data scientists, lawyers, sociologists, and economists studying the implementation of artificial intelligence."[52] Likewise, the MIT Media Lab and the Berkman Klein Center for Internet and Society at Harvard University are participating in a global initiative to fund and advance AI research for the public good.[53] The IEEE has also established a working group focused on ethically aligned design for autonomous systems and AI.[54] In 2016, the United Nations announced that it would establish a Centre for Artificial Intelligence and Robotics in The Hague, the Netherlands, to provide an international resource dealing with issues related to AI and robotics.[55]

As Christians who care about God's world, we must do more than wax eloquent about the issues or critique them from the sidelines. We need to answer the question, Knowing what we know, what will we do?[56] We need to actively join this conversation which has already begun, bringing insights from scripture and from Christian philosophy and theology to contribute to the common good.[57] In particular, as we wrestle with these new developments, we must remember what scripture teaches about what it means to be human, the meaning of work, and the kind of world God would have us unfold.

The third Lausanne Congress on World Evangelization took place in 2010 in Cape Town and highlighted the need for "taking the whole gospel to the whole world," including the area of technology. *The Cape Town Commitment* that came out of the Lausanne Congress includes a "call to action" section that specifically identifies technology (and specifically mentions emerging technologies such as AI) as having "deep implications for the Church and its mission, particularly in relation to the biblical truth of what it means to be human." It encourages us to "promote authentically Christian responses and practical action in the area of public policies, to ensure that technology is used not to manipulate, distort and destroy, but to preserve and better fulfil our humanness."[58] Among the recommendations is a call for "national or regional 'think tanks' or partner-

ships to engage with new technologies, and to speak to the shaping of public policy with a voice that is biblical and relevant."[59] The Christian faith shapes a worldview, one that points to norms that inform ethical considerations, which, in turn, can help give shape to policies and regulations.[60]

The rapid pace of change adds a degree of urgency to this call to engage. In the words of futurist Roy Amara, who coined Amara's law: "We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run."[61] At the end of the movie *Wall-E*, the human captain wrestles in the control room to seize control back from the automated system. Likewise, the future of AI is neither inevitable nor unstoppable. However, Christians will need to join the dialogue and be prepared to carry out our responsibility as we unfold these powerful new technologies. ⌂

Notes

[1]Marvin Minsky and Seymour Papert, *Perceptrons* (Cambridge, MA: MIT Press, 1969), 4.

[2]One landmark paper in particular was D. E. Rumelhart, G. E. Hinton, and R. J. Williams, "Learning Representations by Back-Propagating Errors," *Nature* 323 (1986): 533–36.

[3]To explore a demonstration of how these techniques work, visit http://playground.tensorflow.org.

[4]David Silver et al., "Mastering the Game of Go without Human Knowledge," *Nature* 550 (October 19, 2017): 354–59.

[5]An Open Source machine learning framework for everyone, https://www.tensorflow.org/.

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Challenges for an Ontology of Artificial Intelligence

Scott H. Hawley

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Of primary importance in formulating a response to the increasing prevalence and power of artificial intelligence (AI) applications in society are questions of ontology, such as the following: What "are" these systems? How are they to be regarded? How does an algorithm come to be regarded as an agent? We discuss three factors which hinder discussion and obscure attempts to form a clear ontology of AI: (1) the various and evolving definitions of AI, (2) the tendency for preexisting technologies to be assimilated and regarded as "normal," and (3) the tendency of human beings to anthropomorphize. This list is not intended as exhaustive, nor is it seen to preclude entirely a clear ontology; however, these challenges are a necessary set of topics for consideration. Each of these factors is seen to present a "moving target" for discussion; these factors pose a challenge for both technical specialists and nonpractitioners of AI systems development (for example, philosophers and theologians) to speak meaningfully given that the corpus of AI structures and capabilities evolves at a rapid pace. Finally, we present avenues for moving forward, including opportunities for collaborative synthesis for Christian scholars in theology and science.

Society is undergoing profound transformation due to the increasing effectiveness and reach of artificial intelligence (AI) applications. Predictions and warnings abound that the ascendancy of AI poses an "existential threat" to humanity,[1] and not simply in the form of "killer robots" or sentient AIs rendering humans obsolete. On the contrary, a number of more "mundane" threats and opportunities exist, as AI applications are revolutionizing widely held conceptions of personhood and work. Although much prior work exists from antiquity through 2010, recent advances in machine learning (ML) often exceed prior conceptions of AI's capabilities.

Significant work on "theology and AI"[2] predates the sweeping changes afforded by the successes of ML systems and the scale on which they are deployed. Many key theologians and ethicists were responding to "classic AI." While time-honored reflections on concepts of automation, personhood, and agency still apply, what's new is that the scope and reach of AI applications in society, their effectiveness, their ability to learn and synthesize, and the kinds of tasks they perform all vastly exceed what was widely thought possible, or even conceivable, only ten years ago. As a result, our conceptions of AI have continued to evolve, and there is renewed interest in establishing a clear understanding of these systems and their implications for society. Fundamental questions continue to be asked, such as What is AI? How are such systems to be regarded? Is it appropriate to ascribe agency to algorithms?

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Derek Schuurman argues for the primacy of ontology[3] as a precedent to addressing issues of application:

> Once we have established the ontological question of who we are and what machines are, we can start asking the questions about the best way to move forward, including questions about the appropriate use of AI.[4]

Regarding something on the basis of what it *is,* is consistent with a traditional philosophical orientation that says things act in accordance to what they are, that is, their ontology. There is a sense of immediacy to this approach in our modern technological society. As George Grant remarked, "Technology is the ontology of the age,"[5] and one particular technology increasingly touted for its potentially transformational character is AI. Andrew Ng expresses this in the claim that "AI is the new electricity,"[6] in other words, that AI is poised to empower and revolutionize all areas of society.

Some may regard the matter of ontology to be irrelevant, that one needs only to adopt an instrumentalist viewpoint of studying the interactions between humans, machines, and other *actants* in the form of an actor-network theory,[7] or that the fundamental understanding of AI will result exclusively from rigorous development in the wider context of human-computer interaction (HCI). While these views have merit—indeed, we may arrive at the need for treatment in terms of HCI—there may be significant value in investigating what AI is per se. Such an account will face a few challenges which we will describe. A starting point for these challenges can be seen in the following biographical observations.

Prelude: The Joy of the Creator

I confess that early in my studies in ML, I found myself blurring the lines regarding the ontology of the ML applications I would come across. Although I tended to be one who would be quick to point out the errors of others who anthropomorphize "intelligent" systems of various kinds, I found myself doting on, even cheering on, the very "bots" that I had written from scratch, as I watched them grow in ability to perform some task.

I am a latecomer to the field of ML, although multidimensional nonlinear optimization problems were part of my training and my PhD as a computational astrophysicist. The underlying techniques for the centuries-old problem of "curve-fitting" in the physical sciences amounts to a large class of ML problems. In fact, the problem of fitting a line to a set of data points is so fundamental that many ML curricula and tutorials use it as a foundational example for neural networks and/or evolutionary algorithms.[8]

Yet I never became as excited about watching my equation-solving numerical methods converge to a solution as I have in watching simple ML toys "learn." The first example that hooked me as an ML enthusiast was a tutorial by Andrew Trask in which a recurrent neural network (RNN) "learns" to do binary addition.[9] Seeing this "bot" start from nothing, making mistake after mistake but gradually improving, until finally achieving mastery, lit a fire of eagerness and curiosity in me which continues. It is not obvious to me why this is the case. I had written numerous iterative-refinement solvers over the years (for example, using Newton's method), and yet for these I had never made the cognitive jump to regarding these systems as "learning": I never anthropomorphized them.

Objectively, this RNN system is merely translating a series of binary inputs to a series of binary outputs by successively approximating some multidimensional mapping function; but it kindled in me a *joy*, a sense of having created something (even though the code was Trask's), and that something was a tiny *agent*. Where did this joy and attribution of agency come from? Was it born of *ignorance* about "what's really going on under the hood"? Only partly, for I also painstakingly recreated the code's matrix operations using a large Excel spreadsheet. As I did so, my enthusiasm diminished somewhat, but mostly because the process was indeed painstaking. Sharing the original code with students two years later, I still experienced excitement and a sense of wonder similar to my first encounter.

There seems to be a qualitative difference between regarding something as a mathematical operation and attributing intelligent agency to it. Part of this has to do with the ways we typically define intelligence.

Challenge 1: Changing Definitions of AI

The term "artificial intelligence" has a long and varied history and tends to mean different things to different people. For some, it means nothing short of being able to perform any cognitive task that a human being can. For others, demonstration of very limited and task-oriented competence may suffice. Still, for others, AI is a marketing term chosen in recent years, either intentionally or reluctantly, by those researchers who admit that "statistics" garners the least amount of enthusiasm or "buzz" from the general population, with "machine learning" generating greater buzz, leading up to "artificial intelligence" which may invite media frenzy. The various rebrandings of AI concepts with different terminology throughout its history may further obscure what sort of AI one is talking about. As UC Berkeley professor Michael Jordan notes, "The current public dialogue about these issues too often uses 'AI' as an intellectual wildcard, one that *makes it difficult to reason about the scope and consequences* of emerging technology"[10] (emphasis mine).

Although the concept of "machines that can think" has existed for many years, and initially was investigated in depth by Alan Turing, the term "artificial intelligence" was coined by John McCarthy, who organized the first artificial intelligence conference at Dartmouth College in 1956 for the purpose of organizing an effort to create human-like intelligence in a machine. McCarthy used this terminology to distinguish this line of research from the preexisting field of Norbert Wiener known as "cybernetics," which was defined in terms of control and communication of animal and machine systems. The field of ML arose primarily in a cybernetics context, rather than in trying to simulate human thought, but given that the application goals of many ML systems involve performing human-like tasks, the connection with AI is a close one. ML is now commonly regarded as a subset of AI, and so we will follow similar usage.

Writing a succinct definition of AI is a process with so many non-unique outcomes that there exist catalogues of various definitions,[11] even classified according to the principles underlying each definition.[12] The source of variation in defining "artificial intelligence" lies more in the "intelligence" part than in the "artificial" part.[13] Some experts take a minimal definition, defining intelligence as "doing the right thing at the right time,"[14] or as any adaptive system, including evolution by natural selection.[15] Others cast it in terms of either thinking or action, with the goal of either mimicking humans or meeting some rational standard.[16] Components of intelligence may or may not include awareness, perception, reasoning, planning, and/or goal-setting. "Consciousness," another concept with no clear consensus of meaning, is missing from many definitions of intelligence, and thus may be regarded as non-essential. These variations are reflected in the choices of terminology which AI researchers have employed over the years to describe their work, often developing specialized nomenclature to distinguish their approaches from others. A few such specific terms are worth covering, as they will inform later discussion.

The terms "classic AI" and "Good Old-Fashioned AI" (GOFAI)[17] refer to systems which employ human-programmed expertise and symbolic representations to behave in certain ways, using so-called "hand-crafted knowledge."[18] This approach is exemplified in "expert systems," which often operate on the basis of hard-coded decision trees. Intuit's TurboTax® program is a well-known example of this: by asking the user a series of questions, the algorithm is able to do the work of a tax accountant.[19] One important class of GOFAI consists of game agents, such as the IBM chess system Deep Blue[20] which famously defeated Grandmaster Garry Kasparov in 1997.[21] Another relevant GOFAI example is Joseph Weizenbaum's computerized "therapist" ELIZA,[22] which used a series of preprogrammed patterns to mimic human dialogue.

In contrast to GOFAI, ML systems generally operate in numerical rather than symbolic ways, performing statistical inference from large datasets using an iterative optimization procedure that produces effects akin to human learning. Whereas GOFAI suffered from "brittleness" or catastrophic failure for small deviations outside the prescribed domains of their rules, the numerical nature of ML systems tends to allow for more "graceful degradation—in which imperfections in the data lead to proportionally imperfect but often acceptable performance."[23] To emphasize the statistical nature, some researchers prefer to use the term "statistical learning" for such systems.[24] The ML successor to Deep Blue was Giraffe[25] and later AlphaZero,[26] both of which

achieved chess mastery purely by learning from self-play. The latter not only defeated human experts but also demolished the highest-rated expert-system chess program.[27]

This ability of ML approaches to outperform classic AI systems has been seen dramatically in the results of trained neural network models which exceeded the performance of human-programmed algorithms in domains such as image and speech recognition;[28] these models currently comprise the "best-in-class" solutions for many tasks.[29] This success has become so remarkable that the use of machines for tasks such as image recognition or speech synthesis is increasingly referred to by the tasks themselves, for example, "facial recognition" rather than "AI." We will discuss this de-assignment of the moniker "AI" further as part of Challenge 2: The New Normal, below.

The task-specific nature of applications of classic AI and ML to date have also caused disagreement over whether these constitute true AI.[30] Some choose to use the term "weak AI" or "narrow AI" for such applications, to distinguish them from "strong AI"[31] or "artificial general intelligence" (AGI) which involves mimicry of human-like performance across all cognitive domains. A vast amount of speculative fiction has been written about AGI, but so far, the speculation has vastly outstripped reality; we have yet to see any computer code implementing a significant part of an AGI system. Even recent sensational claims to the contrary seem, upon closer inspection, to fall short of the AGI ideal.[32] One reason for this imbalance of fiction to reality will be discussed later in Challenge 3: Anthropomorphism.

As we described in the Prelude, ML algorithms have much in common with iterative approximation techniques which have been known since the days of Isaac Newton. Given the close association between ML and AI, often expressed mathematically as ML $\subset$ AI, this means that longstanding data analysis techniques used throughout the sciences are becoming rebranded as ML and hence AI, often in order to take advantage of the current cycle of "AI hype."[33] Algorithms, such as fitting a curve to a set of data points, were previously not regarded by many as constituting AI, and yet their implementation as the core methods of AI applications has brought such techniques to the forefront of discussions on AI—indeed, it has often been remarked that the "new wave" of highly successful ML systems applies essentially similar statistical techniques to those from years past, but with the benefit of vastly greater stores of training data made possible by the internet.[34] Thus the underlying ontology of what the algorithm *is* may not be as important for determining the appropriateness of the label "AI" as the *intended use* of the system.

Because of the ambiguities associated with the term AI, some researchers prefer to avoid its use and constrain their discussions to the specific ML algorithms involved—random forests, hidden Markov models, non-negative matrix factorization, independent component analysis, naïve Bayes, Gaussian processes, (artificial) neural networks, deep learning, and others. This specificity is useful from a technical perspective, but ontologically these algorithms are qualitatively of the same kind. What is ontologically relevant for all these is that a deployed ML system is a function of, and thereby not easily separable from, its training dataset and even the particular starting point for the training procedure.[35] This means that an ML-based AI "is" not merely the algorithm and its intended use, but also the dataset used to train it.

In addition to the various uses and terminology just described, the AI definition which seems to be most applicable in regard to the implications of AI on the development of society is one which exists on the level of near folklore:

> AI is a computer doing what we *used to think* only a human could do.[36]

This "folklore" definition seems to capture the way that researchers and the public regard both "new AI technology" (that is, technology that attempts to do a task or to solve a problem, or that introduces a new paradigm) and "old AI technology" (that is, technology that has been accepted once a problem is largely regarded as "solved"). We will explore this in greater detail in the next section; it is the "used to" part of the "folklore" definition that leads us to Challenge 2 for an ontology of AI.

The central point of this section is not the mere observation that there exist a variety of possible definitions for AI. Whereas the fact that AI is not a monolithic, universal concept does pose some difficulty, the principal challenge arises from the fact that

the *scope* of what is considered to "count" as AI is continually undergoing revision. One might assume that this scope is monotonically increasing; however, in the next section we note a mechanism by which this scope can also shrink, and thus the overall landscape of "what is [regarded as] AI" is in a state of flux.

Challenge 2: The New Normal

The "folklore" definition of AI resonates with remarks by Douglas Adams on the "normalization," sometimes referred to as "reification," of technologies:

> I've come up with a set of rules that describe our reactions to technologies:
>
> 1. Anything that is in the world when you're born is normal and ordinary and is just a natural part of the way the world works.
> 2. Anything that's invented between when you're fifteen and thirty-five is new and exciting and revolutionary and you can probably get a career in it.
> 3. Anything invented after you're thirty-five is against the natural order of things … and the beginning of the end of civilisation as we know it until it's been around for about ten years when it gradually turns out to be alright really.[37]

Now that speech recognition systems are successfully employed in smartphones and smart speakers with high degrees of accuracy, many members of the public may not regard speech-to-text conversion itself as "AI," even though previously such systems were considered by many to constitute AI. Even if such applications arose via training of sophisticated ML systems—which themselves may count as AI to the researchers developing them—the normalization, ubiquity, and reification of applications like Siri and Alexa have allowed members of the public to regard speech-to-text conversion as simply a tool or a task without ascribing any intelligence to the system performing it.

One may inquire, "Now that systems are able to learn from 'experience,' do people still regard expert systems as AI?" Or do they say, "That's just … (for example, a set of nested if-then statements)." When one hears the phrase, "That's not really AI, that's just … (an ontological assertion)," it may indicate that the speaker reserves "AI" for AGI, or it may indicate a change in attitude, that is, a reestimation of the worthiness of the "AI" label in favor of a more specific, mechanistic label which focuses on the task being completed without regard for any intelligence used to complete the task. This means that the term AI, even within the limited context of ML, is a "moving target." The challenge this implies for developing an ontology of AI is that the usage of the term may be inseparable from whatever the current state of technology is when the term is being applied.

The first two challenges for a clear ontology of AI may be seen to involve the demarcation of AI in both conceptual and linguistic terms. One may rightfully raise the question of which community's conceptions and language are most relevant: the algorithm developers, the technologists who apply and deploy them, the journalists who break news about these developments, the general public who must come to terms with them, the philosophers who wish to make sense of them, or, notably, the theologians who wish to respond to them in the context of biblical teaching. Surely, one may argue, the general public and journalists often misquote or misapply the ideas of more rigorous thinkers on a variety of topics, and AI should be no exception. But the preceding observations are not limited in scope to any one particular subculture, and there is often an interplay of influence among these various groups. The larger topic of "AI, ethics, and society" merits discussion among all of them. Even the most careful thinkers, it is argued, may have no way to avoid basic human tendencies that obscure attempts at clearly demarcating AI from other related concepts. One such unavoidable tendency is that of anthropomorphism.

Challenge 3: Anthropomorphism

The tendency to ascribe human faculties and/or intentions to entities in the world (animals, machines, objects, "forces of nature") has existed since antiquity. Francis Bacon observed that it often impedes our understanding of the natural world, as what he called "The Idol of the Tribe": "For it is a false assertion that the sense of man is the measure of things."[38] Put differently, anthropomorphism amounts to a "cognitive bias"[39] and as such impedes one's ability to regard things as they are—that is, ontologically. Despite its association with unenlightened eras,

anthropomorphism occurs even today—perhaps even more so than previously. As Waytz et al. observed,

> Although [anthropomorphism is] commonly considered to be a relatively universal phenomenon with only limited importance in modern industrialized societies—more cute than critical—our research suggests precisely the opposite.[40]

Anthropomorphism appears as the "go-to" model or metaphor by which humans initially seek to understand new phenomena—the "hammer" we try to apply to many "nails," if you will. Beth Singler of the Faraday Institute has said anthropomorphism arises "because we are social beings who need to place the things around ourselves into a social scheme that makes sense of them."[41] It is widely speculated that our cognition is biologically optimized to process our "local world" which is predominantly a social one. A common sentiment is that it is "hypothesized to have evolved because it favored cooperation among early humans."[42] So strong is the tendency to project human-like qualities onto other things, that it is regarded as unavoidable. As mechatronics researcher Fumiya Iida has described, "Anthropomorphization is [an] incurable disease for human[s]."[43] Anthropomorphism appears to be more likely to arise in situations for which detailed operational knowledge is not available, or when novel unexpected emergent behavior arises, such as in the case of certain moves by AlphaGo.[44]

Anthropomorphism plays a key role in the *design* of AI systems, and even in the conception of AI. The earliest formulations of the concept of AI are anthropomorphic. The "Turing test" is built around the model of human intelligence: Can a machine communicate in such a way as to fool a human into regarding it (the machine) as human?[45] McCarthy's goal of the Dartmouth conference was explicitly human-centric.[46] Beyond that, anthropomorphism is found to serve a utilitarian purpose in design, which "can be used today to facilitate social interactions between humans and a new type of cooperative and interactive agents—social robots."[47] This means that it can allow for more intuitive use of such robots, particularly in "caregiving" applications, such as intervening in the development of autistic children[48] and in some care of the elderly.[49] It has also been warned that the anthropomorphic urge could be hijacked to create inappropriate bonding with artifacts, and thus ethical design should provide transparency to avoid such misuse.[50] Concerns about the inappropriate use of anthropomorphic aspects of AI led Weizenbaum, creator of the ELIZA "psychotherapist," to later oppose the use of such systems in "interpersonal" settings:

> I would put all projects that propose to *substitute* a computer system for a human function that involves *interpersonal respect, understanding, and love* in the same category. I therefore reject [Kenneth] Colby's proposal that computers be installed as psychotherapists, not on the grounds that such a project might be technically infeasible, but on the grounds that it is immoral.[51] (emphasis mine)

The effects of the cognitive bias of anthropomorphism are manifold. Robert Wortham observes that it can result in "moral confusion about the status of robots in particular, and artificial intelligence more generally."[52] This confusion can involve questions of whether robots should have rights,[53] whether AI systems should be granted status as legal persons,[54] and, in general, whether humans have a responsibility toward robots, so-called "moral patiency."[55] Moral patiency of machines is regarded as such a serious danger that Joanna Bryson states forcefully, "We are therefore obliged not to build AI we are obliged to."[56] It is anthropomorphism which is identified as a key obscuring factor contributing to misperceptions of moral agency and/or patiency, as Wortham continues: "There are serious concerns that our anthropomorphism and misunderstanding of the nature of robots extends so far as to attribute them either moral patiency, moral agency, or both."[57]

A further common effect is that of "overidentification,"[58] in which humans may ascribe additional human attributes to machines, based on performance at tasks of logic and language. That is to say, having observed a system performing tasks of logic and language, there is a common human tendency to ascribe or *project* a host of additional cognitive and behavioral faculties onto the machine. This *extrapolation* by the user may be unwarranted, such as in the example of a "self-driving" car which can stay in its lane well and thus come to be regarded as an excellent driver, but can be thwarted by the appearance of a bicyclist[59] or a lane division[60] and lead to death; overidentification is a likely contributor to driver inattention in such cases.

Finally, anthropomorphism has the effect of making it all too easy to write (yet more) fiction about AGI. This can distract conversations from real, immediate dangers and opportunities, to speculations on severely underdetermined scenarios set in the far future. As Andrew Ng recently lamented,

> AI + ethics is important, but has been partly hijacked by the AGI (artificial general intelligence) hype. Let's cut out the AGI nonsense and spend more time on the urgent problems: Job loss/stagnant wages, undermining democracy, discrimination/bias, wealth inequality.[61]

Existing in a "dual" relationship to anthropomorphism is the tendency to dehumanize (or objectify), an *ontological error* whereby the personhood, individuality, and value of human beings are denied and replaced with a regard for humans as only things. In committing this error, we move from the "I-Thou" mode of relation identified by Martin Buber,[62] to one of "I-It." In an AI context, dehumanization arises in a variety of ways. Firstly, it may be explicitly stated, in a naturalistic approach to the so-called "mind-body problem," that humans are merely machines and that the mind is not simply like a computer, it is a computer.[63] In contrast, in the words of Schuurman,

> A Christian perspective accounts for reality as extending beyond the physical world to include a spiritual realm. This ontological starting point will reject the reductionistic notion that humans are simply complex biochemical machines, while still affirming the value of the physical world.[64]

Secondly, dehumanization can arise as a result of the anthropomorphism of artificially intelligent systems. Bryson states it thusly: "In humanising [robots], we … further dehumanise real people."[65] The other primary avenue for dehumanization arises from its utility in modeling human behavior—for applications such as recommendation systems and targeted marketing—and *manipulating* human behavior. This was evidenced in the news of Facebook's deliberate attempts to make their application more addictive, referring to people as "eyeballs."[66] The ontological error of viewing humans as machines can have a series of ethical consequences, such as in the area of employment. The extent to which we view humans mechanistically suggests the extent to which we will automate people out of jobs. Christians have historically opposed the tendency to dehumanize and objectify, on the basis of love of one's neighbor and the doctrine of *imago Dei*. This is an area in which Christians can continue to have a significant witness to the larger society, as the temptations to dehumanize are likely to increase along with the scale of deployment and success of AI systems at performing various tasks. This also presents opportunities for partnership with secular individuals and institutions dedicated to the ethical use of AI, as Christian positions are often in agreement with secular ones, such as in opposing the dehumanizing implications of sex robots,[67] or of AI-empowered surveillance technology and the utility of classification systems for enabling oppressive government practices.[68]

Avenues for Moving Forward

While a rigorous ontology of AI may be difficult, it has not been shown to be impossible. On the other hand, it may not be necessary, as alternative approaches are available. Given that questions regarding AI are invariably bound up with questions of humanity, it may be that AI is not a distinct concept that can be well demarcated from humanity, and thus a broader context of human-computer interaction may be a more fruitful avenue. Alternatively, an "instrumentalist" approach, such as actor-network theory[69] that would focus on only what AI *does* in its interactions with other parts of a larger system, may provide a more efficient route to answering questions of application and appropriate use. Finally, a "process philosophy" that regards things not as they *are* but how they undergo *change*—which amounts to an ontological position albeit with a different emphasis from the traditional one—may prove profitable.

It is not the intent of this article to evaluate the relative merits of these approaches in comparison to an ontological approach; however, such an evaluation should include one key question: Does an ontology of AI "get you anything" that these other approaches do not? An answer to this may lie in current discussions of explainability and transparency. A "black box" system which is known only via its exterior interactions is unlikely to garner public trust[70] and likely fails to meet the "right to explanation" requirement laid out in the European Union's General Data Protection Regulation (GDPR).[71] There are methods for probing the internal logic of black boxes with the goal of explainability;[72] however, these are not applicable in all situations. In general, the issue of transparency is not a simple one because

naïvely manifesting the totality of what an algorithm *is*—by exposing its source code and, for example, the internal weights of a neural network, and also its (potentially biased) training dataset[73]—does not constitute an explanation, and designers of systems with transparency in mind must consider the *level* of detail shared so as not to overwhelm the user, and to provide transparency with the goal of understanding in mind.[74] Such a level of detail would need to be chosen according to the intended users, and this amounts to a kind of user interface design. In this case, transparency may be regarded as being more consistent with instrumentalism than ontology because the emphasis is on clarifying what the system is *doing* rather than what it is. However, the function of transparency is to foster "the ability of a naïve observer to form an accurate model of a robot's capabilities, intentions and purpose,"[75] with goals which include clearly demarcating the *ontological* difference between a machine intelligence and human, and in so doing, to mitigate the effects of anthropomorphism discussed earlier.

Another notable avenue, which is both a form of ontology and an alternative orientation, is the functionalist approach to AI-ethics employed by Bryson.[76] In this case, there is an ontology that posits the inequality of the human and the machine, with the goal, however, of preservation of the social order rather than the affirmation of any metaphysical significance to the individual, that is, without an *imago Dei*. It is notable that, once again, although the functionalist approach rests on a different foundation than Christian ethics, many of the implications of the former for "AI, ethics, and society" are sufficiently in alignment with traditional Christian moral and ethical positions that significant opportunities for partnership exist between Christians and those operating from such "secular" standpoints.

Finally, we note that the pace of advancements in AI, particularly in the area of ML, has become so rapid that dramatic announcements arise with a frequency of every few months, with six months being a common timescale for significant achievements. It is typical for successful methods to be superseded within a year or two, and the understanding of their implications to require some revision. Thus the peer-review process in the ML field occurs more in the form of conferences than in journals (whose longer review time can impede dissemination). In such a swiftly changing landscape, it is possible for those without immediate connection to the technical field to make statements which no longer apply, for example, "AI doesn't do X, it merely does Y," only to be corrected that indeed "AI now does X, as of six months ago." Thus, for Christian philosophers and theologians, it is recommended that they form partnerships with those in the technical sectors of academia and/or industry in order to stay current—and therefore relevant. This assumes that there will exist participants in the technical domains who are interested in partnering for the purpose of Christian scholarship, and thus we see, as with other areas of science, the need for Christians to enter such fields and perform excellent work with diligence and integrity.

Conclusions

In response to interest in establishing an ontology of AI, we have not achieved this goal, but we have raised awareness of three challenges which can hinder dialogue and obscure clear thinking about what AI is. These challenges are significant and make the establishment of a clear ontology of AI more difficult. The first challenge is the various and changing ways in which AI is defined in terms of the research community and society at large, and the evolving scope of what sorts of algorithms "count" as AI.

The second challenge is a result of the widespread successful deployment of some AI systems, when they reach the point at which the previously challenging tasks they performed come to be reified and regarded as simply "normal," such that the frontier of what is regarded as AI by the general populace advances toward more difficult problems. These first two challenges are more than mere semantic objections: in the words of theologian Michael Burdett, "the language we use is important because it manifests our ontological commitments."[77] Conversely, as Mary Midgley has argued, our language not only exposes but also tends to shape our ontological commitments.[78]

The final challenge is that of the unavoidable human tendency to anthropomorphize, which yields a cognitive bias that can manifest in ways such as projecting moral agency and/or patiency toward

machine intelligences. The advancing performance of AI at tasks of language and logic means that the overidentification of human attributes with AI is likely to evolve as well. This is a challenge but also the reason why developing a clearer ontology for AI is an important undertaking.

In order for scholars in theology and philosophy to keep pace with the rapid changes in the technical performance, conceptions, and scope of AI systems, it is recommended that collaborative partnerships be formed with active technical practitioners of AI systems development. ⌂

Acknowledgments

The author wishes to thank the following persons for helpful discussions: Michael Burdett, Alister McGrath, Tommy Kessler, Andy Watts, William Hooper, Beth Singler, Andreas Theodorou, and Robert Wortham. This article was sponsored by a grant given by Bridging the Two Cultures of Science and the Humanities II, a project run by Scholarship and Christianity in Oxford (SCIO), the UK subsidiary of the Council for Christian Colleges and Universities, with funding by the Templeton Religion Trust and The Blankemeyer Foundation.

Notes

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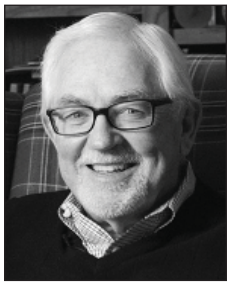
Artificial Intelligence: A Theological Perspective

Albert Erisman and Tripp Parker



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Artificial intelligence is making inroads into many areas of our lives, and it will continue to do so. These changes will be substantial and disruptive. Surprising to some, the Bible has a great deal of wisdom to help us in this transition. First, we find that the development of such systems is a vital part of the creation mandate, and this work can be done to the glory of God. Second, because of the reality of the brokenness of our world, and ourselves, there are important cautions we should consider in the development and the deployment of these systems. In this article, we show why AI system development is different from ordinary programming, how it can be a part of the creative process God has called us to, and where we need to provide biblical cautions for developing and for using these systems.

This time it looks real.* The promises of Artificial Intelligence (AI) were first articulated over fifty years ago, but the excitement and hype died rather suddenly, in part from the book *Perceptrons* by Marvin Minsky and Seymore Papert.[1] They identified fundamental limits of the AI developed at that time.[2] That led to a pessimism about the exaggerated promises of AI and a significant decrease in research funding, ushering in the AI winter of the 1970s.

A second round started in the 1980s. Technology had become more powerful and the PC had come on the scene, distributing computing power to the masses. Expert systems (ES) were being touted as the replacement for many human decision-making challenges, including replacing much of what doctors (or pilots) did. Surely this was the time for AI systems to make a difference. In reality, complex decision making was much more challenging than AI enthusiasts had believed. Much of the work moved from expert systems to expert assistants—parts of the problem could be handled by the ES, but final judgment rested with a person. This was useful sometimes, but a long way from the promise.

In the 1990s, virtual reality (VR) became a focus—the creation of a virtual world in which humans could experience a different reality than they would be able to do in real life. Much of this was reserved for games. Albert Erisman remembers racing down a slalom course on a VR system, competing for time on ski slopes he would never attempt in real life. The vibrations in the skis and the visual cues were amazing and fun. The lack of pain from a crash was even better. In reality, this was far from reality.

At Boeing, Erisman's R&D team began to look at this technology for business use

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* This article is a revised and expanded version of Al Erisman, "Artificial Intelligence," *ethix*, February 28, 2018, https://ethix.org/2018/02/28/artificial-intelligence.

in their lab. Bob Abarbanel led a team in developing FlyThru, a VR system that allowed engineers, managers, and potential customers to "fly through" an assembly of electronic parts as if it were a real airplane. This became a key tool in the design of the 777 airplane. David Mizell headed the team to allow those in the factory to try assembly procedures in the virtual world. Tom Caudell had the idea of merging the virtual and real worlds together, projecting instructions for a repair procedure onto the physical part of the airplane, giving the mechanic hands-free access to information. He coined a new term for this, which he called "augmented reality," in 1990. It is interesting to see the current hype about virtual and augmented reality, as if they were something new. It provides an example of a popular phrase often used by technologists: "The future is already here, it is just unevenly distributed."

When IBM's Deep Blue defeated the then reigning world champion in chess, Garry Kasparov, in 1997, new hype began: "These systems are going to rule the world." Chess had been seen as the ultimate challenge demonstrating that any activity of the human brain is fair game, according to the promises of the 1960s. This thinking simply demonstrated that these researchers did not understand the human brain. In May 2017, a computer defeated Go champion Ke Jie. Since Go is considered the most complicated board game, the promise of AI seemed even more real.

Today, technology seems to have arrived at a point at which these systems will have a greater and greater impact on all of us. They will invade our lives, our workplaces, and society in ways that will produce much more substantial change than all that has happened in the past fifty years. Further, many of these systems will be invisible, not limited to a computer sitting on a desk, as Neil Gershenfeld predicted twenty years ago.[3] These systems will make our lives safer and better; they will make products less expensive and better; and their promise is real enough to lead to substantial investment in the companies that build them. Yet, at the same time, there are significant questions about such systems that should engage us—not with an emotional resistance nor with fear, but with careful thought at the levels of design, personal use, organizational use, and societal policies and impact. To engage thoughtfully requires that we understand enough about these systems to inform our responses to them.

This suggests that we should give careful attention to two questions. The first is, what can go wrong with such systems? Albert Einstein once said, "We cannot solve problems by the same kind of thinking we used when we created them." The second question is, how might such systems impact society?[4] But first we want to briefly describe how AI systems are different from traditional computer programs, because this understanding informs our response to the two questions.

How Does AI Differ from "Normal" Programs?

AI systems differ from standard computer programs in an important way. A typical computer program follows an algorithm, a step-by-step procedure that starts with certain data and instructions and ends with a result in a repeatable, reliable way. A recipe for a cake follows this pattern. Given a set of ingredients, combine them in this way, cook them at this temperature for this period of time, and at the end we have our cake. This is also precisely what an accounting program does. Given this data, produce a cash flow or profit-and-loss statement. The human did the thinking, laid out the steps, and the computer carried out the calculations, producing the results.

AI systems work differently. A human may not understand the process, but the person feeds the system some rules of the game, some examples of good output derived from input, and the computer system (or supervised learning system, in this case) figures out how (through spotting statistical patterns in the data) to produce good output from given input. To emphasize, the person behind the system did not specify what those patterns were—indeed, he or she may not even understand what they are—but the learning system figures out a way to produce a result from the input. In a sense, this is how a child learns. Lots of trial and error, many false starts, some correction, and then she or he learns.

Here are three examples. It used to be that computer-based language translation was based on the programmer providing the instructions for translating a document based on vocabulary, rules of grammar, and so forth. The results were poor. Computer-based translations were barely readable and, at best, were aids to a human translator. More recently, work on computer-based translation has

followed a different course. The learning system is provided with documents in one language and examples of good human translation, and then the system determines the procedure to change from one language to another. Such systems have made a significant improvement in language translation.[5]

A second, simpler example is about teaching a learning system to do what many children can do. How do you tell the difference between a wolf and a dog? The distinctions are challenging to describe in some sort of step-by-step procedure, though many children can tell the difference. In one famous example, researchers provided a series of pictures to the learning system (a neural network, in this case), properly identifying dogs and wolves in the sample learning environment.[6] Once the system had sufficient data, they subsequently fed a variety of new pictures to the system, which it began correctly labelling as either a dog or a wolf, demonstrating (it seemed) that it had learned to distinguish between them.

A third, harder example is self-driving cars. It would be impossible to lay out a step-by-step procedure for all of the decisions a person must make driving across town. But it would be enough to feed a variety of rules to the car's AI system and let it learn how to drive, much like a teenager learns to drive.[7] Speeding is bad, going too slow is bad. Crashing into cars or pedestrians is bad. Anticipating and avoiding accidents involving other vehicles is good. Understanding the shortest way to get to the destination and following that path is good. With experience and testing, the car learns to drive, to navigate through traffic, to avoid accidents, to take the best route. The advantage of a car learning to drive is that the result can then be downloaded to other cars. As experience grows, cars can share their advanced learning with other cars. The result is safer, more reliable driving.

Auto accidents killed about 40,000 people on the highways of the US in 2016. For the first time in history, distracted or drowsy drivers killed more people than did drunk drivers. It goes without saying that computers do not get distracted or drowsy. Self-driving cars, while new and frightening to many, may already be better drivers than humans, though the full complexity of this has not been proven. And they will continue to get better. Because self-driving cars are new, humans do a poor job of comparing risks. This explains why a single accident by a self-driving car in California rates headlines around the nation, whereas thousands of other more serious accidents happen every day involving cars with drivers.

Virtuous AI

The basic question is this: in a scenario in which any decision incurs a cost, how do we make sure the *least bad* decision is made? Can we even agree on what the least bad decision is? How do we build a virtuous AI that could reliably make such a decision?

In discussing this question, let's dispense for the moment with the prospect of an all-knowing and conscious AI. Let's ignore the science fiction version of AI in which it "wakes up" and does things we do not want it to do. Instead, let's focus on a simpler question: why is it difficult to build an AI that reliably does what we want? We call this the "AI alignment problem": How can we build an AI that acts in a way that is aligned with our values? What data might we give the AI that would teach it about our values and what we care about? A Christian might ask, "Can we just feed it the Bible as an input, and have it figure out what to do in a way that is wise and just?"

There are both theological and technical challenges with doing this, but let's start with the theological. This may seem obvious, but not even Christians can agree on what the Bible means when we read it. Even when we agree on the textual interpretation, we are not in full agreement on how to apply it in our everyday lives. How on Earth can we be confident to give scripture to an AI and have it reliably act in a way that is commensurate with our values? We do not agree on our values. We often misunderstand scripture. One can give ten people an algorithm for how much Tylenol® to take, and all ten people can interpret it correctly. If we give ten people the Bible, we will get ten different interpretations. In other words, the Bible is not some kind of holy algorithm for every answer to every problem we face in the modern world.

As Solomon wrote, "There is nothing new under the sun."[8] And like Solomon, we need to be wise in applying the deeper lessons of our faith, but wisdom comes from the Lord, through a relationship with him, not with an algorithm. A great description

of wisdom is something like this: Wisdom is not a rulebook, it is more like a dance.[9] We all have values that sometimes conflict with one another. Wisdom is knowing which value, in any given instance, should take the lead, and which should follow. The Bible is a book full of values, along with examples of wisdom and folly. Solomon, despite knowing what the scriptures said regarding right and wrong, despite being well versed in the law, asked God for wisdom. That did not come in the form of a rulebook. That did not come in the form of an algorithm. That came through a personal relationship.

Therefore, it is critical that Christians, people who have a personal relationship with the Lord of the universe, be involved in building, using, and guiding the future of AI. It will take wisdom, and wisdom cannot be easily prescribed.

Further, even if we completely agreed on what a wise decision looks like in any given scenario, there are technical problems with building such a system. Let's return to the example of telling the difference between wolves and dogs. The AI system seemed to have learned the difference, and was accurate based on the pictures provided. After more pictures were inputted, the researchers noticed that the system was giving a number of wrong answers. Why was it mixing up dogs and wolves? The decision criteria, the patterns between the input data and the correct answer, had not been prescribed by the researchers but had been developed by the learning system itself.

Eventually the researchers figured out, through many tests, that the system was not actually paying attention to the animal. It was looking at the animal's environment. If it saw snow in the picture, it declared that the animal must be a wolf, because the preponderance of the pictures fed to it had wolves standing in snow, whereas most of the dogs had been photographed on grass.

In other words, the researchers did not actually know what the system had "learned." AI solves problems in very different ways than we do, detecting patterns that would not occur to a human. When presented with a new, unexpected situation, AI's response can be unpredictable.

A metaphor that Tripp Parker often uses regarding this problem comes from the Disney movie Fantasia. Specifically, in a segment named the "Sorcerer's Apprentice,"[10] Mickey is an apprentice to a powerful sorcerer who gives him a task to do late at night: fill a cauldron with water. The Sorcerer retires for the evening, leaving his magic hat downstairs where Mickey is supposed to fill the cauldron.

Mickey, wanting to complete the chore with as little effort as possible, uses the magic hat to animate a broom to fill the cauldron for him. The goal that Mickey gives the broom is a completely full cauldron. The broom picks up a bucket, fills it with water, and carries it over to the cauldron. Mickey watches, and the system appears to be working. Mickey goes to sleep, leaving the broom to finish the task assigned to it.

You may remember what happens next: the broom overfills the cauldron, flooding the workshop. You can think of the broom as an AI that is trying to maximize the chance that it successfully fulfills the task given to it. What if there's a leak in the cauldron? What if someone took water out when it was not

Figure 1. Wolf! Photo credit: Okssi/Shutterstock.com

Figure 2. Dogs! Photo Credit: Alan Jeffery/shutterstock.com

looking? What if the broom does not have accurate vision, and while the cauldron appears full, it really is not? The way to maximize the chance that the cauldron is full is obvious to the broom: continuously pour water into the cauldron.

In other words, the broom's actual values did not fully align with Mickey's. Mickey told the broom about only *one* of his values, not all of them. He cares about a full cauldron, but he also cares about a flooded workshop. However, as we have discussed, the broom did not learn that, and therefore created a solution that was worse than the problem Mickey wanted solved. Such a solution would not occur to a human, who intuitively knows this to be a bad solution. But to an AI, it may make complete sense. Such knowledge is often referred to as *tacit* assumptions. Although they are obvious to all in the context of life, it is extremely difficult (or impossible) to document all of our tacit assumptions.

It is a difficult *technical* problem to ensure that the system you build reliably aligns with your values and learns the right output. There will be times when the system learns the wrong output, or it may lack maturity in its learning (not understanding the full range of values it should care about or pay attention to). In the case of human drivers, we have come to peace with making these judgments. We still license teenage drivers, even knowing that the risks of accidents are higher and that the maturity of judgment may be less. Many people are less comfortable with the prospect of an AI that lacks full maturity.[11]

And yet self-driving cars are the wave of the (near) future. Computers now defeat the best of the world's chess or Go champions. Smart algorithms sort through thousands of pages of material in minutes that once took weeks for well-trained (and well-paid) lawyers. Facial recognition software can identify a particular person running through an airport. Computers are changing the face of the factory with robotics and the medical research world with testing procedures. Data analytics frequently drive the decisions made, from the board room to the sports team.

Many excitedly embrace this new world with no thought of what could go wrong. Others fear a future without jobs, without a sense of control or understanding, and with scarcely a thought of the benefits. What do Christians have to offer to this conversation? What is it about this new technology that should offer hope and excitement, and what about it should give us pause? How do we navigate this new world we are entering?

Biblical Insight

Starting with the scripture, it is not difficult to see where creative thoughts originate. Since people are made in the image of a Creator God, we see the roots of the passion and joy that come from the act of creating new things. The first two chapters of Genesis show God as a creator, God making humankind in his own image, and God bringing humankind into his work. Specific instructions include

- Oversight responsibility (Gen. 1:28–30)
- Care for the creation (Gen. 2:15)
- Classification responsibility (Gen. 2:19–20)

God stated that the creation was not complete, in that "there was no one to work the ground" (Gen. 2:5, New International Version [NIV]).[12]

God's purpose for humans in the design and discovery process is referred to beyond the creation account. In Proverbs, we are reminded of the delight in discovering the hidden things in God's creation:

> It is the glory of God to conceal things, but the glory of kings is to search things out. (Prov. 25:2, English Standard Version [ESV])

Rosie Perera, a former Microsoft developer, put it this way:

> As a software engineer, I have had the experience of creating something out of virtually nothing, which is pretty amazing. I love well-crafted, elegant computer code. And I love to see people's faces light up when they learn how to do something on the computer that previously mystified them.[13]

This sense of excitement is rooted in how we were made. It is developed by God and blessed by God. AI systems offer a special place within this creation process. The designer identifies key steps of the design, expecting the system to fill in the rest. These resulting systems can bring true and new insight.

If this were the end of the story, we could all share in this joy. But there is more to the story. In Genesis chapter three, we see the broad impact of sin in our world. In addition to the separation between God

and humankind that came from the Fall, there was a separation between people, and between the people and their work. This impact on work offers insight on how we respond to the changes in our world, including the changes caused by technology. God said,

> Cursed is the ground because of you; through painful toil you will eat food from it all the days of your life. It will produce thorns and thistles for you, and you will eat the plants of the field. (Gen. 3:17b–18, NIV)

Thorns and thistles that grew in the crops were not part of the original plan. They crept into the farming work as impediments to the real task of growing food, sometimes choking out the intended growth. They interfered with the best of plans.

AI systems have their own unique "thorns and thistles." The conclusions that they can draw from incomplete information can be both dazzling and dangerous. The wisdom that is required to assess both what such systems do and how they do them, calls for creative insights and also creative awareness of how these systems can go off track.

Thorns and thistles have an application in the development and use of technology as well, in at least these four ways.

1. Our motives, both as developers and users, are not always pure. Both designers and users may approach technology with nefarious intent. These thorns and thistles can turn good work and good technology in a decidedly bad direction. For example, a talented designer might use his or her abilities to create phishing schemes that harm others. Or a user may employ a powerful system to sync together words and facial expressions in order to create a "deep fake" video of a person saying that which they did not say.[14]
2. Bugs, design flaws, and unanticipated results can show up in our work, producing unexpected results. For example, an AI system used in teacher performance ratings assumes that standardized test score performance is a valid measure for evaluating the performance of a teacher.[15] Sadly, some human performance evaluation is also carried out mechanically without the benefit of human wisdom.
3. The work product may be done well, meeting all specifications, but it may have a surprising application that was not intended. For example, an automobile designed to provide safe, reliable transportation is used as a getaway vehicle in a bank robbery.
4. A great strength of AI systems is that they add insight that humans may not have. The great danger in such systems is that humans trust the system, turning off their own wisdom rather than applying it in new and unique ways. Some fear such systems, wondering if they are not more powerful than humans. Yet perhaps this question arises only because these systems are relatively new. Machines have always been more powerful than humans when muscle is needed. Computers have always been more powerful than humans in carrying out a long string of computation. A simple illustration here is the ability of computer cash registers to compute the proper amount of change in a transaction. Without human wisdom, the amount of change may be very wrong because a data entry error is made, but if no human estimate is made, the answer is believed. The challenge is to find the good and right role for such systems, and not to assume that they have insight and moral judgment as has been given to humans by God.

Interestingly, in spite of the thorns and thistles, the sense of joy and satisfaction that comes from good work remains a part of who we are. The reality of the brokenness of our world should not cause us to lose hope. Christ came to bring hope and healing to the brokenness in our world, and while this will not be complete until his return, we can be agents of reconciliation now. Paul said,

> Therefore, if anyone is in Christ, the new creation has come: The old has gone, the new is here! All this is from God, who reconciled us to himself through Christ and gave us the ministry of reconciliation: that God was reconciling the world to himself in Christ, not counting people's sins against them. And he has committed to us the message of reconciliation. (2 Cor. 5:17–19, NIV)

He says this in a different way in another place:

> The night is far gone; the day is at hand. So then let us cast off the works of darkness and put on the armor of light. Let us walk properly as in the daytime … (Rom. 13:12–13, ESV)

And Jesus said,

> You are the salt of the earth … You are the light of the world … In the same way, let your light shine before others, that they may see your good deeds and glorify your Father in heaven. (Matt. 5:13–16, NIV)

Together, these passages remind us to bring the light of the truth of the gospel to bear on everything we do, including the building and use of technology. And while the final, complete healing will come later, we should look forward to that time when all will be set right.

These conclusions help us put AI systems in their proper place. AI can add to our ability to make decisions, but AI is not the autonomous decision maker. AI can bring insight to a problem, but not without supervision. As Edward Tenner wisely put it,

> Pessimism about the effects of technology is a distraction from the real need for education and self-education on the best way to combine algorithms and intuition, digital and analog.[16]

Christians engaged in AI, either as builders or users, too often regard this work in a separate category from their faith. They are surprised by the bugs, misuse, and unanticipated consequences. They should not be. Sometimes they assume that this is just the difficult world in which we operate, and that somehow the light of the gospel has no connection to their work. In fact, biblical insight on why we can love our work, and why it can yet go so wrong, is valuable for everyone. We should raise questions others might not raise in the context of our work. As a result, people may even ask questions about the gospel!

What Should We Watch Out For?

Even if AI is built *technically* in the right way, there are six main reasons why AI could affect us negatively:

1. Destabilization
2. Idolatry
3. Corruption
4. Unanticipated consequences
5. Contextual misfit
6. Isolation

Let us look at each one briefly.

1. Destabilization

It is no secret that robotics, for instance, has taken many manufacturing jobs away from those who have historically performed them in the US. AI will do the same, but to a larger degree, and will do so much faster than the technology we have created in the past.

Today, three million people earn their living from driving buses, cars, trucks, and other vehicles. If the switch to driverless vehicles happens quickly, as many are predicting, this will be a huge disruption in the labor force. Add to this the medical jobs that involve reading X-rays, supporting diagnoses in general, and testing pharmaceutical drugs, and we see a significant number of jobs that are vulnerable. Sorting legal documents, working though accounting categories, and other diverse jobs are at risk. In fact, *any* job that is repetitive and predictable is at risk of rapid automation.

It is easy to argue that we have been through this before. The Industrial Revolution is one example, as is the larger migration from farm to city jobs. Many of these, however, had longer implementation times, enabling the retraining of workers for other semi-skilled positions. Further, the new positions were similar to the old ones. It is one thing to train someone who had repaired old tools to work in a factory that builds new ones. It is quite another problem to train a tractor-trailer driver to be a physical therapist.

This time, changes will probably happen much more quickly, and the retraining may involve much more complex skills that take longer to learn and do not match everyone's abilities. On the other hand, there are many jobs that need to be filled but do not pay very well—service jobs that support an aging population is but one example.

Society and the church will need to wrestle with how to best address these issues. How will we care for those affected? How do we best help them and their children for the long term? If we are subcreators, made in the image of God, how do we help people find their place in this new world without robbing them of the ability to contribute to it?

2. Idolatry

AI can be a temptation toward idolatry. One could be forgiven if it were suggested that we already wor-

ship our technology. How many times have you seen a family in a restaurant, sitting together but paying attention solely to their smart phones? Is this not a form of worship? How many of us would immediately return home if we realized we had forgotten our phone, whether or not it was *really* needed? Could we not consider this an idol?

AI will make the problem worse. Movies such as *Her* and *Ex Machina* play with this idea, that as the technology starts to better imitate a person, as it caters more and more to our every whim, we may see it less as a tool to use for God's designs and more as an idol that gives us what we want. Why bother with real relationships, when an artificial one will give me what I want (but not what I need) without the messiness of involving another sinful person? Why be present in the real world with all its messiness, when we can interact with an artificial one that's much cleaner and more to our liking? Luke Dormehl develops this case.[17]

Further, it is easy to see how we might use AI to make gods of ourselves. You can see this in, for instance, election advertising. Using one type of AI system, people are classified and put into categories. Another classifies the content needed to target them, and yet another targets people to get them to act in the way the creators wanted. Maybe they can influence you to change your vote? Maybe you were planning to vote, but they make you a little less likely to do so? By selectively providing people with information (regardless of whether the information is *true*), over large populations one might be able to swing a few thousand votes in Michigan, or Virginia, or Georgia. And a few thousand votes in the right place can swing an election.

In other words, these tools allow their creators to influence people *en masse*. I do not need to know you as an individual. I never sit across from you at a table and hear your story. I reduce you to a vote, as clay to be molded so that I can get what I want in the end. I treat myself as God. I commit the original sin. I idolize not the technology, but, through the technology, I idolize myself.

3. Corruption

Here we disagree with a common refrain that you may have heard: "*X (whatever one might be referring to) is just a tool. And any tool can be used for good or for evil.*"

Despite what these common sayings suggest, tools *are not* neutral. One cannot approach a chair and do just *anything* with it. It begs to be sat on, and sat on in a certain way. Your iPhone cannot be used in just any way, and it does not sit idly by as if it were indifferent to how you use it. Try it for yourself. Set it down next to you. Sooner rather than later, it will light up, whether or not you actually received a call or a text message. An app may give you a notification. A news alert will pop up. It is almost as if it were saying, "*Pay attention to me.*"

All these tools were made with a particular purpose in mind. Your phone and the apps on it have *success metrics.* Their creators have defined how their product will serve its purpose; that is, how each part of the product will encourage you to use it for each of its purposes. Therefore, depending on how a tool is made and the purposes for which it was made, you will find specific incentives to use that technology in certain ways. AI is no different. Here are a few examples of the perverse incentives that AI could create.

As we have discussed, AI needs to predict outcomes based on input data. That is how it is trained. AI systems spot patterns between inputs and outputs, make predictions, and perform tasks in order to produce the desired output. The more data the AI has, and the more diverse the dataset, the better it will be able to give the desired output. Therefore, the creator of an AI system has an incentive to acquire as much data as possible from you in order to better train the AI system to make more-accurate predictions. However, your privacy is an impediment to this goal. Next time you click "Yes" on a software user agreement, just ask yourself, "Why is this agreement so long and complicated?"

In what other contexts might this corruption happen? We have already discussed elections, and the selective and targeted spreading of information. Often, people *want* to be told that they are right. Often, people *want* to hear what they want to believe. AI systems that classify you can give you *what you want, even if it is bad for you*. AI systems can give you the bubble you are looking for, efficiently and without complaint, without using information you might find uncomfortable.

We ought also to be concerned about dehumanization. As AI systems behave more and more like people, there is a question about how we ought to treat them. Are they people? Ought we treat them as if they were? Will we?

Immanuel Kant once said, "He who is cruel to animals becomes hard also in his dealings with men."[18] If we can treat with callousness a living being that is not human, often that means we will end up doing the same to people. One might be able to extend this argument to AI systems: if I can treat an AI that *acts* like a person as a tool to be used by me, might I treat other humans that way as well?

As with any human endeavor, we ought to be constantly asking ourselves, "*Who is God? Who are we?*" and "*What does that mean about our current endeavors?*" Are we fulfilling our calling, that of subcreators in attempting to redeem the earth and be fruitful? Are we trying to build the Tower of Babel, thinking that we can build heaven on Earth without the blessing of the Creator of the universe? The answer is not simple. However, if we are trying to build and use this technology in a way that is in keeping with our faith, what might that look like?

4. Unanticipated consequences

The more complex the technological development, the more likely we are to encounter unanticipated outcomes. This hearkens back to the earlier example of Mickey in the "Sorcerer's Apprentice"; Edward Tenner develops this case in general.[19] We need to be vigilant and forward looking as we roll out the technologies, but often our culture of short-term thinking and immediate gratification overrides our best intentions.

5. Contextual misfit

We often find that an AI system works well in the lab, but it has difficulty when placed in a bigger context. For example, consider self-driving cars. Driving laws were created for human drivers and focus on the human tendency to create unsafe conditions. Thus, we have laws against speeding (or driving too slowly), failure to obey traffic lights, and so forth. A good AI system can obey all of these laws, but where might the difficulties lie? What laws are needed to create a safe overall system? Insurance is for the driver of the vehicle. Who is liable for an accident with a self-driving car?[20]

In the transition between horses and cars in New York City at the early part of the twentieth century, the most dangerous time was found to be when both horses and cars were on the road together. The transition involved people holding onto their horses because they liked them, governments trying to deal with changing laws, and difficult interactions between two types of transportation. How will the transition to driverless cars be managed?

6. Isolation

There is the important question of how AI interactions may affect the relationships we have with humans. God made us to be in relationship with people, but might our interaction with AI systems be more comfortable and reliable, and undermine our willingness to engage in the hard conversations we should have with others?[21] Sherry Turkle raises this and related issues in her book *Reclaiming Conversation*.[22] It is possible that reducing the number of human "transactions" (impersonal tasks that we carry out with other people) may cause us to step away from thinking of the other person in terms of the transactions we have with them.[23] This could allow us to focus our true human relationships on a smaller number of people (family, friends, neighbors, some coworkers, church members) and to take these relationships more seriously. Perhaps we would see other people more in the way it was intended, rather than simply as persons who can meet our needs. This will require us to be intentional about developing and fostering relationships with others in spite of their messiness.

The other side of this question, discussed by Turkle as well as by Beavers and colleagues,[24] is that our personal relationships need to go deeper than "technology mediation." Texting, emails, video conferencing, and phone calls are helpful, but they are not enough for properly relating to another person. We need to relate at a deeper level, sharing reality well beyond human transactions. Perhaps AIs will free us to do this.

Frequent Responses

Research is leading to new AI tools and systems that will change our lives. There are several possible responses to these changes.

- **The Blind Enthusiast**: Some will embrace the changes with little thought to a potential challeng-

ing downside. We need to listen to these people because they suggest new possibilities that we might not have considered.

- **The Luddite**: Some will push back against all change, resisting almost all new technology. We need to listen to these people as well, because they might remind us of a downside we would not have considered in our own enthusiasm.
- **The Disaffected**: Some will respond negatively, their objections based solely on how the technological changes will affect them personally. We can easily note potential problems with the technology, but we need to look at the questions from a broader viewpoint. For example, some resist driverless cars because they personally like to drive. Yet with such significant loss of life associated with person-driven vehicles, we cannot afford just one narrow viewpoint.
- **The Observer**: Some will sit on the sidelines for a long time, waiting to see whether the new technology offers a good or a bad outcome. From these people we can learn not only to avoid a rush to judgment but also to make wise calls.
- **The Ambivalent**: Some have little interest in technology and simply want to avoid the questions. These people do not need to be experts, but they need to go beyond naysaying and be open to constructive conversation.
- **The Wise**: Some will immediately try to understand and seek to steer development of AI systems in a way that keeps the big picture in mind. They need to be open to new possibilities, be aware of potential downsides, and be careful to avoid premature judgments. They also need to listen to questions from those who do not understand the technology.

We are delusional if we believe that we can stop this development. The technology is rapidly advancing, and will continue to do so. We were made to do this: to relentlessly create as one made in the image of the Creator. We have an opportunity to be a part of shaping it.

The Role of Christians in This Discussion

Christians do not have a corner on wisdom in any of these areas. We have found both Christians and those with no religious beliefs in all categories of wisdom and foolishness. But followers of Christ who take the Bible seriously need to consider some other factors as they engage in this discussion. There are four principles that Christians should adhere to:

First, God has called his people to not make themselves the center of the issue.

> Do nothing out of selfish ambition or vain conceit. Rather, in humility value others above yourselves, not looking to your own interests but each of you to the interests of the others. (Phil. 2:3–4, NIV)

Second, we should be people who do more than say "no." David Gill developed this case from Titus.[25]

> For the grace of God has appeared that offers salvation to all people. It teaches us to say "No" to ungodliness and worldly passions, and to live self-controlled, upright and godly lives in this present age …" (Titus 2:11–12, NIV)

We are to say no to ungodliness and worldly passions, but we are to "live … in this present age." How do we work together to properly discern the times?

AI tools can be a part of healing the sick, producing safer cars, understanding potential implications that lead to new public policy. If we sit on the sidelines, others will shape the future without the insight we can bring to the issues.

Third, in our instantaneous technological society, there is a tendency to look only short term. We may look at short-term gains or short-term losses. We can be caught in excitement or fear. As the people of God, we should broaden our thinking, living as the people of God with the end in mind. Romans 13:12 says we are to live as the people of light even in the present darkness.

Fourth, God's command to his people in exile can as well be meant for us today.

> This is what the LORD Almighty, the God of Israel, says to all those I carried into exile from Jerusalem to Babylon: "Build houses and settle down; plant gardens and eat what they produce. Marry and have sons and daughters; find wives for your sons and give your daughters in marriage, so that they too may have sons and daughters. Increase in number there; do not decrease. Also, seek the peace and prosperity of the city to which I have carried you into exile. Pray to the LORD for it, because if it prospers, you too will prosper." (Jer. 29:4–7, NIV)

Conclusions

Both the opportunities and the problems of our technological society are real. The effects of AI systems both now and soon to come will challenge our suppositions and draw us into places where we have not been. Even here, we need to live fully for God.

It is no accident that God has placed us in the twenty-first century. Some would sound a call to retreat, but God commands us to be salt and light in *our* world. This means we do not hide from the changes, or simply embrace them as inevitable, but we seek to understand them from the light of the scripture. Like the body of Christ that Paul talks about in 1 Corinthians 12, we do not all have the same role, but different roles. Let us challenge and encourage each other in this world where God has placed us. ⌂

Acknowledgments

The authors are grateful to the referees who reviewed an earlier draft of this article. Their helpful comments encouraged us to add references and to make changes to the original draft.

Notes

[1]Marvin Minsky and Seymour Papert, *Perceptrons* (Cambridge, MA: MIT Press, 1969).

[2]We have chosen not to develop the distinctions between strong and weak AI, or to mark the distinctions between machine learning and AI. While this would be straightforward, it would unnecessarily complicate this article, and we believed that it would obscure the major conclusions.

[3]Neil Gershenfeld, *When Things Start to Think* (New York: Henry Holt, 1999). Gershenfeld argues that computers will disappear as things begin to think.

[4]Many authors have addressed pieces of this problem. The specific issue of job displacement through technology has been addressed, for example, by Carl Benedikt Frey and Michael A. Osborne, "The Future of Employment," a working paper from Oxford Martin School, Oxford University, 2013, retrieved from https://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf. Other references related to the societal impacts of AI can be found here, https://medium.com/@eirinimalliaraki/toward-ethical-transparent-and-fair-ai-ml-a-critical-reading-list-d950e70a70ea. Many cultural critics have addressed aspects of the issues, and we have been influenced by many sources beyond our own experiences.

[5]An excellent summary of this can be found in Gideon Lewis-Kraus, "The Great AI Awakening," *New York Times Magazine* (December 14, 2016).

[6]Marco Tulio Ribeiro, Sameer Singh, and Carlos Guestrin, "'Why Should I Trust You?': Explaining the Predictions of Any Classifier," *Cornell University* (last revised August 9, 2016), https://arxiv.org/abs/1602.04938.

[7]A self-driving car involves much more than the AI system to make it work. It depends on visual systems, including the recognition of objects, reading signs, links to navigation tools, and so forth. For this discussion, we bring these all into one system.

[8]Ecclesiastes 1:9.

[9]This insight is attributed to Malcolm Guite, an Anglican priest, poet, lecturer at the Cambridge Theological Foundation, musician and current chaplain of Girton College Cambridge, from a lecture he gave at Cambridge University. He said he "was riffing on the way Dante has the philosophers whirling round in joyful circles in the Paradiso."

[10]https://en.wikipedia.org/wiki/Fantasia_(1940_film)#The_Sorcerer's_Apprentice.

[11]When roughly 40,000 people per year die in car accidents in the US, and 90% of crashes are due to human error (distracted driving, alcohol, sleep), a strong case is sometimes made that the current early version of self-driving cars is already safer than cars with human drivers. This has not been established, and the transition period will perhaps identify new things: S. Singh, "Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey," Traffic Safety Facts Crash•Stats. Report No. DOT HS 812 115 (Washington, DC: National Highway Traffic Safety Administration, 2015), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115.

[12]Note that while Genesis 1 gives God's orderly account of creation, Genesis 2 looks at the same account from a different point of view. The good creation God had made as stated in Genesis 1 means that the world was perfectly provisioned. Genesis 2:5 says that God invited humans to develop this perfectly provisioned world. God could have created a computer bush allowing us to pick what we need, but he provisioned his world and allowed humans to develop a computer.

[13]Rosie Perera, "Technology: Love It or Hate It?," *Ethix* (February 1, 2008), https://ethix.org/2008/02/01/technology-love-it-or-hate-it.

[14]Deb Riechmann, "I Never Said That! High-Tech Deception of 'Deepfake' Videos," *The Seattle Times*, originally published July 1, 2018, updated July 4, 2018, https://www.seattletimes.com/nation-world/nation-politics/apxi-never-said-that-high-tech-deception-of-deepfake-videos/.

[15]Cathy O'Neil, *Weapons of Math Destruction: How Big Data Increases Inequality and Threatens Democracy* (New York: Crown, 2016).

[16]Edward Tenner, *The Efficiency Paradox: What Big Data Can't Do* (New York: Alfred A. Knopf, 2018), xxii.

[17]Luke Dormehl, *The Formula: How Algorithms Solve All Our Problems … and Create More* (New York: Perigee, 2014), chapter 2.

[18]Immanuel Kant, "Moral Philosophy: Collins's Lecture Notes," in *Lectures on Ethics,* ed. Peter Heath and J. B. Schneewind, trans. Peter Heath (Cambridge, UK: Cambridge University Press, 1997).

[19]Edward Tenner, *Why Things Bite Back: Technology and the Revenge of Unintended Consequences* (New York: Alfred A. Knopf, 1996).

[20]Early indications are that self-driving cars will be insured by the auto manufacturer. What unintended consequences might come from this arrangement?

[21]Justin Anderson, Parker's pastor, brought this up in discussing the cultural consequences of AI, and we found

it insightful. Justin is launching Icon Church (https://iconchurch.org) in the heart of tech country in Seattle in Spring 2019.

[22]Sherry Turkle, *Reclaiming Conversation: The Power of Talk in a Digital Age* (New York: Penguin, 2015).

[23]For many of our routine tasks (e.g., ordering in our local coffee shop), we often mentally reduce the person we are interacting with to a functional level. That person serves to allow me to perform a transaction, and we rarely deviate from thinking of them that way. In other words, we dehumanize them. In fact, many of us might even get a little annoyed if the person taking our order is a little too chatty, a little too human, when all we really want is our coffee!

[24]Randy Beavers, Denise Daniels, Albert Erisman, and Don Lee, "Communication Technology Mediated Relationships: Some Considerations from Theology," *Christian Business Review* 7 (Fall 2018): 12–21.

[25]David W. Gill, "Light a Candle," Baccalaureate speech at Gordon Conwell Seminary, *YouTube* (June 2, 2016), https://www.youtube.com/watch?v=AJMWIFwcY0Y.

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Call for Papers

TRANSHUMANISM: CHRISTIAN DESTINY OR DISTRACTION?

David C. Winyard Sr. (PhD, Virginia Tech) is an engineer and Science and Technology in Society scholar. From 1975–2012, he worked in R&D for the US Navy and Defense Logistics Agency, receiving multiple awards and patents along the way. After retiring from federal service, he taught at Mount Vernon Nazarene University from 2014 to 2018, building its new engineering program.

Since 2010, Winyard's focus has shifted from technology development to its meaning. His 2016 dissertation analyzed connections between Christianity and transhumanism which seek fundamental enhancements of life by science and technology.

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James C. Peterson, *editor-in-chief*

Danilo R. Diedrichs

Mathematics Reveals Patterns That Reflect the Orderly Character of God

Danilo R. Diedrichs

As the "queen and servant of the sciences," mathematics plays a complex role vis-à-vis the other fields of science. This primarily non-empirical method of organizing arguments and deriving truths deductively also proves to be remarkably effective in describing the physical world. Increasingly, the natural and social sciences are becoming "mathematized" and turning to mathematical models to describe patterns in their observations of the world. Although most models fall short of expressing an absolute, universal law of nature, they remain effective tools to reveal structures of order where none are apparent. This article presents the unique place of mathematical descriptions of the physical world in the Judeo-Christian tradition, and their contribution to our understanding of God. Mathematical models reveal God's character of order as well as his reliability, faithfulness, and uniqueness. They also provide a lens through which God's roles as creator and sustainer of the world become visible. As pranalogical instruments of worship, mathematical models help shape a proper biblical worldview and a better understanding of God's creation in order to improve the quality of life on this earth.

As one of the earliest and oldest applications of the ability of the human mind to engage in abstract thoughts, mathematics has a special place in the history of human beings' understanding of the world. Every civilization has developed a system of abstracting numbers into a system that lends itself to visualize relationships between quantities and abstract patterns. Our ability to reason with abstract thoughts is at the foundation of mathematics, just as it lies at the core of our understanding of God.

Mathematics stands alone among other fields of knowledge: it is a science, systematically arranged and subject to general laws, but unlike the other sciences, its content is not primarily empirical. The practice of mathematics does not require any application to the physical world and can be done entirely within the bounds of the human mind. However, mathematics can also be used, and with great effectiveness, to describe elements of the physical world.

Complex concerns in the material world often drive us to reach out to our ability for abstraction to provide order and understanding. Once we discover the mathematical rules that describe patterns revealed by this abstract process, we can dissociate ourselves from the material world completely and continue the study of mathematics in complete abstraction, without any need or concern for the material world. Yet the mathematical discoveries made in deepest abstraction often come full circle, proving themselves useful in providing answers to open questions about the physical world. For example, the concepts of geometry, originally developed out of practical needs for engineers and merchants to measure

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lengths, angles, areas, and volumes, eventually led to the development of an entire system of abstract thought patterns based on postulates and axioms no longer connected to physical concerns. Geometry progressed further into abstraction, extending in the nineteenth century to non-Euclidean geometries and topology. Then Einstein used a non-Euclidean geometry as the framework for his theory of relativity; in addition, the abstract concepts of knot theory, a subarea of topology, provided useful tools for studying the properties of enzymes that unknot the complex knotted structure of DNA molecules, thereby facilitating progress in molecular biology and modern medicine.

The increasing mathematization of the natural and social sciences in the twentieth century led to the widespread use of *mathematical modeling*, a concept that originated in the late seventeenth century with Newton's *Principia Mathematica*, but remained confined to physics and chemistry until the twentieth century. This approach brought together the strengths of experimental science and mathematics into *mathematical models*, the "tendons connecting the muscles of mathematics to the bones of science."[1] The twentieth century saw the emergence of another type of mathematical model called *empirical models*, or *data-driven models*, based on statistical approaches that are common in the life and social sciences. Their primary purpose is less about finding an equation that describes a law of nature, and more about finding an equation that fits a particular data set.

Mathematics is a uniquely effective tool for studying patterns and orderly structures. Mathematician Keith Devlin defines mathematics as the science of patterns that "can be either real or imagined, visual or mental, arising from the natural world or from within the human mind, the quintessential tool for searching structures of order in life, mind and universe."[2]

Philip Davis and Reuben Hersh go even further, using language that mirrors the ordering described in Genesis 1:

> To some extent the whole object of mathematics is to create order where previously chaos seemed to reign, to extract structure and invariance from the midst of disarray and turmoil … To create order—particularly intellectual order—is one of the major human talents, and it has been suggested that mathematics is the science of total intellectual order.[3]

The Christian faith is unique in claiming that, although God is invisible, he delights in the material world and uses it to reveal himself and to reach out to us. The scriptures also emphasize order as being one of the primary attributes of the Christian God. The creation account in the first chapter of Genesis puts emphasis on God's action to create order out of disorder, to give a purpose to the material world.[4] Throughout scripture, whenever God speaks, order appears, and God declares it to be good.

The process of building and defining a mathematical model has been identified by several Christian mathematicians as a unique means for understanding the world God created, and the role he has given us as we interact with his creation. The beauty of patterns revealed by models resonates with our soul, pointing to God's role as creator of order and to the *imago Dei*.[5] Furthermore, the modeling process integrates and shapes our faith by reflecting our motives and attitudes; indeed, models can be used either for destructive purposes or to improve the quality of life on this earth.[6]

This article highlights the role of mathematical models to reveal, study, and explain the patterns observed in the physical world and discovered empirically by experimental science. Some of these patterns are so complex and hidden that experiments do not reveal them; the order within them becomes apparent only through a mathematical model, in that the very definitions of these patterns are based not on the behavior of the systems themselves, but on the mathematical properties of the models used to describe them.

This article begins with an outline of the history and philosophy of the relationship between mathematics and the physical world, leading to the modern concept of mathematical modeling. Then it highlights the effectiveness of mathematics to uncover and study hidden patterns of order in the physical world. Finally, it presents examples of how mathematical models of seemingly "chaotic" systems reveal patterns where none were suspected, thereby providing a means to reflect the underlying order imbued in all of God's creation.

History and Philosophy of the Relationship between Mathematics and the Physical World

The nature of the relationship between mathematics and the physical world has been under debate since the era of pre-Socratic philosophers. One school of thought, formalized by Plato, held that mathematics has its own existence in the "Platonic realm," independent of human beings, and that we humans are merely discovering what has been there from eternity. According to Plato, the most fundamental kind of reality is composed of nonmaterial, abstract Forms, which our senses allow us to perceive only as shadows on the wall of a dark cave with light shining behind us. Mathematics frees us from the cave of our perceptions so that we can directly perceive the Forms through reason alone. Thus, mathematics is *discovered* and is independent of experience. In contrast to this point of view, the realist or empiricist view rejects this idea and instead claims that mathematical forms are *invented* by the human mind; they are artificial constructs that we imagine, and then use to describe the physical world we observe.[7] This debate, which began 2,500 years ago, is far from being settled today. Physicist and engineer Derek Abbott estimates that most pure mathematicians today lean to a Platonist view, whereas most physicists and engineers are non-Platonists, with applied mathematicians falling somewhere in between.[8]

Throughout the Christian era, many Christian philosophers have adapted a Platonist view of mathematics to a Christian worldview. According to St. Augustine, God created the world, both visible and invisible, including the eternal truths of mathematics, which originated in the eternal mind of God and with which God created the patterns of the world. Being created in God's image, our minds possess the ability to apprehend the basic mathematical truths. Johannes Kepler believed that God had embodied some of his essential mathematical nature in creation, and that we humans can think his thoughts after him. True knowledge of natural phenomena can be attained when the geometric schemes in our mind correspond to those prototypes in the Divine mind that have been copied into the world.[9]

The strongest counter-current to the Platonist view in the Christian world is the Aristotelian natural philosophy, systematized in accordance with Christian theology by Thomas Aquinas in the thirteenth century. Aquinas adopted Aristotle's idea that matter is the basis of all that exists, and that the true form of an object, being contained within the object itself, can be perceived using one's senses. His analyses of physical objects, place, time, and motion were especially influential among the Dominicans and Jesuits.

The earliest expressions of the natural philosophies of Plato and Aristotle held that the physical world was too changeable and imperfect to be explained by mathematics, but the fourteenth and fifteenth centuries saw increasing attempts to apply mathematics to the physical world under Aristotle's growing influence, thanks to Aquinas. The gradual development of experimental practices beginning in the thirteenth century saw mathematics as a tool to organize and analyze experimental data. Eventually, mathematics rose to occupy an important role as an ancillary field of knowledge endorsed by the church to help understand the higher disciplines of theology (the "queen of the sciences"), philosophy, law, and medicine.

In the sixteenth century, the Reformation threatened the stability of the Roman Catholic Church's teachings, prompting widespread theological and philosophical disputes. Under the impetus of the Jesuit mathematician Clavius, Catholic theologians turned to mathematics and to the geometrical proofs in Euclid's *Elements* as a model to derive eternal truths deductively and to prove them decisively and irrefutably.[10] At the same time, scientific practice was being formalized into a philosophy of experiment by Mersenne and Gassendi, among others. Christian natural philosophers discovered the ability afforded to them by mathematics coupled with experimental practice to describe, understand, predict, and, ultimately, to control the natural world around them. They put forward the new doctrine that God had structured the universe according to mathematical laws, in which case it was not only possible, but also God's will, that efforts be made to understand those laws,[11] justifying their efforts as a response to God's creation mandate (Gen. 1:28).

One of the chief natural philosophers of that era, Galileo, championed this view of mathematics, but was not satisfied with it, going further and taking the bold step of equating mathematics with God's native tongue.[12] Following Augustine, he claimed that God had written two books of equal importance

and significance: the Holy Scriptures, God's word, to be interpreted by the study of theology; and the Book of Nature, to be interpreted by the study of mathematics. Around the same time, Johannes Kepler was successful in fitting planetary data points to orbits, and Descartes developed significant applications of geometry to the physical world. Eventually, the locus of truth concerning the natural world shifted from theology to mathematics and natural philosophy, causing theology to be supplanted by mathematics as the new "queen of the sciences."[13]

The discovery of the calculus by Newton and Leibniz in the seventeenth century led to increasing mathematization in natural philosophy. Over the next two hundred years, natural philosophers used mathematical equations to write fundamental laws that described the mechanics of the universe, gradually removing much of the mystery from phenomena that had puzzled them for centuries (planetary motion, mechanics, electromagnetism, light, optics, diffusion, heat transfer), and accelerating the scientific revolution.

A shift occurred in the early twentieth century, when many of the laws of nature assumed to be immutable and universal were found not to be as universal as once thought. The laws of Newtonian mechanics were revised to include the theory of relativity, for which Einstein used a formulation based on a geometry inconsistent with Euclidean geometry, also previously assumed to immutably reflect the nature of the known physical world. Furthermore, many fields in the life and social sciences remained resistant to mathematization by models based on theory. These difficulties led to the emergence of a different form of mathematical modeling, now based on experimental data without necessarily having any explicit physical causes, a fundamental shift from the Platonist view held by St. Augustine, Galileo, and their successors. These models are mere tools designed by the human mind to study a specific situation. Under this guise, mathematics has become the "servant of the sciences," providing useful tools to study certain parts of the world, but not all of them, and certainly not with infinite accuracy. As Davis and Hersh state in *The Mathematical Experience,*

> The realization that physical theories may change or may be modified (Newtonian mechanics vs. Einsteinian mechanics, for example), that there may be competing theories, that the available mathematics may be inadequate to deal with a theory in the fullest sense, all this has led to a pragmatic acceptance of a model as a "sometime thing," a convenient approximation to a state of affairs rather than an expression of eternal truth. A model may be considered good or bad, simplistic or sophisticated, aesthetic or ugly, useful or useless, but one is less inclined to label it as "true" or "false."[14]

Laws of Nature, Scientific Laws, and Mathematical Models

The terms *laws of nature*, *laws of science*, and *laws of physics* were coined in the seventeenth century to describe the laws formulated under the experimental methods of that century. These laws emerge after a large number of repeated scientific experiments reveal an underlying regularity, or pattern, in nature.

However, the word "laws" also reflects the prevalent Christian notion that they were ordered by a divine lawgiver. Thus a "law of nature" was more than just a summary of observable features of the world; it reflected the divine decision of the way the world was intended to behave. According to physicist Paul Davies, laws of nature are universal, absolute, omnipotent, and eternal.[15] Although the general belief in a divine lawgiver has been eroded in the secular scientific community, the properties assigned to the laws of nature coincide with those assigned to the Christian God.[16]

All known fundamental laws of nature are mathematical in form, and the earliest laws were also characterized by their simplicity, encapsulated in a single, often linear, mathematical equation. Although linear equations include only a small subset of all equations, until the twentieth century the practice of attempting to write laws of nature as mathematical equations focused almost exclusively on them. It is understandable that scientists would first turn to the simplest and most tractable form of equations, spurred by the widespread belief that laws of nature could not be anything but linear. The orderly and predictable nature of solutions of linear equations was consistent with the character of God who was assumed to have written them.

Although Newton believed that God was continually at work sustaining the order of the universe, his discoveries opened the way to deism, which grew rapidly during the eighteenth century. The laws of nature were considered to be expressions of the

secondary causes with which God had empowered his creation and through which he orchestrated the world's order. With this point of view, God plays the role of a hands-off Master Engineer who rules his creation through deterministic laws, never needing to intervene, as he would have the infinite wisdom and power to make his laws perfect. Deists deny that God plays a direct role in continually sustaining the order of the universe: this function is shifted to nature itself.[17]

Until the end of the nineteenth century, nonlinear models were largely ignored because of the difficulty in solving them. Since the majority of nonlinear models cannot be solved analytically, it is only in the last few decades that computers have facilitated the implementation of numerical methods to approximate their solutions. By the early twentieth century, natural scientists had discovered that most of the principles that describe the world are nonlinear; thus the simple, early formulations of the laws of nature were progressively supplanted by more complicated, nonlinear ones. But these early formulations are not forgotten, as they remain good approximations of reality, accurate enough for practical purposes, and easier to work with than the more universal forms. For example, the Newtonian laws of classical mechanics remain a good approximation of reality in many cases, and are still called "laws." But the fundamental shift is in the knowledge that they are no longer a perfect expression of the reality of the physical world, but merely a conveniently simple approximation for particular applications in certain instances. However, these models are still connected to first principles, albeit imperfectly, so they are distinct from the data-driven models that are based on observations alone.

The fact that the models which approximate reality are still almost universally called "laws" in the twenty-first century is a source of great consternation among modern natural philosophers. Michael Scriven and Nancy Cartwright have attempted to clarify, expand, and redefine the terminology. According to them, the great majority of laws that were once thought to be laws of nature are, in fact, what they define as "scientific laws," approximations of the truth that apply only to idealized models of reality, always subject to the possibility—and often the actuality—of refutation, abandonment, and replacement.[18]

Mathematics: The Tool That Makes the Invisible Visible

Hidden Patterns Revealed by Mathematics

In the physical world, a distinctive sign that something has order is the presence of a pattern, a regular structure in space and/or time that seems to have been deliberately designed and placed there. As creatures of order created by a God of order, we are naturally drawn to notice these patterns; they resonate with our soul, and we find them intriguing, mysterious, and beautiful. The creeds of the Christian church begin with the affirmation that God created everything visible and invisible. He delights in his creation, and reveals himself to us through his created world. As the "science that makes the invisible visible,"[19] mathematics is the language of choice to describe anything in the world that obeys a certain order or pattern, but its true power is revealed in its ability to describe and study abstract structures and hidden patterns.[20] Humankind was created to perceive mathematical beauty, and the world was intentionally created with the abstract-concrete "fit" to benefit humankind.[21]

Although God remains hidden from human eyes, he provides enough light to reveal himself to those who search for him. Thus, he respects our freedom to either accept or reject him. In his *Pensées*, Pascal writes about the tension God maintains between his revelation and hiddenness, so that those who desire him may find him and those who do not want him would not be forced by bludgeoning evidence into believing against their will. He writes:

> Instead of complaining that God has hidden Himself, you must thank Him for revealing so much of Himself … It would not have been right for Him to appear in a way that is plainly divine and absolutely bound to convince all mankind; but it was not right either that He should come in a manner so hidden that He could not be recognized by those who sought Him sincerely. He chose to make Himself perfectly knowable to them; and thus, wishing to appear openly to those who seek Him with all their heart, and hidden from all who flee Him with all their heart, he tempered the knowledge of Himself, with the result that He had given signs of Himself which are visible to those who seek Him, and not to those who do not seek Him.[22]

Theologians distinguish between special and general revelation as the two ways by which God has chosen

to reveal himself to humanity. Special revelation refers to the miraculous means God employs to make himself known to us, including most importantly his physical, human form in the person of Jesus Christ, and his written Word recorded in the scriptures by the inspiration of his Holy Spirit. Through general revelation, God reveals his existence, power, intelligence, and transcendent nature to all humanity, at all times and in all places through nature. Psalm 19:1–4 (NIV) declares,

> The heavens declare the glory of God;
> the skies proclaim the work of his hands.
> Day after day they pour forth speech;
> night after night they display knowledge.
> There is no speech or language
> where their voice is not heard.
> Their voice goes out into all the earth,
> their words to the ends of the world.

In Romans 1:20 (NIV), Paul declares,

> For since the creation of the world God's invisible qualities—his eternal power and divine nature—have been clearly seen, being understood from what has been made, so that men are without excuse.

According to these verses, we can know something of God by observing the universe. The knowledge of God is embedded in his creation; although God himself remains invisible,[23] we can perceive his handiwork in creation.[24] We see in this duality the idea put forth by Augustine and Galileo, among others, that the Bible and the Book of Nature were both written by God, books of equal importance, but to be studied and interpreted by different means.

Echoing Pascal's description of the balance between God's hiddenness and revelation, Davies, although a non-Christian, marvels at our ability as humans to discover the hidden laws of nature when we earnestly search for them.

> What is remarkable is that human beings are actually able to carry out this code-breaking operation, that the human mind has the necessary intellectual equipment for us to "unlock the secrets of nature" and make a passable attempt at completing nature's "cryptic crossword." It would be easy to imagine a world in which the regularities of nature were transparent and obvious to all at a glance. We can also imagine another world in which either there were no regularities, or the regularities were so well hidden, so subtle, that the cosmic code would require vastly more brainpower than humans possess. But instead we find a situation in which the difficulty of the cosmic code seems almost to be attuned to human capabilities … No feature of this uncanny "tuning" of the human mind to the workings of nature is more striking than mathematics, the product of the human mind that is somehow linked to the secrets of the universe.[25]

In his awe at our ability to use mathematics to decode the secrets of nature, Davies echoes the amazement of physicist Eugene Wigner, Nobel Laureate, who, in his paper "The Unreasonable Effectiveness of Mathematics in the Natural Sciences," notes that all of nature seems to follow persistent, unchanging patterns that have been observed since ancient times, but that when these patterns are described in the form of mathematical equations, a miracle occurs.[26] Although Wigner does not mention God or draw any religious conclusions, he uses the word "miracle" twelve times and states that the effectiveness of mathematics is "something bordering on the mysterious … a wonderful gift which we neither understand nor deserve."[27]

Furthermore, writing the laws of nature as mathematical equations uncovers relationships between the laws themselves. Thus, mathematics has the property of making the invisible laws of nature visible, as well as making visible certain relationships between seemingly disparate natural phenomena. Mathematics unifies theories and amplifies our perception; in our attempts to study the behavior of a certain natural system, often we succeed not only in uncovering the law that describes it, but also in discovering several other laws that we had not expected to discover.

In his *Principia*, Newton showed that falling bodies on Earth's surface, the orbits of the Moon around Earth, and the satellites orbiting Saturn and Jupiter, as well as the orbits of the planets around the Sun, all behave like falling masses according to the law of gravity. Later he tied the phenomenon of the tides to the Moon's orbit, thereby demonstrating that celestial and terrestrial phenomena both obey the same physical principles. Similarly, Maxwell's equations were successful in explaining the relationship between electricity and magnetism—two invisible forces which had been observed for centuries, but required a set of mathematical equations to clearly understand the interplay between them. Maxwell's

electromagnetic theory unlocked even further mysteries, explaining the nature of light and predicting the existence of radio waves. The Navier-Stokes equations describe the complex motion of fluids, as well as diverse phenomena such as weather patterns, ocean currents, water flow in a pipe, and air flow around the wing of a bird. Fourier's *heat equation*, originally written to explain the diffusion of heat in a solid, is now commonly referred to as the *diffusion equation*, because it has been found to apply equally to many other diffusion phenomena, such as the diffusion of a pollutant in water or a population in an ecosystem.

The discoveries—whether made accidentally or intentionally—of the many relationships between seemingly unrelated phenomena have encouraged scientists to search more intensively than ever for unifying theories, and even to consider the possibility of a Theory of Everything, a unique, all-encompassing theoretical framework that fully explains and links together all physical aspects of the universe. For Christians, this search is consistent with the desire to know God through his creation and with the belief that all facets of our universe were created by the same, unique God. Christianity is founded on the belief that no part of the universe was created at random, that every element of God's creation has a purpose and a function that is connected to every other in an orderly framework, and that it is God's will for humans to perceive him as creator through the orderly patterns of his creation.

Order and Chaos

Christians have always believed that God created the natural world in such a way as to follow a prescribed order. As Newton studied the motion of planets in the late seventeenth century, he assumed that they followed an orderly pattern in space and time, as does much else in nature. Central to Newton's approach was the belief that the motions of the planets were "imprest" in them at some stage by an intelligent, calculating God who was adept at mathematics and engineering. Newton thought that no natural cause by itself could have produced the harmonious arrangement by which each planet along with its satellites was endowed with precise locations, masses, and velocities that it now had, nor could it have given rise to the mathematically precise laws that described their interaction. Like Kepler before him, he believed that he was a privileged expert—a mathematically adept "priest" authorized to decipher the mathematical texts used by God.[28] Although Laplace, Kant, and many others offered alternative explanations for the order of the natural world, historically, Christians have sought theological reasons for the apparent order of creation.

Newton and Leibniz's development of calculus and differential equations proved to be extremely effective in teasing out the regularities of complex patterns in phenomena that would appear, at first sight, not to have any, such as the motion of planets—a pattern which had baffled astronomers for centuries. With Kepler's and Newton's laws, all of these mysteries are now elucidated. A mathematician need only solve the equations to be able to predict the exact position, velocity, and acceleration of any planet in any direction at any time.[29]

By the end of the nineteenth century, many natural patterns of the world were successfully explained and represented as mathematical laws: motion, hydrodynamics, electricity, magnetism, light waves, and so on. However, there remained some systems, especially in the life and social sciences, that resisted all attempts to explain and predict their behavior by mathematics, displaying a seemingly total absence of any kind of perceivable pattern, earning them the label of *chaotic*. In vain, scientists turned to more and more complex mathematical formulations in their attempts to write the laws and thereby predict and control these systems, until they discovered that the unpredictable nature of these systems was not caused by an incorrect or oversimplified mathematical formulation of the laws but, rather, by the mathematical formulation itself.

The earliest attempt at defining chaos dates back to 1887, as Poincaré studied the disorderly orbits that arise in the dynamics of three attracting bodies, despite the relative simplicity of the underlying equations. This led him to the qualitative definition of *chaotic systems* as those whose behavior appears to be disorderly and random, even though their behavior can be modeled by well-defined, deterministic equations. In addition, Poincaré discovered that the solutions to these equations also have the intrinsic property of being extremely sensitive to initial conditions, making predictions quasi-impossible. In the 1960s, Edward Lorenz discovered these same distinctive features in the nonlinear equations he was using to model weather patterns.

Poincaré suspected that what appeared to be disorderly was, in fact, a pattern so complex that its orderly features could not be seen by the human eye. His suspicions were confirmed with the advent of computing tools, which made it possible to visualize the solutions of equations that model chaotic systems and reveal deep structures of order hidden beneath their seemingly random and unpredictable behaviors. In 1975, mathematician James A. Yorke coined the term *chaos theory* to describe the systematic study of chaotic systems from a mathematical point of view. Since then, chaos theory has been applied to the study of systems as diverse as meteorology, thermodynamics, cryptography, ecology, physiology, and epidemiology.[30]

Currently, the most common method of quantifying the amount of chaos in a dynamical system is by calculating the global Lyapunov exponent (GLE) of the system, a dimensionless number that characterizes the rate of exponential separation of infinitesimally close orbits, with a positive GLE indicating that the system is chaotic.[31] The most recent definition of chaos (2015) introduces the related concept of *expansion entropy* of a system, in an attempt to provide a definition that is quantitative, general, simple, and computable.[32] It is essential to note that all the definitions and descriptors of chaos in a system, whether qualitative or quantitative, refer to properties of the mathematical models used to describe them.

The recent development of chaos theory and nonlinear dynamics has brought the recognition that nonlinear systems are all around us. Although a finite-dimensional dynamical system must be nonlinear to exhibit chaos, it need not be "complex"; indeed, some models can exhibit chaos despite being deceivingly simple, and the same model may exhibit chaotic and nonchaotic solutions under different conditions.

Now that scientists are actively looking for chaos, they find it everywhere—in economics, biology, epidemiology, and other disciplines. As is the case with all mathematical modeling, the strange attractors found in such widely different areas all exhibit the same characteristics; thus, learning about them in one area of interest suddenly unlocks mysteries in others. Freed from the constraining requirements of linear models, it is surprising that we actually find any systems in the world that can be adequately modeled by linear equations at all.

The definitions of chaos outlined above all attempt to describe the same thing, either by describing a qualitative behavior or by quantifiable measurements. For over a century, mathematicians have continued to come up with new definitions, each one shedding just a bit more light on what constitutes this elusive concept. There is no satisfactory single definition of chaos, because of its many different manifestations in different situations. Trying to lock the definition in a box is futile; the concept is just too big for one single definition. When we study a chaotic system, we must make ourselves blind to the entirety of the concept and focus on only a limited number of aspects of the system's chaotic nature.[33]

Christians are familiar with the challenge of defining an unperceivable concept by means of a set of images and partial definitions, each one shedding light from a different angle on an elusive concept, each one increasing our understanding and clarifying our vision of that which we cannot see. Christ's teachings on the nature of the kingdom of God (or kingdom of heaven) employ a series of parables to describe projected images of the kingdom that we can perceive in our world. In his parables, Jesus describes the kingdom of heaven as a hidden treasure, a fine pearl, leaven in bread dough, a grain of mustard seed, and a fishing net. Through these images, we catch different glimpses of the kingdom, all of which will come together in the last days when "the kingdom of the world has become the kingdom of our Lord and of his Christ …" (Rev. 11:15b, ESV). In this sense, the complex nature of chaos provides a pranalogical example of faith integration,[34] that is, a practical analogy that informs our Christian view of heavenly reality.

The parallel between the kingdom of God and chaos moves beyond their definitions alone to the order hidden within them. Just as the chaotic behavior of a system points to structures of hidden order embedded within it, the parables of Jesus that describe the kingdom of God all point to a prescribed order in his kingdom, a way of how things function in God's economy and according to which we Christians should order our lives in this world. Research has revealed that the hidden order of chaos often plays a role in healthy, life-sustaining systems. Recent advances in mathematical physiology have discovered that the occasional chaotic patterns exhibited in a human heart rate are not only innocuous, but actually necessary for its functioning.[35] Similarly,

mathematical neuroscientists who study epilepsy have discovered that they can predict the onset of an epileptic seizure by detecting the exact time when the electrical activity in the brain moves away from its naturally chaotic state.[36] Thus, just as Jesus's parables reveal that his kingdom is at work accomplishing the Father's purposes, the orderly patterns in chaos prove to be purposeful in sustaining life and in promoting human well-being in this world.

Nonlinearity in the World and Order in God's Creation

Although the world is fundamentally nonlinear, described by mathematical equations that contain within them the potential for chaos, the prevalence of chaos is surprisingly rare. A large number of natural phenomena lend themselves to be studied extensively, and often with great precision, using nonchaotic mathematical models that are described by patterns which are unmistakably orderly—reminiscent of the orderly character of the God who created them and sustains them. The rarity of chaos despite the ubiquity of nonlinearity presents a mystery: the world seems to be fine-tuned to maintain the delicate balance between chaos and order that is necessary for human flourishing.

In Isaiah 45:12 (ESV), God says,

> I made the earth and created man on it; it was my hands that stretched out the heavens, and I commanded all their host,

and verse 18 reads,

> For thus says the LORD, who created the heavens (he is God!), who formed the earth and made it (he established it; he did not create it empty, he formed it to be inhabited!): "I am the LORD, and there is no other."

These verses, along with many others, reveal that God has a purpose for his creation. He created humans to inhabit the earth and interact with his creation, just as he desires humans to have a relationship with him. Our interaction with a world that displays evidence of a sustained order leads us to consider the author of this order, a God who reaches out to us in love and reveals his character of order and goodness to those who search for him.

In *Divine and Contingent Order*, Thomas Torrance argues that the development of empirical science rests on the Judeo-Christian doctrine of God as Creator of the orderly universe, who brought it into existence out of nothing and continuously preserves it from lapsing back into chaos and nothingness. Thus, the cosmos is *contingent*, freely created by God, having an existence, freedom, and rational order of its own, while still dependent on him. This claim of contingency, once obscured by Newtonian physics, is now once again drawing attention to itself with modern discoveries in relativity and quantum theories. The universe can be found to be consistently rational only if it is dependent on a creative rationality behind it. The very fact that we derive our understanding of the world from experiments, theories, and mathematical models, implies that we assume the world to be contingent upon God and his character of order. Torrance says,

> The contingency of the creation as it derives from God is inseparably bound up with its orderliness, for it is the product not merely of his almighty will but of his eternal reason. It is not only the matter of the universe, therefore, but its form that comes into being out of nothing, for under the rational creativity of God, matter and form are fused indivisibly together from the very beginning. There is no contingency without order and no order without contingency, for contingency is inherently orderly and order is essentially contingent.[37]

In *The Lost World of Adam and Eve*, John Walton echoes Torrance's claim that there is a connection between the order of nature and the Christian doctrine of creation, which, consistent with Jewish teachings, claims that God is not only the author of life, but also the sustainer of life, and, indeed as Jesus claimed, life itself (John 14:6). According to this doctrine, when God rested on the seventh day, he rested only from his role as *creator* of the world, but not from his role as *sustainer* of life within it. God is always at work in sustaining life, even while resting from creation, as can be seen when Jesus continues to perform life-sustaining miracles, even on the Sabbath.

Torrance and Walton also draw a connection between creation declared as "good" and the order that God formed in the midst of non-order. Walton refers to the Garden of Eden as a "sacred space" of order, and to Adam as a "priest" of that space, with the mandate to extend the order of that sacred space throughout the world.[38] On the other hand, the absence of order can be related to consequences of the Fall—to evil, decay, destruction, and death. Christian doctrine and the scriptures claim that God is essentially good, so he does not create anything for the purpose of being

evil. But he has the power to redeem, restore, and re-order, for good purposes, that which has been corrupted by evil. Torrance says,

> The objective divine order of the good and rational does not merely negate evil, but lays hold of it in a re-creative and re-ordering movement with a view to mastering it, repairing that which is disordered, and making it serve a fuller dimension of order than might have been possible otherwise.[39]

The miraculous ways in which God not only replaces something evil with good, but also restores its goodness to a fuller measure than before its corruption by evil, can be seen in the scriptures from Genesis to Revelation. In Genesis, after being sold into slavery by his brothers, Joseph is elevated to a greater position in Egypt than might have been possible otherwise. God not only restores the relationship between Joseph and his brothers, but also brings about the salvation of both Egypt and Israel in the process. In the New Testament, the risen Lord not only restores his relationship with Peter, the disciple who had denied him, but also entrusts him with the leadership of his church. Ultimately, Jesus claims victory over evil and death itself and reveals his purpose of restoring the world to good by his resurrection, which would not have been manifested without his death caused by the evil of the cross.

Just as Walton views Adam as a priest over the sacred space of the Garden of Eden, Torrance views humans as mediators through which God not only redeems his creation, but also brings it to a greater level of good and order. He says,

> It is his [man's] task to save the natural order through remedial and integrative activity, bringing back order where there is disorder and restoring peace where there is disharmony. Since it is through interaction with man, the culminating point of rational order, that nature unfolds and develops its possibilities, it should not only be "pacified" through man, … but in a significant sense also be "humanized," that is, through human cultivation and development, nature should bring forth forms of order and beauty of which it would not be capable otherwise.[40]

But humans, being inclined toward evil by their fallen nature, are also capable of infecting nature with their own disorder, even as they perform their priestly functions. Conversely, nature itself is capable of exhibiting structures of order independently of humans, and thereby it brings about good to human life. Torrance says,

> In and through the profound interconnection of order and disorder in which man and nature share together, nature constantly reveals surprising new possibilities in spite of man, which can have a healing and rectifying effect on him, for after all it is much more in man himself than in nature that evil has lodged itself.[41]

This point of view is consistent with the stability we observe in nature's life-sustaining structures of order, such as the surprising life-giving effects attributed to seemingly disorderly chaotic patterns exhibited in a human heart rate or electrical brain activity. In this sense, the tension between good and evil lodged in the human soul is mirrored in the mysterious tension between order and disorder exhibited by chaotic systems in nature. As created beings, we can look to nature and creation as a mirror into our own human nature, while simultaneously living out our role as priests over it and obeying our God-given mandate of extending the order of the original created sacred space throughout the world.

Conclusion

The historical narrative of this article demonstrates that mathematics, "queen and servant of the sciences," has always played a central role in humanity's attempts to understand the world. Just as God brought order out of the primordial chaos and created a world for us to live in and care for, we are drawn to order and compelled to bring order and understanding to our observations of the world we live in. So great is the effectiveness of mathematics to represent the laws of nature and reveal patterns in places where none were apparent, that many otherwise-nonreligious scientists and philosophers throughout history have assigned a divine influence to, or at least spoken in religious terms of, its ability to enhance our knowledge of the world. This mystery is nowhere more apparent than in the process of mathematical modeling, by which a human-built model is often surprisingly effective to replicate observable patterns and to reveal concealed structures of order and unforeseen relationships with other seemingly unrelated systems. Just as the power of mathematics lies in its ability to reach beyond the material world into the imperceptible realm of abstraction, so we Christians know that the material world is a reflection of the God who created it. In particular, the patterns of order revealed by mathematical models

are a visible manifestation of the orderly character of the Creator, a powerful witness to one of his most fundamental attributes.

Mathematical models teach us about God and enhance our worship as we strive to behold him and put ourselves in a state of awe and adoration of him. But because of God's hidden nature, we cannot yet behold him exactly as he is, although as children of God, we are being conformed to his image, and we have the promise though scripture that the day will come when we shall behold him face to face. Beholding God requires not only perceiving him through our five senses, but also perceiving his character, his attributes, and his invisible qualities. Mathematics, the science that makes the invisible visible, can be enlisted as a tool to enhance our beholding of God.

One element about God's character that transpires from the exercise of mathematical modeling is his reliability and faithfulness. We humans intuitively feel comforted by the reliability of mathematics and by the fact that the Creator designed his creation to follow certain laws—laws that can be described and studied by mathematics—revealing much of God's faithful and reliable character and his desire that the order of the universe would reflect his character and point to him. Under the old covenant, God guides his children by the Law and the Prophets, reaching out to us and establishing our relationship to him through promises, most of which are stated in the same cause-and-effect ("if …, then …") syntax in which mathematical theorems are stated. Just as we come to trust in the reliability of the laws of nature by beholding the repeating patterns of the physical elements of this world, we can trust in the fulfillment of God's promises as laid out in his laws and covenants. This idea is summarized by Gary De Young in his following statement:

> The consistency reflected in laws and patterns is a reflection of God's upholding hand in creation. As we seek to understand the world around us, we see the resulting consistency in creation and transfer this property to our reasoning. This property, in turn, leads to the general belief in the reliability of mathematical knowledge. Thus mathematical knowledge is ultimately based on God's providential and sustaining hand in creation.[42]

Mathematical modeling also points to the uniqueness of the Creator, as mathematical models reveal how different phenomena found in creation can be described by the same model. For example, light and sound waves are modeled by the same equation, so from a mathematical point of view, the phenomena of sight and sound transmission are exactly the same. The consistent and regular discoveries of mathematical similarities in different areas, which have enabled the unification of many physical theories throughout the centuries, point to a common and unique source and author of all.

When we use mathematical modeling to study, understand, predict, and ultimately control the outcome of a physical system for the good of humanity, we are effectively responding to the cultural mandate expressed in Genesis 1:26–28 and Psalm 8, by which God commands his children to subdue and replenish the earth, and, as Walton explains, to extend the order of the sacred space throughout the world.[43] Mathematical models are used in environmental science to understand and control the harmful effects of groundwater and atmospheric pollution; in meteorology, to predict storms and typhoons, allowing for timely mitigation or evacuation measures; in epidemiology, to understand and control the spread of diseases; and in cell biology, to understand cellular mechanisms and thereby design medical treatments. Through mathematical modeling, we Christians have an opportunity to follow God's command to protect and uphold life and to care for our world, as well as the responsibility to use this tool wisely.

Finally, the language of mathematics lends itself naturally to extensions beyond the physical world of our perceptions. Although many advances in mathematics were (and continue to be) motivated by the desire to find models that accurately reflect the reality of this world, many theories of mathematics have been developed by extending, generalizing, and abstracting the mathematical tools originally developed for the use of mathematical modeling. Analysis, topology, and non-Euclidean geometry are examples of rich mathematical theories that have freed themselves from their ties to the physical world to explore abstract worlds beyond our limited perceptions. Thus, mathematics equips us humans to look beyond the visible, while maintaining a mental anchor in the visible world. For example, we use the word *hypersphere* to describe an object that we humans will never be able to behold in this world, but since it has the same mathematical properties of a familiar three-dimensional sphere, we can attempt to accurately imagine a hypersphere in our mind's eye. God calls

us to the same mental exercise every time he uses familiar words and images of our world to describe the yet unperceivable realities of the world to come and in which we are called to live with him. ⌂

Acknowledgments

I would like to thank Robert Bishop, Mary Vanderschoot, and the referees for their valuable suggestions that improved the clarity of this article.

Notes

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How in Hades Do We Teach Genesis 1–3?

Joshua Marshall Strahan

Joshua Marshall Strahan

I thought I was doing such a good job. There I was, teaching a college course on Genesis to a classroom of mostly evangelical students, who were hoping to go into some form of ministry. I was spreading the good news about how science and Christian faith can play friendly. I had, so I thought, been working through Genesis at an appropriately slow and pastorally sensitive pace. We had been learning about the interpretive significance of genre and how we must take seriously the text's socio-cultural location. We had been reading John Walton, and I was supplementing this with the sometimes supportive and sometimes dissenting perspectives of folks such as Tremper Longman III and Iain Provan.

Although we had plenty of class discussion along the way, it was not until I set aside an entire class hour for questions that it came out that several students were unsettled by our study of Genesis. Despite my careful nuancing throughout, two nagging fears lingered in some students' minds: (1) if Genesis 1–3 is not offering a straightforward historical description, then perhaps nothing else in scripture is historical either—including the incarnation and the death and resurrection of Jesus; and (2) if Genesis 1–3 is not teaching scientific truths about the mechanics and timeline of creation, then perhaps we should not take seriously any theological claims of Genesis 1–3, since those theological claims would be interwoven with cosmological material that we find inaccurate.

On the one hand, it is refreshing that some college students still care deeply about the authority of scripture, about learning from and submitting to the truths it proclaims. On the other hand, I was disappointed that these students had not followed my nuanced claims that, I thought, had addressed both these fears. I left the classroom discouraged that day. I deeply love scripture and regard it as authoritative, special revelation. It hurt to think that I was inadvertently undermining that conviction in my students. It also angered me that too many churches are perpetuating flat, unthoughtful approaches to scripture, which set students up for faith crises when they discover that scripture is not like what they were taught.

Fortunately, serendipity was waiting for me in my Advanced Greek course, in which we were reading the account of the Rich Man and Lazarus from Luke 16. Reading that text on that day with three students from my Genesis course led to an insightful conversation, which inspired a lecture I would give my Genesis students at our next meeting. What follows is a sketch of that lecture, which I believe helped my struggling students to fit the pieces together in a way that allowed for (1) a high view of scripture, (2) the lack of scientific claims in Genesis about the precise mechanics and timeline of creation, and (3) historical claims about events such as the death and resurrection of Jesus. The lecture below is by no means intended to replace

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the incredible work of the scholars mentioned above; it is merely a humble supplement that may help to ease the concerns of Christians who are struggling to align their theological convictions with a more nuanced reading of Genesis.[1]

From Creation to Hades and Back Again

I opened the class by reading Luke 16:19–31, instructing the students to pay attention to genre clues in this pericope.[2]

> There was a [certain] rich man who was dressed in purple and fine linen and who feasted sumptuously every day. And at his gate lay a [certain] poor man named Lazarus, covered with sores, who longed to satisfy his hunger with what fell from the rich man's table; even the dogs would come and lick his sores. The poor man died and was carried away by the angels to be with Abraham. The rich man also died and was buried. In Hades, where he was being tormented, he looked up and saw Abraham far away with Lazarus by his side. He called out, "Father Abraham, have mercy on me, and send Lazarus to dip the tip of his finger in water and cool my tongue; for I am in agony in these flames." But Abraham said, "Child, remember that during your lifetime you received your good things, and Lazarus in like manner evil things; but now he is comforted here, and you are in agony. Besides all this, between you and us a great chasm has been fixed, so that those who might want to pass from here to you cannot do so, and no one can cross from there to us." He said, "Then, father, I beg you to send him to my father's house—for I have five brothers—that he may warn them, so that they will not also come into this place of torment." Abraham replied, "They have Moses and the prophets; they should listen to them." He said, "No, father Abraham; but if someone goes to them from the dead, they will repent." He said to him, "If they do not listen to Moses and the prophets, neither will they be convinced even if someone rises from the dead." (NRSV)

The students nearly all agreed that this pericope was a parable. I pointed out, though, that Luke *nowhere* specifies that this is a parable. So, I asked what clued them in to this particular genre. They came up with the following—with a little help from me: the characters ("a certain rich man," "a certain poor man"), the bizarre setting (Hades, beside Abraham), the horrific situation (speaking across a chasm separating Hades and Abraham), instinct (this feels like a parable), and ancient parallels using similar motifs (an afterlife scene, messengers for the dead).[3] However, we also noted the oddness of Jesus providing Lazarus's name, since Jesus nowhere else names characters in parables. This, however, may be explained as foreshadowing, since Lazarus is the Greek name for Eliezer, meaning "my God helps."[4]

I asked next, "What truths are being taught in this parable?" They responded: one's status in this life is not guaranteed in the next; showing mercy now is important; the Law and the Prophets support Jesus's teaching; God cares for those whom others disregard.

Then, I asked, "Is this parable offering us a plain and precise depiction of the afterlife?" They nearly all agreed that this is not likely the case—that such a claim would be pushing the parable too far, a misinterpretation. This presented a nice opportunity for them to consider (and explain to me) *how the Bible can communicate truth by using a medium that borrows common motifs and/or folkloric elements*.

This left us with several important questions. First, if this parable is adapting folkloric depictions of the afterlife, does this mean that the Christian belief in the afterlife—in heaven and hell—is also a folkloric doctrine that we should set aside? Here, the students needed a little extra help. I explained that the church's convictions about the afterlife are not based solely on the Parable of the Rich Man and Lazarus. Rather, they ideally arise from a thoughtful reading of the larger canonical witness on the matter that takes into account the various genres of any relevant texts. Moreover, such doctrinal study should be informed by the church's historic witness, especially as found in the Apostles' and Nicene Creeds. For example, on the afterlife, the Apostles' Creed confesses: "I believe … [Jesus] will come again to judge the living and the dead … [I believe] in the resurrection of the body and the life everlasting."

Second, and related, I asked, "If we read this passage of Luke as having folkloric elements, does this mean that Luke's account of the resurrection is also folkloric?" Once again, the students needed a little help. I explained how a book such as Luke has an overarching genre (ancient historiography) that includes within it certain subgenres (such as genealogies and parables). We must be careful not to interpret the subgenres according to the same exegetical rules as

the overarching genre, or vice versa. When Luke narrates Jesus's resurrection appearances, he is working within the genre of ancient historiography (and not parable), so it would be a misinterpretation to treat the resurrection scenes as folkloric. If any doubt remains, we also look to the larger canonical witness and church tradition, both of which have made it abundantly clear that the resurrection is a historical event.

I then summarized the following main ideas from this exercise:

1. Not all genres come with labels, so we have to be attentive to genre clues.
2. A genre that contains folkloric elements can nonetheless communicate authoritative truths.
3. It is unwise to treat the Bible's folkloric elements as straightforward, precise descriptions of reality.
4. A single biblical book can contain subgenres that are to be treated differently than the overarching genre.
5. Christian doctrines should arise from listening to the canonical witness while keeping an ear open to the church's historical witness, particularly the church's great creeds.

Having taken the students through this exercise in Luke, we turned to Genesis and went through the same steps. Ideally, this would help them see how the nonthreatening conclusions we drew about Luke 16 might also apply to Genesis 1–3. Once again, I began by asking what genre clues we might notice. Here are some of what we came up with: the artistic structure and style of Genesis 1 (the repeating pattern: God said … God called … evening and morning, the parallel of days 1–3 with days 4–6); the folkloric elements (a talking snake, God walking and breathing, the names of the main characters are Human and Life); the Ancient Near East (ANE) parallels (humans made from clay and the blood of a god, a snake that steals life-prolonging fruit, creation as temple construction); and the geographical and historical markers (Tigris and Euphrates Rivers, genealogies in Genesis 4–5). Along the way, I drew their attention to parallel genre clues from our Lukan parable (Table 1).

These parallels—though not exact—illustrate how such genre clues had earlier signaled us to treat Luke 16 as more figurative than literal; hence, it seemed wise to take a similar approach with Genesis 1–3.[5] In light of these parallels and the aforementioned genre clues, I suggested that Genesis 1–3 is something like an ancient, folkloric account of origins, which uses motifs and cosmology from the ancient world to teach theological truths.[6] Genesis 1–3 may indeed have some historical referents (for example, Adam, Eden, the Fall), though the precise nature of such referents cannot be determined with any certainty due to the nature of the genre.

Next, I asked what truths are being taught in Genesis 1–3. Their response: God is the sole creator (monotheism and transcendence; not polytheism or pantheism); humans have a special status and role (image bearers who are to care for creation; not the gods' slaves, who are formed in violence and tasked with menial labor); creation has an intrinsic goodness (declared "good" seven times; neither a primordial accident nor a result of violence among the gods); males and females are meant for healthy relationships (partners and image-bearers, a reality which becomes only adversarial because of sin); sin distorts the goodness and harmony that God intends (as opposed to evil and brokenness being intrinsic to the created order).

Then, reminding them of what we had learned from our exercise in Luke, and what we had learned about genre clues in Genesis 1–3, I asked, "Should we treat Genesis 1–3 as offering a straightforward, scientific, literal description of the timeline and mechanics of creation?" I think that, for the most part, they could grasp how treating Genesis 1–3 like a literal, scientific description could be a mishandling of the genre,

Table 1. Comparison of Luke 16:19–31 and Genesis 1–3

	Luke 16:19–31	Genesis 1–3
Characters That Seem Archetypal	a certain rich man, a certain poor man	Human (Adam), Life (Eve)
Extraordinary Setting	Hades, Abraham's side (likely referencing the Great Banquet)	Heavenly council, cosmic viewpoint, Paradise
Extraordinary Situation	an afterlife dialogue across an unpassable chasm	God forming the world; God forming humans; sin's entrance
Ancient Parallels	an afterlife scene, messengers to the dead	humans made from clay and the blood of a god, a snake that steals life-prolonging fruit, etc.

much like using Luke 16 to create a diagram of the afterlife. Here, I reiterated what we learned earlier: *a genre that contains folkloric elements can nonetheless communicate authoritative truth.* Just as Luke 16 communicated authoritative truths while using folkloric motifs about the afterlife, so also does Genesis 1–3 communicate authoritative truths while using folkloric motifs about ancient origins.

This led to an important clarification question. If Genesis 1–3 uses folkloric elements, does this mean that major Christian doctrines on creation, such as God is the creator and humans are made in his image, are also folkloric doctrines that we should set aside? Once again, I pointed them to the larger canonical witness as well as to the Apostles' and Nicene Creeds. The canon and Creeds bear witness to a transcendent God creating *ex nihilo* and to humans being endowed with special dignity and responsibilities. Folkloric elements in Genesis 1–3 do not threaten such doctrines. However, the diversity of canonical descriptions of God's creative act along with the Creeds' silence on the mechanics and timeline of creation all suggest that Christians are not required to hold specific views on the chronology, timeline, or technique of God's creative act.[7]

Lastly, I asked, "If we read this section of Genesis as having folkloric elements, does this mean that the Genesis narration of the patriarchs is also folkloric?" Here we returned to the distinction between a book's overarching genres and its subgenres, and how we must be careful not to interpret the subgenres according to the same exegetical rules as the overarching genre, and vice versa. When we turn to the patriarchal narratives beginning around Genesis 12, we must once again be mindful of genre clues. As I understand it, the patriarchal narratives are much less folkloric and much more historiographical (although we must be careful not to treat ancient-near-eastern historiography the same as modern historiography).

As the lecture hour came to a close, I anticipated one nagging issue that my students might have—namely, "Why didn't God just describe creation more like it actually happened instead of using folklore?" After raising this issue, I read an extended excerpt on the Big Bang from Stephen Hawking's *A Brief History of Time*.[8] After their eyes were sufficiently glazed over from mental exhaustion and bewilderment, I suggested that perhaps God thought it better to communicate truths in ways that met people where they were, rather than communicating truths in ways that were incomprehensible to the ancient audience—and to most of us, too. I think, upon realizing that they also are incapable of handling a technical, scientific description, my students saw why Genesis narrated the creation account as it did.

I then opened the floor to questions and was pleased to see that some of my more distressed students were now less bothered. At this point, our fifty minutes of class were up; if I had had time, though, I would have restated my five main points from earlier.

It is my sincere belief that it is life giving and liberating and convicting and inspiring to read Genesis in such a way that takes seriously both its authoritative status and its socio-cultural location. ⌂

Notes

[1]I am particularly grateful to my student, Elly Jack, both for her willingness to discuss her concerns with Genesis, and for the many insights she provided from her prior research on The Rich Man and Lazarus.

[2]I am borrowing the notion of "genre clues" (as well as insights about genre clues in Genesis) from Tremper Longman III, *Genesis: The Story of God Bible Commentary* (Grand Rapids, MI: Zondervan, 2016).

[3]On genre clues, ancient parallels, and further speculation about the precise genre of Luke 16:19–31, see Richard Bauckham, "The Rich Man and Lazarus: The Parable and the Parallels," *New Testament Studies* 37, no. 2 (1991): 225–46; Darrell L. Bock, *Luke 9:51–24:53,* Baker Exegetical Commentary on the New Testament 2 (Grand Rapids, MI: Baker Academic, 1996).

[4]Luke Timothy Johnson, *The Gospel of Luke,* Sacra Pagina 3 (Collegeville, MN: Liturgical, 1991), 252.

[5]This is not to ignore the aforementioned historical markers such as genealogies and geographical referents; it is, however, to suggest that geographical and genealogical references are not the sole determinative factors in discerning the genre in question. To make them the sole determinative factors might be equivalent to claiming that Luke 16:19–31 cannot be a parable because Lazarus is given a name. In fact, just as there is a plausible explanation for Lazarus being named, so there might be plausible reasons for including geographical and genealogical references in a genre that is more folkloric. This becomes even more plausible when one takes into account both the artistic shaping of the genealogies and the mysterious geographical references to the Pishon and Gihon Rivers, which have no clear corresponding locations.

[6]I tend to avoid the term "myth," given its obvious baggage; in my opinion, "folklore" seems less alarming to students.

[7]Mark Harris, *The Nature of Creation: Examining the Bible and Science* (Bristol, CT: Acumen, 2013), 79.

[8]Stephen Hawking, *The Illustrated A Brief History of Time* (1988; updated and expanded edition, New York: Bantam, 1996), 145–49.

CALL FOR PAPERS

God's Wisdom and the Wonder of Creation

Exploring the Intersection of Scripture, Theology, and the Sciences

October 25–26, 2019

Co-sponsored by:
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Location:
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The faculty and administration of Northeastern Seminary (in conjunction with the Canadian-American Theological Association, the Canadian Scientific and Christian Affiliation, the American Scientific Affiliation, and BioLogos) welcome proposals for papers to be presented at an interdisciplinary conference at Northeastern Seminary in Rochester, NY. This *Call for Papers* goes out to established scholars or practitioners in the theological and scientific disciplines, as well as to graduate students, post-docs, and pre-tenured faculty.

Our keynote speaker is **Dr. William P. Brown,** William Marcellus McPheeters Professor of Old Testament at Columbia Theological Seminary. Dr. Brown is the author of numerous books, including *The Ethos of the Cosmos: The Genesis of Moral Imagination in the Bible* (Eerdmans, 1999); *The Seven Pillars of Creation: The Bible, Science, and the Ecology of Wonder* (Oxford University Press, 2010); and *Wisdom's Wonder: Character, Creation, and Crisis in the Bible's Wisdom Literature* (Eerdmans, 2014).

In line with the topic of Dr. Brown's lectures, we invite submission of high quality papers on any topic related to the broad theme of **"God's Wisdom and the Wonder of Creation: Exploring the Intersection of Scripture, Theology, and the Sciences."** We welcome papers from the theological or the scientific side, especially those that explore intersections of a biblical vision with issues in science. Papers should be scholarly but not highly specialized presentations of about 25 minutes, aimed at an audience of students, pastors, and faculty from across the spectrum of theological and scientific disciplines.

Proposals should be approximately 250 words in length. Please prepare them for blind review and submit as an email attachment, accompanied by a short curriculum vitae or resume in a separate file. To facilitate anonymous review of proposals, please include your name, institutional affiliation, contact information, *and the title of your proposal* in the body of your email. All proposals should be submitted electronically as file attachments in *DOC, *ODT, or *RTF format to the address below. Please title your email "God's Wisdom and the Wonder of Creation."

Please email conference paper proposals to J. Richard Middleton at Middleton_Richard@roberts.edu **by June 15, 2019**. Papers chosen for participation will be notified by mid July 2019. Graduate students, post-docs, and pre-tenured faculty are invited to submit finished papers that address biblical interpretation by September 15 for the *Jack and Phyllis Middleton Award for Excellence in Bible and Theology* (further information about the Award will be sent upon request).

Biology

THE WONDER OF BIRDS: What They Tell Us about Ourselves, the World, and a Better Future by Jim Robbins. New York: Spiegel & Grau, 2018. 352 pages. Paperback; $13.62. ISBN: 9780812983760.

The photo of an Anna's hummingbird in flight is what first caught my attention. As I further inspected the cover of Jim Robbins's book *The Wonder of Birds: What They Tell Us about Ourselves, the World, and a Better Future*, I have to admit that I expected the book to be a secular version of John Stott's classic *The Birds Our Teachers*. I anticipated that each chapter would be a vignette about a wondrous feat accomplished by some far-flung species of fine-feathered friend, with each feat being a metaphor for our lives, or the human condition, or our relationships with each other. Instead, Robbins's book takes the reader on a four-part journey that reveals his insights regarding what birds tell us about the natural world, ourselves, and our future (as promised in the title of the book), along with a discussion of the "gifts of birds" (what ecologists might call "avian ecosystem services").

The book certainly includes the obligatory wondrous feats of birds that can be handy knowledge during a trivia contest (e.g., a calliope hummingbird can hover nonstop for 90 minutes, and bar-headed geese can migrate over the Himalayas at 30,000+ feet). However, the focus of his eighteen chapters is not really to wow us with impressive statistics, but to draw us to a deeper appreciation for our avian neighbors, which are often ignored and/or taken for granted. Each chapter of Robbins's book is prefaced with a handsome illustration of one of the chapter's focal species. But the book is not really about how pretty birds are (in fact, one chapter focuses on the unseemly practices of vultures and another chapter discussed slaughtering practices in the chicken industry), and appropriately, the illustrator, D.D. Dowden, does not embellish the drawings with mountains, ponds, prairies, or fields of wildflowers.

Robbins begins Part I (What Birds Tell Us about the Natural World) by bringing the reader up to speed on the origin of birds (as a surviving lineage of dinosaurs) and the evolution of bird flight. Upon reading the first chapter, I was starting to wonder whether the author had pulled a bait-and-switch, but my puzzlement was short-lived, as the next three chapters examine avian versus human (mechanical) flight, what canaries, black-backed woodpeckers, and other birds tell us about their/our environment, and flock dynamics (information used in the battle scenes in the *The Lord of the Rings* and *The Hobbit* film trilogies).

In Part II (The Gifts of Birds), Robbins presents us with other origin stories, those of industrial chicken production ("Big Chicken") and of the $5 Costco fully-cooked rotisserie chicken. Robbins then discusses the myriad of ways that birds serve humankind just by doing what they do, and how the loss of birds can be catastrophic for human societies. For example, Robbins describes the recent loss of vultures in India due to poisoning by a livestock drug and the ripple-effects of this loss, including the loss of an estimated 48,000 human lives.

As a graduate student studying birdsongs of black-capped chickadees and house finches in the 1990s, I was often asked at social gatherings why anyone would care about birdsongs and whether there was something more important that I could be studying. I quickly learned that most people do not find birds to be particularly interesting, cool, or worthy of investigation. I soon began weaving what in my mind were embarrassingly simplistic fabrications to appease the masses—explanations about how studying birdsong development and song learning can help us understand more about human vocal development and perhaps provide us with treatments for speech pathologies such as delayed speech acquisition. Twenty years later, Robbins presents his readers, in Part III (Discovering Ourselves through Birds), with a similar but much less "fabricated" story about how spatial memory develops similarly in bird and human brains and how, if scientists can unlock the secrets of neurogenesis in the vocal centers and other areas of bird brains, we may be able to "usher in a new era of therapy for stroke, trauma, Alzheimer's, Parkinson's, and other brain ailments." Other topics in Part III include the soap-opera-like family dynamics of bee-eaters, the language of birdsongs in chickadees (ever wonder why there are sometimes so many "dees" in the "chick-a-dee-dee-dee" call?), the intellect of ravens and crows, and the athletic prowess of birds such as bar-headed geese.

In Part IV (Birds and the Hope for a Better Future), Robbins begins with a discussion of how we have put bluebirds and falcons to work controlling pests. Next time you are at a party and someone drinking a Spring Mountain (Napa Valley) chardonnay asks you why birds matter, you can tell them that they can thank western bluebirds for helping make their beverage pesticide-free. Robbins's next chapter focuses on the beloved yet maligned domestic pigeon, with the harrowing story of Cher Ami, the pigeon that saved a battalion of 194 US soldiers during World War I. While these stories seemed somewhat out of place as I read them (they seem like fodder for Part II), Robbins then shifts the focus toward the emotional connection some urban dwellers have with pigeons,

as the pigeons are the only nature some of them ever experience. Interestingly, Robbins posits that the love for pigeons may be vital to protecting the rest of the world's biodiversity. Robbins continues Part IV with chapters about the transformational power of owls and other raptors, including how at-risk inner-city youth were able to return the bald eagle to its historic nesting areas along the Anacostia River in Washington, DC. Robbins concludes with a discussion of ethno-ornithology, a relatively new field of study that looks at the holistic relationship between some tribal societies and their avian companions. As Robbins puts it, "Understanding the relationship between native cultures and birds may lead us back to a sustainable world in which their fate—and ours—is no longer in doubt" (p. 295).

This is a book that would appeal not only to fans of honeyguides, corvids, vultures, eagles, hawks, owls, linnets (house finches), penguins, chickens, hummingbirds, zebra finches, chickadees, egrets, flycatchers, waterfowl, starlings, bluebirds, ratites, pheasants, or any of the other myriad birds described in the book, but also to anyone who wants to learn more about birds and their roles in our lives. Robbins's use of swear words on two occasions might be distracting or offensive to some readers, but all in all, Robbins has produced a thoroughly researched and well-written book on the ecological, economic, and spiritual value of birds to humankind. The book reminds us of the value of biodiversity, and although Robbins is writing for a secular audience, his scientific approach to the subject matter and ability to weave the science into an entertaining narrative can help *PSCF*'s readers and other Christians to understand more fully and to appreciate more deeply the responsibility we bear in having dominion over creation.

Reviewed by T. Todd Tracy, Professor of Biology, Northwestern College, Orange City, IA 51041.

History of Science

DARWIN'S FIRST THEORY: Exploring Darwin's Quest to Find a Theory of Earth by Rob Wesson. New York: Pegasus, 2017. xxi + 383 pages, including endnotes, index, and 62 figures. Hardcover; $29.95. ISBN: 9781681773162.

DARWIN'S FOSSILS: The Collection That Shaped the Theory of Evolution by Adrian Lister. Washington, DC: Smithsonian Books, 2018. 215 pages, including sources, references, index, 16 figures, and 9 maps. Paperback; $19.95. ISBN: 9781588346179.

Charles Darwin, while en route to authoring *On the Origin of Species*, was widely appreciated as an explorer and as an observant field geologist. His geological and paleontological observations and inferences influenced his approach to nature as well as his appreciation for the significance of history for interpreting what we see today. The two volumes reviewed here narrate and interpret the effort, physical and mental, that Charles Darwin exerted as a young and vigorous naturalist while on board *H.M.S. Beagle* (1831–1836). *Darwin's First Theory* also covers Darwin's tutelage in field geology under Adam Sedgwick in the weeks prior to setting sail, and his field excursions in Scotland and Wales following his return. Together, the two books complement one another, revealing Darwin's growing understanding of Earth function, the implicated depth of geologic time, and the relationships of past biotas to those of today. These three subjects arguably provided the young scientist with a foundation for his later work on the mechanisms channeling the history of life.

The young Darwin was a keen geologist. His first book (1839) was his *Journal of Researches into the Geology and Natural History of the Various Countries Visited by H.M.S. Beagle*, only later retitled by a publisher as the *Voyage of the Beagle*. On the title page, the author's name is subtended by his credential as a scientist: "Secretary, Geological Society." This may have been meant in part as a claim to professional status, but it also declared the author's identity as a geologist. Wow! Darwin dedicated the second edition (1845) of the *Journal of Researches* to the geologist Charles Lyell, explicitly referencing Lyell's *Principles of Geology*. Darwin's debt to Lyell while a young scientist has been noted by many historians, but the intellectual link has often been developed merely to underscore Darwin's developing uniformitarian approach to natural history. This thinning of Darwin's early fascination with geology has been remedied by the biographies of Darwin by Desmond and Moore (1991) and by Janet Browne (1995; 2003). Further rehabilitation of Darwin the geologist and paleontologist has been provided by Richard Darwin Keynes, in *Fossils, Finches and Fuegians* (2003), a thorough account of the voyage of the *Beagle*; and by Sandra Herbert, in *Charles Darwin, Geologist* (2005), which examines many facets of Darwin's development as a scientific observer and communicator. The books by Lister and Wesson, here under review, continue this revelation of Charles Darwin, field geologist.

Darwin's Fossils, as the title suggests, is focused on the kinds of fossils that Darwin collected while on the *Beagle* expedition. A preliminary chapter introduces us to Darwin's associates on the *Beagle* and

the paleontologists and zoologists to whom Darwin forwarded his fossils while en route. Following this chapter are three long chapters treating fossil mammals, fossil plants, and fossil marine life. The penultimate chapter takes a look at Darwin's examination of coral reefs while on the return voyage across the Pacific. The last chapter is a brief exposition of Darwin's development as a scientist following his return, and the significant impact of his paleontological collecting on his development as an evolutionary biologist. The numerous illustrations include many photos of the very specimens collected by Darwin. There are also photos of Darwin's South American landscapes and collection sites, as well as modern South American organisms relevant for comparison to the fossils. The illustrations are in color and uniformly well executed, resulting in an attractive volume that grabs and sustains the reader's attention. In addition, the several maps are clear and make the narrative much more understandable.

Darwin's First Theory is a more complicated read. It is actually three interwoven narratives. The fundamental narrative is that of Darwin's field geological researches in South America and in the Pacific. In this respect, there is great overlap between this volume and *Darwin's Fossils*. But the book also looks at the effects of plate tectonics—earthquakes, tsunamis, and volcanism—on contemporary life (and death) along the Pacific margin of South America, a significant chunk of what is often termed the "Ring of Fire." The third interwoven component is that of author Rob Wesson's geophysical researches into tectonism in southern South America, plus his personal retracing of Darwin's inland excursions. The common theme to these three narratives is that of motions in Earth's crust, and the decipherment of the cause(s) of said motions. Wesson explicates the gamut of geologic and paleontologic phenomena (including the great Conceptión earthquake of February 1835) that Darwin encountered, which convinced him that Earth's crust had experienced a long but punctuated history of localized vertical motions. Darwin pondered over what he was seeing and continued to ponder after his return to England, where he wrote up his geological discoveries. Among his realizations was the necessary role of protracted crustal subsidence in the evolution of coral atolls.

Wesson demonstrates how Darwin grappled with geologic data. The eastern and western South American coastlines as well as the Argentinian coastal plain bore features indicating that in some places, land surfaces had bobbed down while in other places, they had been elevated. Confusingly, some localities provided evidence of complex motions in both directions. Lacking an understanding of plate tectonics and of underlying mantle dynamics, Darwin and his contemporaries attempted to resolve the whys of vertical crustal translations. In the process, Darwin developed a preliminary sketch of the geologic history of the Andes. Darwin also was drawn into the debates surrounding massive glacial advances and retreats in the past. In these efforts, Darwin relied on Lyell's work as a compendium of background information and as a foil.

The new volumes by Lister and by Wesson underscore Darwin's strenuous and sometimes risky journeys along shorelines or cross-country and often at high altitude, driven by his realization of the opportunity with which he had been presented. Darwin collected all manner of marine invertebrates, terrestrial plants, mammals, fishes, reptiles, birds, and fossils, which were periodically sent back to England to be referred to specialists. The fossil mammals went to Richard Owen. One of the helpful aspects of both of these books is to highlight the respectful friendship between Darwin and Owen during Darwin's early career, countering the common perception of Darwin and Owen as perennial intellectual adversaries. Darwin learned much from Owen's store of anatomical knowledge. Lister's book makes clear the personal impact upon Darwin that his up-close encounter with fossils provided: it was apparent that the fossils in more recent sedimentary layers resembled their modern counterparts more than the fossils in earlier strata. And the recent fossils of South America, including monster ground sloths and giant armadillo-like glyptodonts, were obviously more closely related to the modern biota of South America than to those of other continents. There were biogeographic patterns as well as historic patterns to be found, hidden in the rocks.

Darwin was poised at an interesting point in history. The preceding generation had elucidated the fact that fossils occurred in an order within the strata; Darwin's contemporaries were deploying that discovery to chronicle the major contours of the history of life. Meanwhile, the origins of major Earth features such as continents, ocean basins, and mountain chains remained highly problematic. Darwin was propelled into the study of natural history during this exciting period. His growth as a natural scientist while on the *Beagle* expedition has often been flattened to a two-dimensional perspective, focused on the revelatory power of biogeography linked to his evolutionary tool-kit. The volumes at hand help restore the third dimension and illuminate Darwin the historical scientist, pondering processes and time.

Readers of *PSCF* who wish to better understand the logical train of reasoning that led to the *On the Origin*

of Species, and to remediate the distortions of the history and role of biostratigraphy that have been and continue to be put forth by the proponents of flood geology, will profit from these volumes.

Reviewed by Ralph Stearley, Professor of Geology, Calvin College, Grand Rapids, MI 49546.

THE GREAT RIFT: Literacy, Numeracy, and the Religion-Science Divide by Michael E. Hobart. Cambridge, MA: Harvard University Press, 2018. xiv + 506 pages, with appendices, endnotes, and index. Hardcover; $39.95. ISBN: 9780674983632.

Michael Hobart's book *The Great Rift* presents a novel and provocative perspective on the age-old conflict between religion and science. In his words:

> My central thesis may be baldly and succinctly stated: the shift between two distinct information technologies—literacy and numeracy—resides at the source of how science and religion went their separate ways, producing the Great Rift between them. (p. 4)

To be clear, Hobart does not specifically address the alleged discord between science and religion but delineates how a chasm (his word) opened up to drive them apart. Nevertheless, Hobart holds that as life became ever more secularized, religion became less relevant to science and was "not so much conquered as ignored" (p. 10), so that "from the late nineteenth century to our own times we have reached the point where observers and participants alike … have come to view the widening separation between science and religion as an impasse, or even a war zone" (p. 323).

To support his thesis, Hobart fleshes out and refines some research begun two decades earlier with a colleague on transitions between the three stages in the history of information technology: literacy, numeracy, and computerized information processing. The result here is a well-researched book, based on a lifetime of work, that extensively examines medieval and Renaissance developments in mathematics as well as Galileo's seminal role in the rise of modern science. The detailed scholarly treatment given these topics, which we cannot adequately recapitulate here, makes the book well worth its modest price, completely aside from its take on the science-religion divide.

Hobart begins his narrative with a brief look at the ancient world, which introduced and developed the information technology of recorded language. Greek writing is epitomized by its literature and philosophy, which make extensive use of definition and classification to capture the essence of things. Aristotle systematically codified forms of deductive reasoning based on this type of thinking in his logic. Medieval schoolmen later adopted this mode of knowledge acquisition in their educational practices and intellectual debates. Classification and fine distinctions permeated the writings of those who studied the quadrivium (arithmetic, music, geometry, and astronomy) as well as the writings of those dedicated to more advanced topics in theology and philosophy.

During this time period, there was a methodological unity overall to science and religion. Thinkers described the observed behavior of natural phenomena in terms of causes related to their essential natures, leaving room for divine purposes at the head of it all. They employed the same sort of reasoning that explained the structure of the natural world to incorporate religious ends and means. Science and religion in medieval Europe formed a fairly harmonious whole.

As people began to use mathematics more consistently in the late Middle Ages and Renaissance in order to relate things in everyday arenas such as commercial transactions, music, perspective painting, and astronomy, the explanatory focus for natural phenomena moved away from appealing to the intrinsic nature of things to demonstrating how they functioned quantitatively. Mathematically relating numerical features of events or activities via ratio and proportion (the rule of three was an omnipresent mainstay) became the new mode of accounting for natural phenomena. This approach was fruitfully employed by Galileo in his scientific analysis of terrestrial motion, yielding his times-squared law for falling bodies and parabolic paths for projectiles. Such an approach left both traditional philosophy and theology on the outside, creating a fault line between science and religion. Galileo's clash with the Roman Catholic Church over the factual status of Copernican astronomy, the nature of scientific demonstration, and the legitimacy of theological incursions into science only exacerbated this rift.

Hobart attributes the new analytic approach in natural philosophy to changes in information technology, indeed, to the rise of numeracy. He sees developments within mixed/applied mathematics during the Renaissance and early modern period as embodying a new understanding of the nature of mathematics and the role of symbols. Using terms proposed in 1959 by Jagjit Singh (but for distinguishing formalistic late nineteenth- and twentieth-century mathematics from its more concrete antecedents), Hobart brands classical and medieval mathematics as "thing mathematics" and Renaissance and early

modern mathematics as "relation mathematics." This characterization works to some extent, but it has shortcomings.

Classical mathematics was certainly about mathematical entities encountered in everyday life (numbers, spatial figures), but it also treated their basic properties (being prime, being isosceles) and relations (being divisible by, being congruent to). Hobart correctly notes that late medieval, Renaissance, and early modern mathematics made extensive and productive use of relations such as ratio and proportion (a significant part of what qualifies them as being relation mathematics) to formulate functional dependencies, but these relations were also prominent in earlier mathematics—in the works of Euclid, Archimedes, Apollonius, Heron, and Ptolemy, and even in the mathematical practice of earlier cultures.

Another aspect of the new relation mathematics, as Hobart conceptualizes it, is an emphasis on the use of abstract or empty symbols. In one sense, this was not new. As far back as the end of the third millennium BC, for instance, the Mesopotamian sexagesimal place-value system made abstract computations possible, so that the differing concrete metrological systems still in use could be bypassed. But, in another sense, applying this characterization to late medieval, Renaissance, and early modern mathematics is anachronistic. Hindu-Arabic numerals referred to quantities such as goods, weights, and monetary value in commercial arithmetics; musical notation denoted temporal duration, pitch relations, harmonies, and time signatures; and letters used in the analysis of motion stood for speeds, times, and distances. More-abstract symbols were introduced in algebra by Viète and others to stand for numerical operations as well as unknown and known quantities, and these were used to formulate and solve equations, but they were not vacuous—they had numerical meaning in some assumed domain of quantities. Furthermore, while Viète made some major notational advances in algebra for solving equations prior to 1600, Galileo remained rooted in an older geometric form of ratio arithmetic that he learned from the recently recovered Book V of *Euclid's Elements*. In his earlier work, Hobart highlighted Viète's role in the new numeracy, but here Galileo is his protagonist. Galileo does use mathematical symbolism to analyze relations among physical quantities, but these are neither empty of meaning nor related by equations.

However, there is some validity to Hobart's assertion that the symbols of modern relation mathematics were becoming empty. As mathematics was increasingly being used to quantify empirical realities such as cost, distance, harmony, time, speed, and so on, time-worn metaphysical and occult connotations of numbers and spatial configurations became superfluous, and, as a result, symbolic representations were emptied of enchanted meaning. This practice became more widespread as time went on, though as Hobart acknowledges, it was not uniformly followed even by the start of the 1600s. Mystical associations of mathematics were often deemed as important as practical applications; in fact, this development encouraged some to believe that mathematics would unravel the secrets of nature. Kepler's astronomical writing, for example, contains hard-nosed calculations about elliptic planetary orbits and also religious and mystical ruminations about Platonic solids and the ability to think God's thoughts after him.

More could be said about Hobart's defense of his thesis—particularly his idiosyncratic use of the notions of cardinality and ordinality in connection with mathematicians beginning to join the fields of number and space in their practice of mixed mathematics—but I will end with a question and follow that with a few concluding remarks.

What is gained, I wonder, by conceptualizing the transformation of natural philosophy (from using Aristotelian teleological argumentation to employing mathematical analyses of functional dependencies) as a sweeping shift in information technology, exchanging words for empty quantitative symbolism? Why is this not seen instead, for instance, as a renewed neo-Pythagorean/Archimedean emphasis on the primacy of quantifying (mathematization) combined with a more experimental and mechanistic bent in physical investigations? That is, why concentrate so exclusively on the how of information technology—"the humanly constructed screen between the knowing mind and the world outside" (p. x)—rather than on the what of the discovered numerical connections between meaningful content? Hobart would no doubt respond that the latter does not occur without the former and that his stated aim is to determine the extent to which a change in information technology is implicated in the new mode of doing science, but I think more could have been done with developments on the religion and philosophy side of the divide to contextualize the shift.

Hobart successfully documents the changing methodology of science in the early modern period, especially in his expert examination of Galileo's work, but his thesis does not account for other important issues concerning the relationship of science and religion, even in this time period. I remain convinced that much more than information technologies are involved in the rise of modern science and its con-

nection to religion. To be fair, some of these factors are acknowledged in passing by Hobart. He admits that changing attitudes toward the roles of religion and philosophy in the pursuit of natural knowledge were influenced by historical developments such as the rise of nominalism, the Reformation, Renaissance humanism, the revival of Platonism, gradual secularization, and so on, but these lie mostly outside the scope of his thesis. More importantly, Hobart does not probe the significant ways that Christian religion—in both its medieval and early modern versions—provided a hospitable intellectual environment in which modern science could develop and thrive, Galileo's conflict with the church notwithstanding. Readers who recognize God as the author of nature (and of creation more broadly) will not be persuaded by Hobart's allegation that "the deep incompatibility of religion and science" is now "simply too great to overcome" (p. 323). Distinct epistemic methodologies or information technologies do not automatically create territorial conflicts, and what discord there is, can often be attributed to other factors, such as the opposition between Christian faith and a strong commitment to naturalism.

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ORIGINS

KNOWING CREATION: Perspectives from Theology, Philosophy, and Science by Andrew B. Torrance and Thomas H. McCall, eds. Grand Rapids, MI: Zondervan, 2018. 341 pages. Paperback; $39.99. ISBN: 9780310536130.

The late modern unfurling of interdisciplinary studies continues to produce innumerable volumes. The relationship between theology and science is no exception. Zondervan recently released two volumes exploring "perspectives from theology, philosophy, and science," edited by Andrew Torrance and Thomas McCall, each with over a dozen qualified contributors. The first is *Knowing Creation* and the second *Christ and the Created Order*. This review looks at the first.

As one skims the introduction, it seems the volume might be just another opinionated survey of the stale debates over "creation, science, and intelligent design." But in reading through each chapter, it quickly becomes apparent that the book is far broader. In fact, readers generally interested in and familiar with this intersection of disciplines might find it a simple pleasure to read (as I did), without worrying about locating arguments within a contemporary context and making judgments. At any rate, the book fulfills its purpose: to give a microphone to the multiplicity of dimensions in this arena, all without reducing or overemphasizing one aspect over another.

It is not possible to review each contribution, but I do want to highlight points from some of them to give readers a sample of the contents.

Christoph Schwoebel, in "We Are All God's Vocabulary," focuses on a topic vital for any discussion about interacting disciplines: language. Although many of us tend to think we understand basic concepts such as "metaphor" and "analogy," we often don't. "Metaphors do not simply add a coat of meaning to things which underneath remain what they are," he writes. "They change the way things are for us and how we are to relate to them" (p. 49). In a modern age that privileges the literal, propositional, and measurable/quantifiable and downplays the symbolic, metaphorical, and qualitative (that is, "it's *just* a metaphor"), getting a handle on the linguistic dimensions of the science-theology enterprise cannot be overstated.[1]

Andrew Torrance, in "Not Knowing Creation," attempts to clarify methodological naturalism. There's much to comment on here, but the essay is more thoughtful and persuasive than those in *Theistic Evolution* (2017) edited by J. P. Moreland et al. on the same topic. Inevitably, there remain loose ends—especially with regard to the main assumptions of this discussion, such as models of God and creation, "special divine action," and how science done by Christians is substantially different than that done by non-Christians. Torrance writes, for example, that "there should be a difference between the way in which the Christian scientist and the naturalistic scientist approach and interpret the structure, behavior, and history of the natural world" (p. 101); this view gets the ball rolling but does not take us too far.

John Walton, in "Origins in Genesis," condenses some of his published research. In contrast to modern thought, he presses the superficiality of the natural/supernatural distinction. This default way of thinking simply is not part of biblical consciousness. "We cannot claim the Bible says something that makes no sense in the original context; it cannot make a categorical distinction if it does not have the categories" (p. 109). Walton is by no means the first to make this observation, but his repeated focus is justified given that many of those speaking and publishing on this topic still talk in ignorance; for instance, "miracles" are said to be part of the "supernatural" realm (that is, where God does stuff) in the Bible whereas "natural events" are said to be distinct and in the "nature

world" (that is, where the "real world" happens). "Scientific claims, then, are typically premised on this metaphysical divide, with the idea that if a natural explanation can be offered, then any biblical claims about God's involvement can be disregarded" (p. 108). In contrast, "When the Old Testament describes God's extraordinary involvement in the world, it is not to specify a supernatural event that is in defiance of natural, scientifically describable cause and effect" (p. 110).

Francis Watson then answers the question, "How Did Genesis Become a Problem?" He challenges the stereotypes about "truth" types, as well as the false equivocation "literal = reality."

> It is true that Earth revolves on its own axis and around the sun, but it is also true that the sun rises and sets. To ascribe motion exclusively to Earth in one context does not make it false to ascribe motion exclusively to the sun in another. These are two distinct truths, not a single truth accompanied by a necessary fiction or a higher truth accompanied by a lower one … In no circumstances … is a literal interpretation obliged to demonstrate a direct and exclusive relationship between the text and the reality to which it refers. One can interpret the text literally without having to claim that, according to the Bible, the sun revolves around the earth. (pp. 129–30)

William Brown switches gears to a fascinating look at "Job and Astrobiology," and Susan Eastman to an interesting discussion of "neurological mirroring" and the formation of identity as witnessed in Paul's letters and ministry.

Marilyn Adams (who sadly passed away after submitting her contribution) writes on "Sanctifying Matter," addressing the bigger philosophical contexts of God, creation, and meaning. This contribution alone made the book worth buying. I have never seen anyone so eloquently and concisely address the purpose of creation, meaning of life, problem of evil, death and hope, scientific reductionism, divine action and presence, God's love, and wise living all within such a short space. But she pulls it off in beautiful prose and precision that will probably remain one of my all-time favorite essays in Christian theology.

Getting more technical, C. Stephen Evans answers the question "Are We Hardwired to Believe in God?" He challenges the late-modern/post-modern emphasis on epistemological construction and the arbitrariness of cognitive categories, asserting instead that "evolution actually shows that the order we experience on the surface of things, so to speak, depends on a still deeper, hidden order" (p. 207). Along the way, he tips over some common misunderstandings about evolution and Christianity. "Atheists often seem to think that evolution and God are rival, mutually exclusive hypotheses about the origins of the natural world," but this "fails to grasp the relationship between God and the natural world by conceiving of God as one additional cause within that natural world" (p. 208). Likewise, biological explanations for one human feature or another are not automatically reductionistic, hegemonic, or totalizing. "From an evolutionary perspective, all our cognitive faculties must have a biological explanation," he argues. "The mere fact that a cognitive mechanism has an evolutionary explanation gives no reason to doubt that this mechanism is conducive to truth" (p. 211).

Robert Koons and William Simpson survey pertinent issues in ontology and metaphysics (for example, categories, reductionism, quantum theory, and materialism), with the latter making a philosophical case for transformative hylomorphism in contrast to emergentism and physicalist reductionism. Simpson concludes,

> The transformative hylomorphists can agree with structured emergentists concerning the vanity of trying to reduce everything in biology, neuroscience, and psychology to fundamental physics but should reject both the reification of matter in terms of physical constituents and the identification of forms as structures with physical parts. (p. 258)

The variants of emergentism probably should have been given more attention.[2]

After two other excellent essays, Tom McLeish attempts to craft a summary of a theology of science: "Science is the participative, relational, cocreative work within the kingdom of God of healing the fallen relationship of humans with nature" (p. 320). Behind this is the assertion that "Science and theology are not complementary; they are not in combat, they are not just consistent—they are 'of each other'" (p. 320).

Given the wide range and quality of writing in these contributions, one looks forward to the second volume with much anticipation. *Knowing Creation* is an excellent book for anyone interested in getting their feet wet with this complex subject.

Notes

[1]Compare the recent publication, Paul Chilton and Monika Kopytowska, eds., *Religion, Language, and the Human Mind* (New York: Oxford University Press, 2018), with my review in *Reading Religion,* Nov. 12, 2018, http://readingreligion.org/books/religion-language-and-human-mind.

[2]Note, for example, the qualifications offered in Jamin Hübner, "A Concise Theory of Emergence," *Faith and Thought* 59 (October 2015): 2–17.

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Science and Religion

MERE SCIENCE AND CHRISTIAN FAITH: Bridging the Divide with Emerging Adults by Greg Cootsona. Downers Grove, IL: InterVarsity Press, 2018. 184 pages. Paperback; $17.00. ISBN: 9780830838141.

Mere Science and Christian Faith: Bridging the Divide with Emerging Adults is a call by author Greg Cootsona to the importance of basic science literacy if one hopes to do ministry with young adults (aged 18–30). Cootsona is Lecturer in Religious Studies and Humanities at California State University at Chico and directs Science and Theology for Emerging Adult Ministries, a three-year, $2 million grant project, funded by the John Templeton Foundation and housed at Fuller Theological Seminary. From 2002–2016, he served as associate pastor for adult discipleship at Bidwell Presbyterian Church in Chico, and from 1996–2002 at Fifth Avenue Presbyterian Church in New York City. His experience makes him highly qualified to speak to the issues addressed in this book. Cootsona's popular appeal is evidenced by his writings in major newspapers, as well as by his interviews by national television networks. He is also a member of the American Scientific Affiliation.

Mere Science and Christian Faith has eight chapters, as well as a list of books for further reading. The chapters are short, pithy, provocative, and sprinkled with a plethora of interesting quotes. The book is well referenced. Cootsona discusses both the positives and negatives of technology, and then considers several topics that seem more like hot topics of interest to young adults than science topics critical to Christian faith. Some of these topics include the New Atheism, cognitive science, cosmic fine tuning, intelligent design, sexuality, and global climate change. This review will begin by highlighting three strengths, and then describe three weaknesses of *Mere Science and Christian Faith*.

First, this book is written for people who are ministering to 18– to 30-year-olds. Cootsona's working hypothesis is spot on. He argues effectively that the younger generation takes science and technology for granted. The impact of technology is an essential element of the world in which they live, as seen in advanced medical care, the internet, space travel, and environmental protection. The church today needs to take science and technology into account in order for its message to gain a hearing. So while the ministry of the gospel need not pander to popular trends, neither can it ignore them.

Second, the author has a good sense of humor, and uses it effectively. However, in some cases his approach is a bit too relaxed and compromises the intellectual tone of the book. For example, "Google, the source of all information," may be humorous to young adults, but considering that Google is the primary source of information for many university students, it may not be a joke at all.

Third, the author has made a start on his stated goal of creating a theology of culture, with science as a key component of that culture. For the Christian message today to have more impact, it must engage science. The author has a good grasp of the problem of science avoidance in church, and effectively alerts the reader to this problem.

Areas where the book could be improved include the following. First, *Mere Science and Christian Faith* popularizes and simplifies science enough to leave practitioners of science wanting more. And while the book's call to incorporate concepts from science and technology in ministry to young adults is well defended, it is not successful at telling the reader how to do so. The author seems to assume that talking about hot topics in science will pique the interest of young people and keep them engaged with the gospel. This leads to a second weakness.

Cootsona argues that science and technology are what young people want to hear and discuss, so that is what they should be given. That this is universally the preferred spiritual appetite for young Christians is debatable. Furthermore, spiritual growth is not always best served by giving people what they perceive themselves to need. According to many young people, what they want is that the church allow people trained in science to have a voice, and neither muzzle the true scientists, nor give the pulpit to people who are not qualified to speak adequately about science. The goal should be to normalize science and technology within the church, so that the topic is discussed responsibly and with faithfulness to scripture. Young people want science that makes a difference. The author acknowledges that young people want to see technology used in service to the poor and underprivileged, but seems to also consider titillating topics such as transhumanism to be important in engaging young people. But while generating fun conversations, such topics are probably less important to young adults than being able to observe spiritually mature, scientifically literate mentors living lives of integrity. These characteristics are probably more important to young people's spiritual formation than whether one is able to discuss the prospect of every human possessing a digital

version of their brain on file in case they develop Alzheimer's disease.

Third, the author plays around with technology like playing around with an apple in one's hands, not sure whether to eat it or not. It would have been helpful if the author had done more to explain the circumstances in which science and technology serve good purposes and those in which they do not. Although Jacques Ellul died in 1994, his *Technological Bluff* remains a prophetic word with implications more profound with every passing year. Interaction with some of the classic works on the ethics of technology would have strengthened the book's argument.

This book is an enjoyable read, and could be used as a springboard for conversations about the ways science and technology interact with Christian faith. People who minister to the age group which is the focus of this book will find it enlightening. However, a classic ASA member might find this book lacking in scientific rigor, and with an inadequate delineation of science and technology. But, to find out, buy the book, share it with your young adult friends, and have a conversation about it. Cootsona's experience in increasing the confidence of young people, by showing that the gospel is not made irrelevant by science, is impressive. This book is another contribution to that end.

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CITIZEN SCIENTIST: Searching for Heroes and Hope in an Age of Extinction by Mary Ellen Hannibal. New York: The Experiment, 2016. 423 pages including notes, references and index. Hardcover; $25.95. ISBN: 9781615192434.

> [G]eology, biology, and human history may be investigated by us as separate chapters but, in fact, they make up one book. And the time has come for us to learn to "read" that book. (p. 6)

Mary Ellen Hannibal is a prolific environmental journalist. Her previous works include *Evidence of Evolution*, commemorating the 150th anniversary of *On The Origin of Species*; and *The Spine of the Continent*, describing the most ambitious conservation effort yet attempted. She is an appropriate author for this rich and lengthy volume about the legitimacy of citizen science research. She takes it much further than mere legitimacy, however. This book amplifies her claim that data produced and reported on a variety of subjects (migratory birds, bees, redwoods, and tide pool creatures are a few specifically described) by interested members of the general public is crucial for the preservation of endangered species and ecosystems. Essentially, scientists simply cannot do it all. They need to enlist all the help they can get, and passionate volunteers make worthy contributors.

Hannibal has a particular gift for connecting the scientific community to the public. This is evident in this book, and indeed, it could almost be considered the theme of it, because this connection is the core of citizen science. Perhaps a clarification of the term "citizen science" is needed here. Citizen science is simply scientific work that is done by interested citizens rather than by professional scientists. *Citizen Science* describes a number of projects that are underway and functioning because of the efforts of countless nonscientists who document the honey bees they observe, or count the migrating hawks that pass over a particular point each fall, or note the dates that local plants first bloom in the spring. They typically record their data electronically and submit it to scientists who use it in various ways, such as establishing population baselines so that changes can be documented, or the reverse—comparing reported numbers with baselines established in past decades.

The book includes several citizen-science-related scenarios in eleven, sometimes lengthy, chapters. The author lives in Northern California, and many of the ecosystems and associated projects and people she details occur there. These include California's original habitats and how they have been altered in the last two hundred or so years, citizen science and Silicon Valley technology, the redwood forest, Pacific tide pools, the founding of the California Academy of Sciences (by citizen scientists, not professionals!), and Mt. Tamalpais ecosystems.

My favorite account was the story in chapter 9 of a champion citizen scientist, Ed Ricketts, and his friends Joseph Campbell and John Steinbeck. Hannibal's picture of Monterey, California, in the 1930s and the development of the classic natural history books *Between Pacific Tides* and *The Log from the Sea of Cortez* are fascinating. The intriguing and enduring relationships among these brilliant characters are also explored. Campbell is the author of *The Hero with a Thousand Faces* (1949) and the originator of the phrase "follow your bliss"; Steinbeck received a Pulitzer Prize for *The Grapes of Wrath* (1939) and authored many other outstanding books. Ricketts's holistic approach to science in general and ecology in particular comes together in *The Log from the Sea of Cortez* (co-created with Steinbeck), which can be rightfully considered a manifesto of citizen science if not even a bible. Darwin is to evolution what Ricketts is to the integration of science with its sister humanities. Hannibal carries this sense of integration throughout her book, quite intentionally. "I'm trying

to do in this book what they [Ricketts and Steinbeck] were trying to do—put it all together, the personal, the historical, the scientific" (p. 7). This is an appropriate approach to a defense of citizen science, which combines the layperson's love of nature with the desire to do something to make a difference, and it results in valuable contributions to professional scientific efforts.

Hannibal weaves these various components together smoothly and in an appealing way. She points out that crucial themes from *The Grapes of Wrath* continue to resonate today, from the perspective of land use and climate change to the consequences of human dissociation from the land, which leads to destruction of that land and then to the destruction of humanity itself. As the subtitle indicates, extinction is a recurring theme of her book. Disappearing species drive the urgency behind her calls for cooperation between nonscientists and scientists. She details the way citizen science efforts bridge academic and applied sciences and the growing validation by academic scientists of the value of data acquired by nonprofessionals. It is becoming more and more widely recognized that "citizen science monitoring … is probably the only tool that can really scale to aggregate big enough numbers of local observations to create a picture of global consequence" (p. 59).

A significant point Hannibal makes in support of citizen science is that it is a way to cultivate a scientifically oriented society—something that is desperately needed. Understanding the ability of species to change in response to climate conditions requires interdisciplinary scientists and huge networks of citizen scientists (p. 287). One of many scientists Hannibal interviewed, Julia Parrish, works with between 750 and 800 volunteers monitoring beaches from Northern California to Alaska. She comments,

> Scientists alone can't begin to document what's normal, let alone how fast things are changing. We need a willing army to make that happen. In short, we need citizens—the locals who watch, and know, and love their backyards, their environments. (p. 80)

The book includes some chapters that become overly long and seem to veer away from the chapter's theme. Some readers may find the recurring personal account of the author's experiencing the death of her father tiresome—but its link to the disappearance of species and the fragile nature of life is both relevant and sad. Any reader who is interested in the natural history of California would find *Citizen Science* intriguing. As well, academics who question the value of data acquired by nonprofessional scientists would be wise to read the perspectives of scientists that Hannibal presents in order to understand the significance of citizen scientists' contributions. This book would also be of great benefit to anyone who wants to know more about the burgeoning approach to "doing science" that citizen science has become.

Moreover, from a Christian reader's perspective, the biblical mandate for stewardship of God's invaluable creation supports the entire concept of citizen participation in the scientific effort splendidly. We who claim relationship with the Creator can joyfully support scrutiny of the creation; it yields not only data but opportunity to marvel.

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TECHNOLOGY

TEN ARGUMENTS FOR DELETING YOUR SOCIAL MEDIA ACCOUNTS RIGHT NOW by Jaron Lanier. New York: Henry Holt, 2018. 160 pages. Hardcover; $18.00. ISBN: 9781250196682.

As one who rarely uses social media, I found it easy to agree with Jaron Lanier. As stated in the title of the book, Lanier offers ten arguments as to why readers would be better off not using social media, particularly social media services provided by Facebook and Google.

A problem Lanier introduces early in his book is that social media automatically optimize for attention, and this usually means presenting negative information. This can come in the form of negative news feeds or encouraging negative, argumentative, and unhelpful discussions. This is not necessarily intentional from the makers of social media platforms; the process of automatically testing users with small random changes leads to promoting negative content in social media over positive content. The purpose of this automation is to make users available and susceptible to advertisers, who are the actual customers for social media companies. Additionally, users may unknowingly interact with automated users and consequently adopt the viewpoint selected by advertisers. Similarly, social media can initially be helpful with early adopters with impressive results, but it subsequently lends itself to trolls taking over after the human users have been sufficiently modeled.

As mentioned in his title, Lanier's proposed solution is to encourage widespread deletion of social media accounts. He specifies that it is not the social media platform itself that is the problem, but the application of current algorithms that ruin the platform. At the end of his eighth argument, he suggests the need for users to pay for social media platforms, own their

data, and set the price for using their data. Earning money on valuable data should be normal and easy for the user. The hope is to use and reward social media platforms that promote positive interactions, but he feels that this cannot happen with the current methods of the dominant players, particularly when advertisers are the customers. Consequently, mass deletion of social media accounts is the necessary next step.

Overall, Lanier's arguments are timely for users concerned with privacy, personal choice, and advertisers' influence over their minds and values. Each argument in the book is supported with references, although I would like to see more references to support his eighth argument (although this chapter relies on his previous work, and presumably on the research presented there, it does not stand on its own when compared to other chapters in the present book).

While not written from a Christian perspective, I find it easy to agree with a writer who places people over profits and machines. Lanier presents the costs of using such social media platforms, such as creating people who act less humanely, behave more troll-like, are sadder, and have less empathy for others. The benefits go to advertisers who pay to manipulate users for profit or political benefit. Additionally, Lanier presents arguments that long-term use of social media decreases the user's ability to recognize truth, since platforms remove the context of facts (except for podcasts at the moment).

Consequently, Lanier unwittingly provides an argument that aligns with the Bible's instructions in 2 Corinthians 10:5, where Paul tells his readers to take captive every thought. Similarly, I found that his arguments agree with Romans 12:2, where readers are instructed to renew their minds to test and approve of God's will. It seems that social media have been competing for the attention of our hearts and minds, with purposes at odds with biblical instruction.

Argument ten relates most directly to spirituality and religion, in that he states "SOCIAL MEDIA HATES YOUR SOUL." While not favorable toward religion, this argument highlights parallels between religion and social media. For example, Larnier argues that social media platforms erode users' free will and transfer decision-making power to companies; he compares this to how (he assumes) the church makes decisions for its constituents. Another example is how social media use group mentality thinking to encourage users to treat others badly, similar to how he sees religious conflicts engaging people more intensely. Larnier sees his suggestions to reject the current version of social media platforms, while not rejecting the core of social media, as similar to the Protestant Reformation during which Protestants rejected harmful practices such as indulgences. Larnier also sees social media as defining truth for its users by selecting the context for facts. He aligns this with the church defining truth within a religious framework, including a reference that some religious people still think the sun orbits the earth. Like religious frameworks, social media provide ultimate purposes for its users, although he mentions that they are poor choices for ultimate purposes, stating that the purposes of Google and Facebook are to organize information and give users a sense of purpose and community.

The part I appreciated from argument ten was the suggestion that people are using social media platforms in a spiritual and religious way. I hope this encourages readers to reflect on the use of such platforms in their lives, so that they can be empowered to use them as a tool, rather than the other way around. As for the church, argument ten observes that social media compete to define truth and purpose for people. This point is helpful as it stands, but the negative portrayal of religion and the church is not. While I realize that the church has issues to work on, it was grating that every issue of comparison presented religion in a negative light without acknowledging a valuable role for the church in society. One gets the impression that Lanier wants people to quit both their social media accounts and their church.

One could do without some of the colorful language used in parts of the book, but the language does not diminish Lanier's arguments. The book convincingly warns its readers of the destructive effects of social media on individuals and society. It is timely for both thought and action.

Reviewed by Michael Janzen, Associate Professor, Department of Computing Science, The King's University, Edmonton, AB T6B 2H3.

EVERYBODY LIES: Big Data, New Data, and What the Internet Can Tell Us about Who We Really Are by Seth Stephens-Davidowitz. New York: Dey Street Books, 2018. 352 pages. Paperback; $16.99. ISBN: 9780062390868.

Everybody Lies, as the subtitle suggests, is Seth Stephens-Davidowitz's book about "Big Data" and what it tells us about ourselves. He is quite explicit that he is inspired by *Freakonomics* and hopes to apply its irreverent but quantitative approach to new kinds of data that have been enabled by the internet.

Stephens-Davidowitz is an economist; however, his choice of topics strikes me as being rather sociological. More important to his work are his data sources. Key sources include search strings in Google, search strings used at the website Pornhub, Facebook posts, tweets, word frequency counts from Google Ngrams, and more. Stephens-Davidowitz makes a good case that this sort of data, only recently available to the public, has been underused by researchers. However, while some of this avoidance stems from a lack of creativity, there are many statistical issues (such as self-selection, nonrandom groups) that make it hard to meet academic standards with these sources.

Much of the book looks at the search strings used to find things on the internet, and these provide a good example of the challenges of these new data types. The companies the author works with to obtain this data provide him the anonymized strings with some counts on how often it occurred and possibly certain background data such as geographic area or gender. However, the statistics about the search strings are less helpful if we cannot relate them back to a population that we understand. There is no guarantee that internet users are "representative" of the population.

Unlike survey questions, in which everyone gets the same questions and answers, everyone gets to type in their own search string. This leaves the researcher on her own to decide when two different strings are "equivalent" and thus should have their counts combined. Stephens-Davidowitz makes a good case that the same terms in a different order can make a difference in meaning. For example, looking at searches with the names of candidates for political office, say A and B, a search string with A first and then B shows a preference for A, whereas a search string with B first and then A shows a preference for B, possibly even an unconscious preference. Even if one accepts this case, how is one to generalize it? Does the order matter for two different competing products? Does the order of my grocery list matter? It might at first appear that we must accept any difference as significant, but that probably gives us too many different categories from which to draw conclusions. However, trying to combine multiple terms into one category gives us a problem with researcher bias. If nothing else, the researcher has to assume a particular understanding of what the user really means, even when it is expressed differently.

We have counts for the search strings, but this does not mean that the count represents unique users. For example, if one has a simple situation in which the search string is A or B, it is possible that five users do search A and one user does search B five times. Based on the count, A and B are equally likely, but if I care about the underlying population of users, a particular user is five times more likely to search for A then for B. The number of times someone makes the same search would seem to be associated with a particular user, not random. For instance, the address I am most likely to search for in google maps is my home address, as a starting or ending point.

Many of the topics that interest Stephens-Davidowitz are those in which people tend to avoid the truth; hence the book's title *Everybody Lies*, or at least they lie on surveys. The topics in the book include sex (quite a bit), race, cheating on taxes, and more. The difficulty with these topics is well enough known to have its own technical name: social desirability bias. This is a bias in which people answer questions in a manner that will be viewed favorably by others, a form of hypocrisy. As La Rochefoucauld said: "Hypocrisy is the homage which vice renders to virtue." While inconvenient for social scientists, this is an inevitable consequence of having a conscience—even if badly damaged—in a fallen world. People retain a sense of what is and what should be.

In an effort to work around the inaccuracies caused by this bias, the author looks for sources in which someone voluntarily discloses information, which, in his work, is often a search string. He may have found a way around the problem, but such remains unclear. When the user enters a search string, it is voluntary, and the string is one of their own choosing. It is unprompted by a survey, and it is anonymous. This appears to avoid social desirability bias; even so, there is no reason to think that we have avoided a self-selection problem. The very approach we use to avoid social desirability bias, that of a user voluntarily picking a search string, means that the user is self-selecting. The social sciences have long been concerned about self-selection and have been dubious of studies that fail to account for it.

Everybody Lies succeeds, in the spirit of *Freakonomics*, in telling some good stories that tie back to quantitative thinking. Stephens-Davidowitz shows creativity in finding information from new data sources. However, this often takes us into areas where we do not understand the data well. A common problem with his work is a desire to delve into areas involving social desirability bias, areas that people are reluctant to talk about. In trying to handle this, he almost certainly strays into the problems of self-selection, which makes his samples unrepresentative and, in turn, makes it difficult to draw valid conclusions. While *Everybody Lies* opens up vistas of new possibilities, its explanatory reliability is questionable.

Reviewed by John Hunt, Professor of Computer Science, Covenant College, Lookout Mountain, GA 30750. ⌂

Letter

In Response to the Review of My Book

Darrel Falk is a highly valued Christian colleague with a wealth of knowledge and experience: I have always appreciated interacting with him at meetings and through email. I know that Darrel and I agree on a great many points.

In his review of my book, *Standing on the Shoulders of Giants: Genesis and Human Origins* (*PSCF* 71, no. 1 [2018]: 63–65), Darrel first addressed a very important point: Intelligent Design (ID). He is correct that I was making my way through the arguments for and against ID. I wish to clarify that I myself am not "decidedly pro-ID": a perusal of my blog-site archive (https://lukejjanssen.wordpress.com) will make this abundantly clear. My primary target audience for this book is nonscientific believers with a young earth creationist (YEC)/fundamentalist background who wish to be better informed about human evolution and how this might influence one's theology. I did present several arguments against ID, but did so gently because I've learned that some interpret a staunchly anti-ID stance as a belief that God had nothing to do with Creation and/or that he is not intelligent.

Next, he drew attention to certain "scientific misstatements" made to my nonscientific audience. One which he labelled the "most disconcerting" was an unfortunate use of word-play on my part: in one instance, I juxtaposed and contrasted a hypothetical "*Homo australopithecus*" against *Homo sapiens* in order to make a theological point, but everywhere else (31 times) described it scientifically using the correct term *Australopithecus* (without the prefix "*Homo*").

Also "disconcerting" was my use of the word "millions" in the context of the genetic bottleneck from which humans emerged. However, I was pointing to the ancestral population existing before that bottleneck: three sentences later I referred to a natural disaster which left only a few thousand survivors (the bottleneck). My goal was not to describe that stage in human evolution in scientific terms, but to confront the view that humans descended from a single pair.

Space constraints prevent me from going through the other specific examples point-by-point, but none of them change the central point I was trying to make to my nonscientific audience in the first half of the book (one with which I'm sure Darrel agrees): an abundance of data convinces us that humans evolved.

The rest of Darrel's review pertained to the theological impact of human evolutionary theory. He stated it "need not shake up theology in any major ways." For me, however, three or four decades of a YEC/fundamentalist upbringing shaped a worldview which simply could not reconcile with my world of science, let alone accept human evolution. Upon finally accepting it, I felt forced to re-think the nature of scripture (inspiration, inerrancy, infallibility, authority), atonement theology, human ontology (sin, death), and so many other big issues. The dominoes started falling, and the unceasing cognitive dissonance brought me to a point of complete agnosticism bordering on atheism.

Many of the believers that I interact with are still struggling with that tremendous paradigm shift; many others have entirely given up their faith because of it. I fully agree with Darrel that the central tenets of a Christian faith can survive human evolution, but I still feel that it will require extensive remodeling: I've written previously in this journal about one example.[1] The second half of my book was intended to help the reader over many of the theological stumbling blocks.

This final comment is directed at the ASA community in general (not Darrel in particular) to convey why books such as this one are needed. I often quote from Roy Clouser writing against the down-playing of any perceived conflict between Genesis 1 and science: "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."[2]

I question whether the Christian Academy is adequately preparing ministry leaders for our new understanding of anthropogony: as a student attending a divinity school, I still regularly witness discussions which are based on theological presuppositions that no longer comport with many well-documented, repeatable, and testable facts. And the ministry leaders produced by the Academy are not adequately preparing their flocks: most churches still teach their children a literal reading of the story of Noah's Flood. We need to do better at all these levels of Christian education. This is the stated purpose of my book.

Notes

[1]Luke Jeffrey Janssen, "'Fallen' and 'Broken' Reinterpreted in the Light of Evolution Theory," (*PSCF* 70, no. 1 [2018]: 36–47).

[2]Roy Clouser, "Reading Genesis," (*PSCF* 68, no. 4 [2016]: 238).

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