PERSPECTIVES on Science and Christian Faith

JOURNAL OF THE AMERICAN SCIENTIFIC AFFILIATION

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VOLUME 76, NUMBER 2 **SEPTEMBER 2024**

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

Perspectives on Science and Christian Faith

https://doi.org/10.56315/PSCF

Perspectives on Science and Christian Faith (USPS 28-3740, ISSN 0892-2675) is published three times a year by American Scientific Affiliation, 218 Boston St, Ste 208, Topsfield, MA 01983-2210. Periodicals postage paid at Topsfield, MA, and additional mailing office. POSTMASTER: Send address changes to: Perspectives on Science and Christian Faith, 218 Boston St, Ste 208, Topsfield, MA 01983-2210.

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James C. Peterson

DOI: https://doi.org/10.56315/PSCF9-24Peterson

Final Words

That might sound too absolute, to title this editorial "Final Words." At this point, I have carefully studied and given feedback on over a 1,000 essays offered to the journal, and 700 book reviews. Days have been filled, as well, with listening across the wide discussion in academia and the church, envisioning future themes for the journal, encouraging promising submissions, giving copyright and translation permissions, adding keyword and DOI identification tools to support our readers' research, creating job descriptions for journal posts, recruiting to them… Continuing that service is our esteemed colleague Stephen Contakes, but I hope to continue to be part of the friendships and conversations of *PSCF* for years to come. These are my parting words then as specifically the Editor-in-Chief of *PSCF*.

PSCF has often found theology and science to be allies. That will no doubt continue under the able leadership of our new editors. Such is a needed counter to one of the most influential perspectives on our campuses today, that of writers such as Michel Foucault, that language and concepts are in essence just power games, one speaker defeating another. For that view, there is no actual truth, just "*my truth*" to further my ends. In contrast, theology and science are allies in their conviction that some answers are better than others. There is a reality to discover which is not of my making or desire. Realizing that, is not to place in triumph one person over another, rather to mutually seek what is actually the case. It is a wonderful thing to be delivered from an incomplete or false perception. We are inherently finite and limited in our approaches, but there are ways to test and improve with each other our recognition of what is. This is essential to excellence in science and theology.

A second dominant perspective today is a variation on the romanticism (that personal feeling is the *sine qua non*) that was influential before, in the early 1800s. For the current gnostic version, the only truth that is truly known, hence that exists, is one's own experience and desire. My self-perception is most real to me and so trumps any other reality claim. If I identify as a member of the first nations, I am a member of the first nations regardless of my parentage, history, or the discernment of the tribal council. Science, as the careful systematic observation of what materially is, is an ally of Christian faith when it calls for recognition of what is, not just what I might want or think things to be. Saying or wanting, is not enough to make it so.

While theology and science are allies concerning these perspectives, they each bring also unique contributions. Science serves theology, when it reminds theology that certain material connections are quite clear. There is always room for science to improve its understanding, but there are assertions, such as that the earth tracks around the sun, that are so evident, and reinforced by comprehensive coherence, that it is hard to imagine that we will ever need to revisit their trustworthiness.

Theology serves science well when it reminds science that science is very good at what it does, but only at what it does. There is no scientific basis for claiming that science is the sole way to apprehend reality. Such is the ideology of scientism, not science. Science seeks to recognize causal connections between material entities. It does not have the tools or expertise to do else, even to pronounce that it is a good thing to study science! Much that is real, is not accessible to scientific verification.

When they work well together, the best of theology and science welcomes apparent contradictions and anomalies. One's pulse should quicken when they do not seem to fit together: in anticipation, not in dread. Such challenges are opportunities to learn, to understand a little bit better what actually is. One approach may need to adjust, or more likely, both. Theology and science, at their best, are allies in the quest to pursue the truth, including that the more we learn, the more aware we become of how much more there is to learn. We do learn, including that we have so much more to learn. Hence 76 years of *PSCF*.

Thank you to all who have made that happen at *PSCF*. What a privilege and opportunity to bring together such experience and insight, in both theology and science, to understand better. To that purpose, and progress in it, science and theology are much needed allies.

Carry on!

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

Ximian Xu

Article

DOI: https://doi.org/10.56315/PSCF9-24Xu

How Virtuous Can Artificial Intelligence Become? Exploring Artificial Moral Advisor in Light of the Thomistic Idea of Virtue

Ximian Xu

Is artificial intelligence (AI) virtuous? Can AI become as virtuous as humans? This article is intended to explore these questions with a focus on artificial moral advisor (AMA). AMA is a proposal for the future application of AI to human moral life. Hence, this article will be dedicated to the theoretical analysis of the issues surrounding AMA. Socratic AMA will be the specific object of study. To this end, this article will examine whether or not the Socratic AMA can enhance human virtuous life through exploration of Thomas Aquinas's theology of virtue. It will argue that the Socratic AMA is not as virtuous as humans insofar as it lacks both the subject and ultimate end of virtue and is characterized as measurable. Nevertheless, the Socratic AMA can be considered to be embedded with delegated virtues and is expected to assist humans in their cultivation of virtue in certain contexts by reason of both its capacity to gather voluminous information and its tremendous processing power.

Keywords: artificial moral advisor, Thomas Aquinas, virtue, virtuous AI, teleology, technology ethics

A virtue refers to a trait or excellence that gives birth to right actions leading to flourishing. A virtue may grow or wither across time. In the sphere of ethics, virtues that grow will foster morality, but withering virtues are coupled with moral vices. This definition of virtue is deliberately made in a broad sense insofar as some scholars suggest that technology ethics should eschew an anthropocentric construal of the moral status of smart machines.[1] With considerable reservations about such a claim, I have demonstrated elsewhere, from a theological perspective, how the moral status of smart machines can be construed in the light of human morality as a starting point without running the risk of anthropocentrism.[2] That said, for the purpose of this article, a broad definition of virtue can conduce to exploration of the distinction and yet connection between human virtues and so-called artificial intelligence (AI) virtues.

The idea of virtue features in recent studies on technology ethics. A typical example of these studies is Shannon Vallor's elaborate account of contributions that virtue ethics can make to technomoral futures. That is, virtue ethics can help articulate a framework for diverse ethical narratives in relation to technological society.[3] The idea of virtue also draws much attention in recent discussions of AI ethics. Scholars such as Robert Sparrow attend to the importance of virtue ethics for the evaluation of the relationship between humans and robots as well as AI.[4] Others explore the way in

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which virtue ethics can help individuals and governments use AI-powered technologies.[5]

This article is intended to address the questions of whether and how AI itself can be considered virtuous, through the lens of Thomas Aquinas's theology of virtue. Given the limited space of the article, we cannot go into a comprehensive consideration of the details related to virtuous AI. I will instead put the spotlight on the artificial moral advisor (AMA) in relation to human virtues and moral growth. Some AI ethicists are convinced that AI is expected to advise humans on moral life, including, among others, moral decision making, moral deliberation, and moral judgment. Good moral advice can be called virtuous insofar as it leads to right actions and facilitates moral flourishing. Virtuous advice cannot be made without a virtuous entity precisely because virtue must be a trait or excellence within advisors. For example, a virtuous human person is capable of offering moral advice on making moral decisions in accordance with virtuous principles while confronting a moral dilemma. If AI can, *on its own*, generate virtuous advice to make human moral life flourish, then it can be argued that AI itself is virtuous.

It is worth pausing here to clarify that AMA is a proposal for the future application of AI to human moral growth. This means that there is no existing AMA system that we can use to generate moral advice; so, there are no real-life examples available for analysis. For this reason, this article is dedicated to the theoretical analysis of the issues surrounding AMA in the relevant literature.

I will argue that despite gathering voluminous information and having tremendous processing power, AI is not as virtuous as humans because it lacks both the subject and ultimate end of virtue and is characterized as measurable. That said, the AMA can be considered to be embedded with delegated virtues; consequently, it is able to facilitate the cultivation of human virtues and moral growth. In what follows, I will first elucidate how the AMA operates to generate moral advice with a focus on the Socratic AMA, which is designed to question human agents when they are confronted with moral dilemmas. Second, I will unpack Aquinas's view of virtue, bringing to light the particularities of the human being as the virtuous agent. Finally, I will flesh out the sense in which the AMA may possess delegated virtues and may be able to promote human moral life in certain contexts.

AMA's Advice and Its Nature

The AMA was proposed against the backdrop of wide debates over biomedical moral enhancement. The proponents of biomedical moral enhancement maintain that biomedical technologies can significantly and rapidly foster human morality. All the more provocative is the claim that extensive biomedical moral enhancement is urgent and inescapable. The reason is that, as per Ingmar Persson and Julian Savulescu's claim, the exponential growth of knowledge and the advancement of science and technology can empower any individual to perform gravely immoral actions.[6] The development of human moral capacities lags behind technoscientific progress, and biomedical moral enhancement can effectively bridge the gap between morality and scientific knowledge so as to safeguard against any potential catastrophes caused by technoscientific advancements.

The proposal of biomedical moral enhancement has sparked vigorous debate. Some argue that this proposal gives us a misleading impression that morality can be biologized.[7] The proponents of AMA criticize that the effects of biomedical interventions are short term in comparison with the moral advice offered by AI systems.[8] Among these proponents, Francisco Lara and Jan Deckers raise the idea of the Socratic AMA, which is designed to assist humans in moral decision making by asking certain questions when humans are in moral dilemmas.[9] Compared with other proposals of AMA (which I will touch on later), the Socratic AMA seems to be the most viable approach to the development of AMA. For this reason, I will concentrate on the idea of the Socratic AMA before exploring the question of virtuous AI.

Lara and Deckers's proposal of the Socratic AMA aims to achieve AI-powered moral enhancement that can be made "more rapidly and successfully than traditional methods, and with fewer risks and controversies than bio-enhancement."[10] They begin with the critique of the two proposals of AMA: exhaustive and auxiliary enhancement.

Lara and Deckers take issue with the proposal of exhaustive enhancement. This proposal suggests that autonomous artificial agents can be created to make moral decisions in place of humans insofar as these AI-powered agents are more capable than human agents to deal with moral issues. Lara and Deckers contest the following idea:

> The essential aspect of this proposal is that all human participants, including the designer, would

> be expected to take a passive role after the original programming had been completed.[11]

This criticism targets Blay Whitby's claim that AI technology can create a moral machine which generates moral decisions *for* humans. First, Whitby suggests that

> the general acceptance of machine-generated moral judgments is not incompatible with either or both of these assertions. Firstly it is necessary to make the banal observation that the use of tools—from flint axes to computers—is also an essential part of what it is to be human.[12]

In this way, exhaustive enhancement by the AMA becomes constitutive of the human being as moral agent. From this, it follows that AI systems are always embedded within human social structures and, consequently, within "a network of authority."[13] As such, the decision made by the AMA is morally authoritative for human agents. For Lara and Deckers, however, exhaustive enhancement deprives humans of decision making and arrests human agenthood in that it is the autonomous machine, rather than humans who perform their moral agency, that makes moral decisions.

The second proposal that Lara and Deckers criticize is called auxiliary enhancement, advocated by Julian Savulescu, Hannah Maslen, and Alberto Giubilini.[14] In contrast to exhaustive enhancement, auxiliary enhancement refrains from making moral decisions on behalf of humans in order not to render humans *passive* moral agents. Savulescu and Maslen contend that

> the moral AI would monitor physical and environmental factors that affect moral decision making, would identify and make agents aware of their biases, and would advise agents on the right course of action, based on the agent's moral values. In being tailored to the agent, the moral AI would not only preserve pluralism of moral values but would also enhance the agent's autonomy by prompting reflection and by helping him overcome his natural psychological limitations.[15]

Even though the proposal of auxiliary enhancement pays due attention to human autonomy in moral enhancement, Lara and Deckers disapprove of this proposal for two reasons. Firstly, human agents are, by and large, passive in that humans still depend upon the AMA and are ignorant of the connection between their moral values and the AMA's moral decisions. Secondly, it is taken for granted that the AMA can provide moral advice according to programmed moral values. Yet, such fixed moral values may undermine human reflection when humans are making moral decisions.[16]

Having brought to light the flaws of the proposals of both exhaustive and auxiliary enhancement, Lara and Deckers flesh out the idea of the Socratic AMA. The rationale behind the Socratic AMA is rooted in Socrates's pedagogy.

> Socrates always presents himself and acts as a mere assistant who aims to refute the definitions he receives from his interlocutors. He … is like a midwife who only helps the other to give birth to his own knowledge. In our case, this knowledge would not reveal any hidden or common-sense truth, but consist in a moral judgment that was formed by applying conditions of empirical, logical and ethical rigor to one's beliefs. The agent should always have a privileged place, should always provide the first solution in a significant conflict, which is then submitted to staged scrutiny so that the machine, like Socrates, may ask relevant questions and reveal potential failures in the argumentation.[17]

Three observations can be made in reference to this passage. First, as a "midwife," the Socratic AMA is designed to influence human agents rather than to generate a decision forthrightly. In spite of their differing methodologies, both exhaustive and auxiliary enhancement are intended to produce moral decisions for human agents. By contrast, Lara and Deckers's "emphasis is placed on the formative role of the machine for the agent, rather than on the result."[18] Although the Socratic AMA provides moral advice, it is always the human agent who makes moral decisions. To this extent, the Socratic AMA is more capable than the previous two AMAs of enabling humans to foster their own virtues.

Second, the Socratic AMA's task is to assist human agents in the formation of moral judgments, which are characterized by "empirical, logical, and ethical rigor." Instead of using biomedical technologies to intervene in human moral judgments, the Socratic AMA is an apparatus through which to advise humans on gaining proper knowledge for moral decision making. Lara and Deckers suggest six functions of the Socratic AMA:

1. invalidate moral judgments by empirical premises,
2. clarify concepts for moral judgments,
3. pinpoint the logical deficiencies of moral judgments,

4. test the ethical plausibility of moral judgments,
5. remind humans of personal limitations, and
6. advise on the execution of moral decisions.[19]

All these functions rely on AI's rapid accumulation of voluminous information and tremendous processing system. For example, AI's voluminous data bank collects a huge number of moral concepts for moral judgments, a quantity that is far beyond human moral knowledge. Coupled with its tremendous processing ability, the AMA can identify, select, and clarify moral notions in nanoseconds for humans when making moral judgments. A second example is its ability to track human personal limitations. For instance, an AI-powered device (e.g., Apple watch) can monitor the human agent's sleep, and it has been discovered that sleep deprivation can increase intergroup bias.[20] The AMA can monitor the human agent's quality of sleep (e.g., average deep sleep, average light sleep, and average awake time) as a reminder of the potential to make wrong judgments on moral matters.

Third, the Socratic AMA operates by posing questions to human agents. It raises some questions when human agents are wrestling with moral dilemmas, such as, "Are you aware that both assertions are contradictory?"[21] These questions aim to remind human agents of errors (e.g., logical contradiction) lurking around moral reasoning and judgment. By doing so, it is expected that the human agent's "motivations and emotional dispositions" can be changed to make good moral judgments and decisions, leading to moral enhancement. Francisco Lara argues elsewhere:

> The virtual assistant will make the person aware of their possible errors and *they will feel motivated*, where appropriate, either to respond as to why they believe they are not errors or to avoid them with revised positions. It is foreseeable that, with this dialectical training, the person will acquire the capacity to make decisions *critically and self-sufficiently* in the future.[22]

Moral questioning signals the nature of the Socratic AMA. That is, through questioning human agents, the Socratic AMA is conducive to the formation of human motivations for making good moral decisions and performing good actions accordingly.

During moral questioning, the human agent's mental activities concerning morality can be nudged in the direction of moral good to give birth to good actions. As such, some moral traits and excellence must be cultivated within human agents to elicit virtuous actions. To put it differently, the Socratic AMA asks moral questions with the purpose of cultivating the virtues in human agents. From this, we can infer that the Socratic AMA's questions must be somewhat characterized as virtuous or that the Socratic AMA's questions must have virtues as their *telos*. Either of the two inferences may yield the corollary that the Socratic AMA is, to a certain degree, virtuous precisely because moral questioning per se as virtuous action should be derived from a virtuous entity.

It is beyond doubt that the Socratic AMA can somewhat assist in the cultivation of human virtues by posing questions related both to moral decision making and to virtuous actions. The moral questions generated by the Socratic AMA can alert human agents to the factors that must be taken into consideration while making moral decisions. However, this corollary raises the question of to what extent and in what sense the Socratic AMA is considered to be virtuous. To complicate this question further, recent studies on artificial general intelligence (human-level AI) may induce us to draw a hasty conclusion that the Socratic AMA is as virtuous as humans. In what follows, Aquinas's theology of virtue will provide us with a lens through which to spell out the meaning of being virtuous in relation to AI.

Being Virtuous

Moral theology occupies a crucial place in Aquinas's theological system. As an illustration of this, the elaboration on moral matters makes up the majority of the second part (*Secunda pars*) of *Summa theologiae*.[23] Virtue is a subject matter of Aquinas's moral theology. As he claims, "all moral matters are reduced to the consideration of the virtues."[24] For this reason, his view of virtue can be a conceptual tool for theological analysis of morality in relation to AI, more so when exploring whether the Socratic AMA could be considered virtuous.

A virtue is, for Aquinas, a habit (*habitus*) within an agent. The Latin word "*habitus*" literally means "to have," which can connote either "to have something" or "to have relation to itself or something else." Aquinas's use of *habitus* in relation to virtue is associated with the latter sense: "habit is a disposition whereby that which is disposed is disposed well or ill, and this, either in regard to itself or in regard to another … Wherefore … habit is a quality."[25] As a

quality, a habit is durable within the agent.[26] To put it in Bonnie Kent's words, "habits grow to be, or are habituated as, a 'second nature'" for the agent.[27]

As a quality of the human agent, "habit is that whereby we act when we will."[28] A habit implies a relation to an act and "a state of potentiality" (disposition) in respect to operation.[29] If operations of the body are caused by the body's natural qualities, then the body needs not to be disposed. To this extent, such operations have nothing to do with habits. As such, habitual operations of the body can be moved only by the soul, and so the soul is the authentic subject of habits.[30] Aquinas takes a further step to elucidate that habits are in the powers of the soul insofar as "the soul is the principle of operation through its powers [*potentias*]."[31] From this it follows that a virtue as a habit consists only in a power of the soul. Aquinas argues:

> Virtue denotes a certain perfection of a power. Now a thing's perfection is considered chiefly *in regard to its end*. But the end of power is act. Wherefore power is said to be perfect, according as it is determinate to its act. Now there are some powers which of themselves are determinate to their acts; for instance, the active natural powers. And therefore these natural powers are in themselves called virtues. *But the rational powers, which are proper to man, are not determinate to one particular action, but are inclined indifferently to many: and they are determinate to acts by means of habits* … Therefore human virtues are habits.[32]

Two points are of note here: (1) having turned to the soul as the subject of virtue, Aquinas emphasizes human rational powers; and (2) virtue carries the connotation of teleology, which means that a power of the soul is perfected toward an end. These two points will be unpacked below and set a scene for clarification on the meaning of being virtuous in relation to the Socratic AMA.

Aquinas maintains that virtues can only be in the rational part of the soul. "And therefore reason, or the mind, is the proper subject of virtue."[33] He reformulates that virtue refers to "a good quality of mind by which we live righteously."[34] Aquinas moves on to elucidate the sense in which virtue is tied up with the rationality of the soul: since the "mind is chiefly called the intellect," the subject of virtue is the intellect.[35] The intellect as the subject of virtue should be understood in reference to virtue understood in a relative sense—that is, a virtue enables humans "to have the aptness to do well." On the other hand, if virtue is understood simply or absolutely (*simpliciter*), which means that a virtue enables humans to do well *actually,* then the will is the subject of virtue. This is so because the will, "a rational power," moves all other powers to act in a rational way.[36]

It is worth noting that for Aquinas a virtue cannot consist in several powers of the soul at the same time. One virtue is in one power. That said, a virtue can belong chiefly to one power but, at the same time, diffuse to the other powers in a certain order.[37] Hence, the subject of virtue is, properly speaking, the soul as a whole, not a single power of the soul. As will be discussed, the soul as the subject of virtue draws attention to the differing meanings of being virtuous in relation to the Socratic AMA and human agents.

The second point Aquinas emphasizes carries a teleological implication: a virtue perfects a power toward an act as its end. For all that rational powers are directed toward many actions, one virtue perfects one power toward one act as its end: "diversity of ends demands a diversity of virtues."[38] In Aquinas's position, an act itself is not the ultimate end of virtue. His teleological account of virtue must be read in tandem with his view of the cause of virtue. As Jeffrey Brower remarks, Aquinas characterizes agents as "always acting for ends" due to their "teleologically directed causal powers."[39] The only ultimate end is God himself, who can completely satisfy all human desires.[40] God as the ultimate end of virtue presupposes that God is the cause of infused virtues that are necessary for the perfection of the soul in relation to things exceeding human nature.[41] No acquired virtue can, in its own right, dispose humans to the ultimate end. Rather, it is theological virtues—that is, faith, hope, and charity—that are infused by God and dispose humans toward God.[42] Furthermore, God infuses cardinal virtues—that is, prudence, justice, fortitude, and temperance—that are "corresponding, in due proportion, to the theological virtues." In this way, the soul is effectively perfected toward the ultimate end.[43]

As infused virtues, theological virtues are formed within humans without reference to human action. Given this, the prominent feature of theological virtues is the *immeasurability* of theological virtues.

> It follows that human virtue directed to the good which is defined according to the rule of human reason can be caused by human acts: inasmuch as such acts proceed from reason, by whose power

> and rule the aforesaid good is established. On the other hand, virtue which directs man to good as defined by the Divine Law, and not by human reason, cannot be caused by human acts, the principle of which is reason, but is produced in us by the Divine operation alone.[44]

Given their divine origination, theological virtues cannot be measured by human standards. Rather, as Aquinas argues elsewhere, "theological virtue has for its object the first standard itself, which is not measured by another standard."[45] While faith, hope, and charity can be measured in accordance with our condition, they cannot be measured with reference to God precisely because God, the ultimate end, is *the* rule and measure of theological virtues.[46] As will be seen, this immeasurability of theological virtues brings to light a critical distinction between virtuous human agents and the AMA in that the latter is created with *measurable mathematical models*. Furthermore, Aquinas maintains that theological virtues radically differ from and underlie both intellectual (wisdom, science, and understanding) and moral (temperance, justice, prudence, and fortitude) virtues.[47] The distinctiveness of theological virtues signals that both intellectual and moral virtues need to be oriented by theological virtues toward the ultimate end.

To summarize, Aquinas's theological account of habitual virtues shows that virtues can be habituated either by acquiring or by divine infusion. He does not restrain the idea of virtue within moral confines but rather extends it to human life as a whole. Aquinas's view of virtue is anthropocentric. As Thomas Osborne rightly notes, Aquinas concentrates on "which is proper to humans and not to other animals or bodies" while developing his theology of virtue.[48] Be that as it may, Aquinas's theology of virtue fits well into the broad concept of virtue laid out at the beginning of this article. Putting Aquinas's theology of virtue alongside the Socratic AMA, we are now turning to exploration of how virtuous AI can become, if it is considered virtuous somehow.

If the AMA Becomes Virtuous

If the Socratic AMA can advise humans on moral decision making, then moral advice that underlies questions generated by AI systems can be characterized as virtuous insofar as it directs humans toward a virtuous life. As per Aquinas's view of being virtuous, virtuous actions must be traced back to a virtuous agent. A question arises here: is the Socratic AMA as virtuous as humans? The answer to this question is entangled with the debate over whether AI can evolve to be a human-level agent. Even if the answer is negative, a further question may be brought up: how virtuous can the AMA become in its potential contribution to the flourishing of human moral life?

Some AI philosophers and ethicists claim that a human-level artificial agent will be created in the future. An example of this position is John Sullins's endorsement of the moral agency of robots. Sullins contests that robots are fully moral agents provided that they are significantly autonomous (without the direct control of others), act intentionally ("seemingly deliberate and calculated"), and behave in a way that implies moral responsibility to others.[49] By arguing so, the boundaries between human and artificial agents are obliterated.

In contradistinction to scholars like Sullins, Robert Sparrow reminds us of the discrepancy between scientific and moral truths.

> When it comes to performing a mathematical calculation or analyzing a mechanism, someone else could make "my" decision because any consideration for them is also a consideration for me and vice versa. By contrast, ethical dilemmas attach to agents in such a way that they are essentially dilemmas for particular people. The nature and role of ethical truths are correspondingly different from that of scientific truths.[50]

A major distinction drawn by Sparrow between scientific and moral truths involves the contextual variables and personal features concomitant with moral issues. Viewed in this light, AI cannot become a fully moral agent like humans because AI algorithms, as mathematical operations, cannot fully deal with moral issues related to particular people in particular contexts at particular times.[51] Considering this in the light of Aquinas's definition of virtue, it can be argued that since virtues are not habituated as a second nature of the Socratic AMA, the artificial agent per se is not disposed to virtuous actions across different circumstances and times. For this reason, the Socratic AMA cannot become virtuous in the same sense as virtuous human agents.

Aquinas's view of virtue provides another theological objection to human-level artificial agenthood and, at the same time, echoes and theologically consolidates Sparrow's stance in three respects: (1) the

subject of virtue, (2) the *telos* of virtue, and (3) the immeasurability of infused virtues. Aquinas broadly identifies the soul as the subject of virtue. Locating virtues in the rational part of the soul, he suggests that a virtue is in the mind as the proper subject.

Aquinas's connection between the mind and virtues resonates with recent studies on the link between mental activities and AI's moral status. Kenneth Einar Himma contends that inasmuch as agency is intertwined with volition, intention, belief, desire, and other mental states, AI cannot evolve to be a human-level moral agent due to the impossibility of human-level artificial consciousness.[52]

Likewise, Richard Spinello argues that

> personal actions are those consciously brought about by free will responding to the intelligible goods presented to it by reason. Only a person can make this choice for one of these goods and thereby qualify for moral agency. Moral agency requires a "free will" that is capable of voluntary action.[53]

Due to the lack of volitional actions, AI and smart machines cannot have human-level moral agency. Both Himma's and Spinello's arguments locate the human mind at the center of moral life.

Aquinas argues in a similar way that the mind—the will, in particular—moves all rational powers to enable the body to perform good actions.[54]

> Now the proper nature of a power is seen in its relation to its object … [I]f man's will is confronted with a good that exceeds its capacity, whether as regards the whole human species, such as Divine good, which transcends the limits of human nature, or as regards the individual, such as the good of one's neighbor, then does the will need virtue. And therefore such virtues as those which direct man's affections to God or to his neighbor are subjected in the will, as charity, justice, and such like.[55]

Accordingly, being virtuous implies that an entity can volitionally perform virtuous actions toward both God and humans. Recent studies have cogently demonstrated from multifaceted perspectives that the particularities of humanity, including human religious and moral nature, cannot be reduced to mathematical models or algorithms. For example, Antonio Damasio demonstrates that social emotions such as shame, embarrassment, and envy—which carry moral values—are associated with the ventral and medial aspects of the prefrontal cortex.[56]

Jobst Landgrebe and Barry Smith also underscore the uniqueness of humans as organisms vis-à-vis smart machines.

> We cannot model and engineer in a machine the human way of perceiving and interacting within a social environment. Instead, the machine must rely on sensory data, and on serial interpretation of these data in order to obtain the inputs to its algorithmic counterpart of social norms. We can imagine improvements in engineering that go beyond this sort of serial interpretation, but however far these improvements will take us, we will … still not be able to model the complex systems that enable human social behavior. Therefore, we cannot build machines that can know and apply social norms with the facility that is characteristic of human beings.[57]

Needless to say, like social norms, moral and religious norms cannot be simplified as mathematical operations. As Mark Coeckelbergh rightly argues, humans "are meaning-making, conscious, embodied, and living beings whose nature, mind, and knowledge cannot be explained away by comparisons to machines."[58] As a crucial constituent of the human being, the mind as the subject of virtue cannot be mathematized. As a result, the Socratic AMA cannot operate as a human-level virtuous agent to generate virtuous advice on human moral growth.

Aquinas's teleological account of virtue features in a theological objection to the view of Socratic AMA as a human-level virtuous agent. In discussion over virtue ethics with reference to technology as well as AI, "virtue" is often construed in a moral sense. Through exploration of Aquinas's view of virtue, especially his view of the ultimate end of virtue, it comes to be seen that virtue should be understood in a broader sense.

In Aquinas's position, virtue involves the whole human life. Being virtuous means that the human being must be disposed toward the ultimate end on all levels and in all circumstances. Within this ideal view, religion itself is a virtue. All the more important is that religion is a special, moral virtue which excels among all moral virtues in that it gives special honor to God as its end.[59] It is clear that Aquinas's view of moral virtue is broader than the notion of virtue in the present literature on technology ethics, which separates religion from morality. Aquinas's position is a good reminder to us that being virtuous must be tied to an end beyond the natural sphere where humans reside and behave morally.

It has been argued in recent literature, however, that AI can be directed toward God, the ultimate end, in the future.[60] The above analysis of the mind as the subject of virtue turns down the human-level virtuous Socratic AMA. Aquinas's teleological view of moral virtue reinforces this refutation. If the Socratic AMA is as virtuous as humans, then God as the ultimate end must be embedded within its AI system. Yet, those who endorse AI's direction toward God are oblivious to the way in which AI is made purposeful. Mihaela Constantinescu and her colleagues note that "it is not the AMA app that initiates and controls the facts leading to the human decision and action: it is the human users who decide to take benefit of the app and start using it for their own purposes."[61]

Added to this observation is that programmers and designers can endow particular *telos* to AI systems and make AMAs operate in a way to generate expected advice. As an artefact, the AMA reflects the values of programmers and designers who are involved in the creation of AI.[62] From this it follows that AI's *telos* is predicated upon human values. Sarah Lumbreras's distinction between two kinds of delegation can help us make further clarification on this point. The delegation of the first sort means that we trust in someone who shares our same values to orient our actions. The delegation of the second sort requires humans to provide "sufficiently detailed instructions, instructions that cover the full spectrum of situations that could emerge in the context of the decision."[63] The creation of AI falls into the second category of delegation. Those who are involved in the creation of AI delegate to the Socratic AMA to generate advice in certain contexts. This delegation becomes obvious when we look at the Socratic AMA's questions. The questions proposed by Lara and Deckers for the Socratic AMA include the following examples:

> Are you aware that this deduction/induction/analogy … is not valid? Do you know that this is not a common value? Are you aware that your current physical condition/environment is not the best one to make an important decision? Do you know that, in these circumstances, your decision could be best executed like this?[64]

These questions can help human agents in certain circumstances make their own moral decisions prudently after weighing up various factors. Yet notwithstanding this, the words such as "contradictory," "valid," "common value" imply that an inducing, preliminary judgment has already been made for humans. Given AI as created by design, such judgments can be considered the delegation of the second sort, being embedded with detailed instructions for asking specific questions in certain circumstances. Doubtless, AI programmers and designers can endow the Socratic AMA with a *telos* during such a delegation process. To say the least, it is widely recognized that AI can be manipulated by capitalists and technocratic elites to achieve their own purposes. Hence, it suffices to say that it is misleading to say that the Socratic AMA in itself is as virtuous as humans such that it can be well disposed to an end and even to the ultimate end. That said, it can be argued that the Socratic AMA has the potential to become virtuous by delegating virtues to AI. In this light, the Socratic AMA's *purposes* are nothing other than the *telos* of human virtues.

The third observation to the Socratic AMA as the human-level virtuous agent is a summary of, and intensifies, the above two observations. That is, Aquinas's emphasis on the *immeasurability* of divinely infused virtues underpins the claim that, unlike human agents, the Socratic AMA neither has the subject of virtue nor is teleologically virtuous. Since infused virtues—theological virtues *par excellence*—are caused by God, their measure must overstep the rules and principles established by humans. The immeasurability of divinely infused virtues echoes Sparrow's distinction between scientific and moral truths, which demonstrates the impossibility of mathematically measuring morality.

One may draw machine learning in support and argue that the Socratic AMA can be an autonomous agent who is able to ask questions when human agents are in particular contexts and moral dilemmas. There are diverse models for creating machine-learning systems. Yet all these systems are designed to perform particular tasks. As Peter Flach observes, "models lend the machine learning field diversity, but tasks and features give it unity."[65] This unity of tasks is rooted in the fact that these models, along with AI algorithms, are made according to possibilities that are foreseeable and susceptible to measurement. According to Stuart Russell,

> AI researchers simply bought into the standard model that maps our notion of human intelligence onto machine intelligence: humans have objectives and pursue them, so machines should have objectives and pursue them.[66]

From this we can infer that the Socratic AMA's virtuous actions can be measured insofar as human virtuous objectives (that is, virtuous actions) are subject to measurement.

The same applies to predictive AI systems, which use AI to anticipate what is likely to happen through analysis of gathered data. The term "predictive" should not be understood in the very sense of the word. The gathered data for predictive AI systems prove that predictive AI is reliant upon existing social contexts and decision making policies.[67] From this perspective, we can see that the Socratic AMA with a predictive system does not operate in an immeasurably predictive way. Rather, AI-powered mathematical and statistical methods for data analysis make it evident that the Socratic AMA's virtuous actions are not the same as human actions flowing from divinely infused virtues. As such, the Socratic AMA can never become as virtuous as humans in that immeasurable infused virtues cannot be embedded within AI systems through measurable models and algorithms. Having received detailed instructions from humans through measurable models and algorithms, the Socratic AMA becomes virtuous in the sense that its moral questions are imbued with the purposes of virtues to guide human agents toward the cultivation of virtues through addressing moral dilemmas.

The above three observations made in light of Aquinas's theology of virtue foreground the particularities of virtuous human agents in contrast to AI, showing that the Socratic AMA cannot be as virtuous as humans. Given that Aquinas's view of virtue is anthropocentric, one may ask whether the Socratic AMA is virtuous in a broader sense. To be sure, the Socratic AMA is expected to possess powerful capacities to gather information related to our moral life and rapidly process this information to identify certain lurking issues (e.g., logical contradiction) and to generate moral advice. Yet, the Socratic AMA's moral questioning related to limited circumstances can be of help to the cultivation of virtues. We also need to bear in mind the role that human agents play in designing, programming, using AI, through which, as stressed above, virtue-related purposes can be imposed upon the Socratic AMA. In this way, the Socratic AMA becomes virtuous when its embedded purpose-oriented virtues are actualized through questioning human agents for the sake of their virtuous lives.

Conclusion

Is the Socratic AMA or AI virtuous? This article is not intended to leverage an anthropocentric definition of virtue to combat the qualification of AI as virtuous. What has been demonstrated above shows that the Socratic AMA's moral questioning is considered virtuous insofar as it can be created with purpose-oriented virtues for the cultivation of human virtues.

Be that as it may, the Socratic AMA is not virtuous in the same sense as virtuous human agents. Aquinas's theology of virtue brings to light the conceptual particularities of virtue with reference to human agents. Since the subject of virtue is the soul and the mind, the technological impossibility of reproducing the mind turns out to be the impossibility of emulating the function within AI to habituate virtues as its own nature. From the theological perspective, the teleological and immeasurable features of virtues intensify the technological impossibility of creating a human-level AI to offer humans moral advice while humans are caught up in moral dilemmas.

In a nutshell, Aquinas's theology of virtue underscores the distinctiveness of humans as virtuous agents while leaving open the possibility that the Socratic AMA can be considered virtuous in the sense of delegation. It can be anticipated that AI with delegated virtues can assist humans in their cultivation of virtues provided that it does not operate as a moral decision maker in place of humans. After all, it is the virtues habituated as the second nature of human beings that need to be cultivated through addressing moral dilemmas.

Acknowledgment

A short version of this article was presented at the conference 'Virtuous AI?: Cultural Evolution, Artificial Intelligence, and Virtue,' hosted by the Centre for Theology and the Natural Sciences of the Graduate Theological Union in Berkeley, California. I am grateful to Prof. Bob Russell (the Principal Investigator of the Program) and Dr. Braden Molhoek (Program Director) for organizing this conference.

Notes

[1]See, e.g., Luciano Floridi and J. W. Sanders, "On the Morality of Artificial Agents," *Minds and Machine* 14, no. 3 (2004): 349–79, http://dx.doi.org/10.1023/B:MIND.0000035461.63578.9d.

[2]Ximian Xu, "A Theological Account of Artificial Moral Agency," *Studies in Christian Ethics* 36, no. 3 (2023): 642–59, https://doi.org/10.1177/09539468231163002.

[3]Shannon Vallor, *Technology and the Virtues: A Philosophical Guide to a Future Worth Wanting* (Oxford: Oxford University Press, 2016).

[4]Robert Sparrow, "Virtue and Vice in Our Relationships with Robots: Is There an Asymmetry and How Might It Be Explained?," *International Journal of Social Robotics* 13 (2021): 23–29, https://doi.org/10.1007/s12369-020-00631-2.

[5]See, e.g., Michael Cuellar, "A Virtue Ethical Approach to the Use of Artificial Intelligence," *Data and Information Management* (2023), https://doi.org/10.1016/j.dim.2023.100037 (withdrawn article in press).

[6]Ingmar Persson and Julian Savulescu, "The Perils of Cognitive Enhancement and the Urgent Imperative to Enhance the Moral Character of Humanity," *Journal of Applied Philosophy* 25, no. 3 (2008): 162–77, https://doi.org/10.1111/j.1468-5930.2008.00410.x; also see Parker Crutchfield, *Moral Enhancement and the Public Good* (New York: Routledge, 2021), 42–73.

[7]See, for example, Harris Wiseman, "The Sins of Moral Enhancement Discourse," *Royal Institute of Philosophy Supplement* 83 (2018): 35–58, https://doi.org/10.1017/S1358246118000280; and Celia Deane-Drummond, "The Myth of Moral Bio-Enhancement: An Evolutionary Anthropology and Theological Critique," in *Religion and Human Enhancement: Death, Values, and Morality*, ed. Tracy J. Trothen and Calvin Mercer (Cham, Switzerland: Palgrave Macmillan, 2017), 175–90.

[8]Interestingly, Julian Savulescu endorses this criticism; see Julian Savulescu and Hannah Maslen, "Moral Enhancement and Artificial Intelligence: Moral AI?," in *Beyond Artificial Intelligence: The Disappearing Human-Machine Divide*, ed. Jan Romportl, Eva Zackova, and Jozef Kelemen (Cham, Switzerland: Springer, 2015), 80.

[9]Francisco Lara and Jan Deckers, "Artificial Intelligence As a Socratic Assistant for Moral Enhancement," *Neuroethics* 13 (2020): 275–87, https://doi.org/10.1007/s12152-019-09401-y.

[10]Ibid., 276.

[11]Ibid., 277. Following this major criticism, they raise further objections to exhaustive enhancement: moral pluralism, human or nonhuman fallibility, doubts on the autonomous status of machines, impossibility of moral progress, implying the death of morality (pp. 277–80).

[12]Blay Whitby, "Computing Machinery and Morality," *AI & Society* 22 (2008): 559, https://doi.org/10.1007/s00146-007-0100-y.

[13]Ibid., 561.

[14]Savulescu and Maslen, "Moral Enhancement and Artificial Intelligence"; and Alberto Giubilini and Julian Savulescu, "The Artificial Moral Advisor. The 'Ideal Observer' Meets Artificial Intelligence," *Philosophy & Technology* 31, no. 2 (2018): 169–88, https://doi.org/10.1007/s13347-017-0285-z.

[15]Savulescu and Maslen, "Moral Enhancement and Artificial Intelligence," 80.

[16]Lara and Deckers, "Artificial Intelligence As a Socratic Assistant for Moral Enhancement," 281.

[17]Ibid., 281–82.

[18]Ibid., 282.

[19]Ibid., 283–84.

[20]Jinxiao Zhang, Yang Yang, and Ying-Yi Hong, "Sleep Deprivation Undermines the Link between Identity and Intergroup Bias," *Sleep* 43, no. 2 (2020): zsz213, https://doi.org/10.1093/sleep/zsz213.

[21]Lara and Deckers, "Artificial Intelligence As a Socratic Assistant for Moral Enhancement," 284.

[22]Francisco Lara, "Why a Virtual Assistant for Moral Enhancement When We Could Have a Socrates?," *Science and Engineering Ethics* 27, no. 4 (2021): 42, emphasis added, https://doi.org/10.1007/s11948-021-00318-5.

[23]Given the limited space, this article does not offer a detailed treatment of the important place of moral theology in Aquinas's thought. For a helpful overview of his moral theology, see Stephen J. Pope, "Overview of the Ethics of Thomas Aquinas," in *The Ethics of Aquinas*, ed. Stephen J. Pope (Washington, DC: Georgetown University Press, 2002), 30–53.

[24]Thomas Aquinas, *Summa Theologiae*, ed. The Aquinas Institute and trans. Fr. Laurence Shapcote, Latin/English Edition of the Works of St. Thomas Aquinas, vols. 13–20 (Green Bay, WI: Aquinas Institute, 2012), II–II, pr. Hereafter *ST*.

[25]*ST*, I–II, q.49, art.1, resp.

[26]*ST*, I–II, q.49, art.1, s.c.; and art.3, ad.3.

[27]Bonnie Kent, "Habits and Virtues (Ia IIae, Qq. 49–70)," in *The Ethics of Aquinas*, ed. Pope, 116.

[28]*ST*, I–II, q.49, art.3, s.c.

[29]*ST*, I–II, q.49, art.3, ad.1. Thus, Aquinas contends, 'Wherefore habit is called first act, and operation, second act.'

[30]*ST*, I–II, q.50, art.1, resp. It is beyond the scope of this article to discuss Aquinas's view of the connection between human body and morality. On a critical inquiry into this view in *Summa Theologiae*, see Marika Rose, "The Body and Ethics in Thomas Aquinas' *Summa Theologiae*," *New Blackfriars* 94, no. 1053 (2013): 540–51, https://doi.org/10.1111/nbfr.12016. In any case, Aquinas's view of ethics cannot be simply construed as rationalist or being preoccupied with the soul. Rather, his view of habit and virtue pays due attention to the whole being of humans.

[31]*ST*, I–II, q.50, art.2, resp.

[32]*ST*, I–II, q.55, art.1, resp; emphasis added.

[33]*ST*, I–II, q.55, art.4, ad.3.

[34]*ST*, I–II, q.55, art.4, resp; also see Thomas Aquinas, "On the Virtues in General," in *Disputed Questions on the Virtues*, ed. E. M. Atkins and Thomas Williams, trans. E. M. Atkins (Cambridge, UK: Cambridge University Press, 2005), art.1, s.c.

[35]*ST*, I–II, q.56, art.3, s.c.

[36]*ST*, I–II, q.56, art.3, resp; and q.50, art.5, resp.

[37]*ST*, I–II, q.56, art.2, resp.

[38]*ST*, I–II, q.54, art.2, ad.3.

[39]Jeffrey E. Brower, "First Principles: Hylomorphism and Causation," in *The New Cambridge Companion to Aquinas*, ed. Eleonore Stump and Thomas Joseph White (Cambridge, UK: Cambridge University Press, 2022), 50.

[40]*ST*, I, q.12, art.7, ad.1; and *ST*, I–II, q.11, art.3, ad.3.

[41]Aquinas asserts that "there are some habits by which man is disposed to an end which exceeds the proportion of human nature, namely, the ultimate and perfect happiness of man … Wherefore such habits can never be in man except by Divine infusion, as is the case with all gratuitous virtues" (*ST*, I–II, q.51, art.4, resp.).

[42]*ST*, I–II, q.62, art.1, s.c. Aquinas maintains that these virtues are characterized as theological for the following reason:

> it is necessary for man to receive from God some additional principles, whereby he may be directed to supernatural happiness, even as he is directed to his connatural end, by means of his natural principles, albeit not without Divine assistance. Such like principles are called *theological virtues*: first, because their object is God, inasmuch as they direct us aright to God: second, because they are infused in us by God alone: third, because these virtues are not made known to us, save by Divine revelation, contained in Holy Writ. (*ST*, I–II, q.62, art.1, resp.)

[43]*ST*, I–II, q.63, art.3, resp. The term "cardinal virtues" connotes that these virtues imply the rectitude of appetite, which "not only confers the faculty of doing well, but also causes the good deed done." Hence, these virtues are principal among moral virtues (*ST*, I-II, q.61, art.1, resp.).

[44]*ST*, I–II, q.63, art.2, resp.

[45]Aquinas, "On Hope," in *Disputed Questions on the Virtues*, ed. E. M. Atkins and Thomas Williams, trans. E. M. Atkins (Cambridge, UK: Cambridge University Press, 2005), art.1, ad.7.

[46]*ST*, I–II, q.64, art.4, resp. As Justin Anderson notes, for Aquinas, the "measures themselves arise according to the different ends toward which one moves," *Virtue and Grace in the Theology of Thomas Aquinas* (Cambridge, UK: Cambridge University Press, 2020), 32.

[47]*ST*, I–II, q.62, art.2, resp; also see Thomas Aquinas, *On Love and Charity: Readings from the Commentary on the Sentences of Peter Lombard*, trans. Peter A. Kwasniewski, Thomas Bolin, and Joseph Bolin (Washington, DC: Catholic University of America Press, 2008), III, dist.23, q.1, art.4, s.c. In *Aquinas's Ethics: Metaphysical Foundations, Moral Theory, and Theological Context* (Notre Dame, IN: University of Notre Dame Press, 2009), Rebecca Konyndyk DeYoung, Colleen McCluskey, and Christina Van Dyke, observe that "[t]he three theological virtues function as the roots of all other virtues, shaping the deepest orientation of our person and informing every other inclination and movement relevant to moral action" (p. 142).

[48]Thomas M. Osborne Jr., *Thomas Aquinas on Virtue* (Cambridge, UK: Cambridge University Press, 2022), 23.

[49]John Sullins, "When Is a Robot a Moral Agent?," in *Machine Ethics*, ed. Michael Anderson and Susan Leigh Anderson (Cambridge, UK: Cambridge University Press, 2011), 151–61.

[50]Robert Sparrow, "Why Machines Cannot Be Moral," *AI & Society* 36, no. 3 (2021): 688, https://dl.acm.org/doi/10.1007/s00146-020-01132-6.

[51]For a recent in-depth study on this front, see Yuxin Liu et al., "Artificial Moral Advisors: A New Perspective from Moral Psychology" (paper presented at the Proceedings of the 2022 AAAI/ACM Conference on AI, Ethics, and Society [AIES '22], Oxford, UK, August 1–3, 2022), 436–45.

[52]Kenneth Einar Himma, "Artificial Agency, Consciousness, and the Criteria for Moral Agency: What Properties Must an Artificial Agent Have to Be a Moral Agent?," *Ethics and Information Technology* 11, no. 1 (2009): 19–29, https://dl.acm.org/doi/10.1007/s10676-008-9167-5.

[53]Richard A. Spinello, "Karol Wojtyla on Artificial Moral Agency and Moral Accountability," *The National Catholic Bioethics Quarterly* 11, no. 3 (2011): 496, https://www.pdcnet.org/C1257D43006C9AB1/file/FF4F20AE689EB31785257D8E0061BA79/$FILE/ncbq_2011_0011_0003_0061_0083.pdf.

[54]*ST*, I–II, q.56, art.3, resp.

[55]*ST*, I–II, q.56, art.6, resp.

[56]Antonio R. Damasio, "Neuroscience and Ethics: Intersections," *The American Journal of Bioethics* 7, no. 1 (2007): 3–7, https://doi.org/10.1080/15265160601063910.

[57]Jobst Landgrebe and Barry Smith, *Why Machines Will Never Rule the World: Artificial Intelligence without Fear* (New York: Routledge, 2022), 248.

[58]Mark Coeckelbergh, *AI Ethics* (Cambridge, MA: The MIT Press, 2020), 37.

[59]*ST*, II-II, q.81, art.2-6. For Aquinas, "religion is not a theological virtue whose object is the last end, but a moral virtue which is properly about things referred to the end" (q.81, art.5, resp.).

[60]For example, see Yong Sup Song, "Religious AI As an Option to the Risks of Superintelligence: A Protestant Theological Perspective," *Theology and Science* 19, no. 1 (2021): 65-78, https://doi.org/10.1080/14746700.2020.1825196; and Eugene A. Curry, "Artificial Intelligence and Baptism: Cutting a Gordian Knot," *Theology and Science* 20, no. 2 (2022): 156–65, https://doi.org/10.1080/14746700.2022.2051248.

[61]Mihaela Constantinescu et al., "Blame It on the AI? On the Moral Responsibility of Artificial Moral Advisors," *Philosophy & Technology* 35 (2022): 14, https://doi.org/10.1007/s13347-022-00529-z. Furthermore, they observe that "it is always up to the users to decide whether to act upon the advice offered by the AMAs" (p. 15).

[62]For some scholars, this value-loaded feature of AI underpins AI ethics. For example, in "Responsibility and Artificial Intelligence," in *The Oxford Handbook of Ethics of AI*, ed. Markus D. Dubber, Frank Pasquale, and Sunit Das (Oxford, UK: Oxford University Press, 2020), Virginia Dignum argues:

> Artificial intelligence systems use data we generate in our daily lives and as such are a mirror of our interests, weaknesses, and differences. Artificial intelligence, like any other technology, is not value-neutral. Understanding the values behind the technology and deciding on how we want our values to be incorporated in AI systems requires that we are also able to decide on how and what we want AI to mean in our societies. (p. 221)

[63]Sara Lumbreras, "Lessons from the Quest for Artificial Consciousness: The Emergence Criterion, Insight-Oriented AI, and *Imago Dei*," *Zygon: Journal of Religion and Science* 57, no. 4 (2022): 973, https://doi.org/10.1111/zygo.12827.

[64]Lara and Deckers, "Artificial Intelligence As a Socratic Assistant for Moral Enhancement," 284.

[65]Peter Flach, *Machine Learning: The Art and Science of Algorithms That Make Sense of Data* (Cambridge, UK: Cambridge University Press, 2012), 13.

[66]Stuart Russell, *Human Compatible: Artificial Intelligence and the Problem of Control* (New York: Viking, 2019), 176.

[67]Further, see Michael L. Littman et al., *Gathering Strength, Gathering Storms: The One Hundred Year Study on Artificial Intelligence (AI100) 2021 Study Panel Report*, Stanford University (Stanford, CA, September 2021), 63–64, http://ai100.stanford.edu/2021-report.

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DOI: https://doi.org/10.56315/PSCF9-24Miller

Contemporary Challenges to the Pursuit of Truth

Keith B. Miller

In our current cultural climate, a growing problem is not so much the abandonment of belief in truth, but the absence of a commonly held basis upon which to discern between competing truth claims. This problem goes far beyond the rejection of established scientific paradigms, to the inability to agree on truth claims of any kind, even objective observational facts. Without a shared reality, there can be no shared pursuit of truth rooted in observations of a real universe. There are thus no common criteria by which statements about the world, and events in that world, can be judged. This lack of agreement on how to evaluate truth claims, and the divisions that result, is a cause for concern in both the secular and Christian communities.

Keywords: nature of science, consensus, historical context, cultural diversity, confirmation bias

Obstacles to the Pursuit of Truth

In recent years, social media and polemical "news" have gained increasing influence over society. The various social media platforms have also enabled the extremely rapid dissemination of falsehoods, misrepresentation, and conspiracies. The worldwide web has given us access to an almost unlimited volume of unfiltered information and opinion. As a result, it has become increasingly difficult for individuals to discern the difference between truth and error. Almost any falsehood will find a ready online community of people who will accept and promote it. As a consequence, encompassing false realities are being created.

There are several underlying factors that have come together in our current culture to undermine a common understanding of pathways to greater knowledge of the truth. These factors have resulted in unfounded attacks on foundational scientific conclusions and the rise of alternative scientific claims inconsistent with current evidence and practice. However, more than just scientific claims are faced with these challenges. The inability to critically evaluate truth claims has affected all areas of human knowledge, social interaction, and historical understanding.

Obtaining a broad cultural acceptance of the standards by which truth claims are evaluated requires confronting a number of widespread barriers to the pursuit of truth. These barriers are the following:

1. The absence of shared presuppositions and methodologies needed to ground the pursuit of truth and reject claims without evidentiary support;
2. The loss of trust in the consensus views of expert communities, allowing the views of anyone to be treated as equally authoritative;
3. The lack of historical knowledge, or a rejection of its value, that removes a critical foundation for understanding and evaluating truth claims and correcting biases;
4. The increased polarization of society separating people into like-minded communities so that they are isolated

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from diverse disciplinary, cultural, and religious perspective; and

5. Probably most significantly, the ubiquitous presence of personal confirmation bias, and our temptation to reflexively defend our views.

The Absence of Shared Presuppositions and Methodologies

Our knowledge of the physical universe rests on several basic presuppositions: (1) there is an objective physical reality independent of the observer; (2) our senses give us real information about that physical reality; and (3) that reality is substantially comprehensible to us.[1] This understanding of truth is called realism. Realism is based on the commonsense arguments of eighteenth-century philosopher Thomas Reid, who advocated it as the only secure foundation for philosophy and science.[2] We pursue knowledge that corresponds with reality—that which is true. The object of knowledge is to move our understanding closer to the truth of the objective reality of the universe.

Furthermore, our perceptions and truth claims must be tested against that objective reality. As stated by Hugh Gauch, "… presuppositions answer the question: How can we reach any conclusion to an inquiry? But evidence answers the question: How can we assert one particular conclusion rather than another?"[3] In short, observational evidence matters.

In contrast to realists, skeptics and relativists claim that all that we have are our personal perceptions, and they deny that the world is objectively real or comprehensible. As summarized by Gauch, "Relativism accepts personal truth-for-me but not public truth-for-everyone, so there is no objective and shared knowledge about the world such as the scientific community claims."[4] In our current culture, it is not uncommon to hear truth used as a synonym for what any particular group, or individual, believes. It is as though I can have my "truth" and you can have your "truth." If truth is to have any meaning at all, it is that it represents the real nature and history of the universe, and the real history of human events. In this sense, there are no competing alternative "truths."

A belief in a creator God whose character and being are unchanging undergirds belief in an objective reality. It similarly provides a basis for the expectation that the natural world follows regular, consistent, and predictable patterns. Such an expectation undergirds the practice of science as well as the ability to practically interact with the natural world around us. Furthermore, the belief that God does not lie or deceive gives us confidence that our senses provide access to true aspects of the physical creation. The "very good" physical creation, and our own physical embodiment, validate the value and truthful integrity of physical reality. Truth claims that deny or reject the testimony of our senses are inconsistent with a creator God who is a God of truth. Such a denial also makes the search for truth rudderless.

What is true about the universe is true regardless of whether we know it, or believe it, to be true. It is the pursuit of the objective truth of the physical universe that unites all the sciences. We continually strive to obtain the knowledge of that truth, yet complete knowledge remains elusive. No one knows the full truth about anything. But we can have confidence that our search can move us ever closer to a fuller knowledge and understanding of reality. We progress in our knowledge of the truth through the continual testing of our limited conceptions against observations of that external reality.

In addition to the broad essential presuppositions necessary for the pursuit of science, there are related fundamental perspectives that undergird the description and interpretation of our observations of physical reality. These include the recognition that observational "facts" are not the goal, but rather, it is the construction of explanatory theories that give meaning to our observations and provide the predictions that guide further research. Furthermore, theories are not widely held because they are "proven," but because they provide the best current explanation of a wide range of observations. Much of the public rejection of scientific conclusions is rooted in misunderstanding these and other aspects of the nature of science.[5]

Science education at all levels needs to incorporate how knowledge of the natural world is actually acquired.

> The nature of science needs to be taught as part of the subject content, and currently accepted theories need to be understood as the result of a long process of rigorous testing and challenge within a diverse community of scientists. Students need to understand science as a dynamic, exciting, open-ended, and thoroughly human activity. Science is

> a process of developing explanations for how our natural world works, of making sense of our diverse observations of the world around us.[6]

The absence of a common basis for testing truth claims results in the individual becoming the arbiter of truth. Our perceptions of truth must be continually tested against external reality, and against the perceptions of others similarly pursuing the objective truths of the universe. We do not construct truth but discover it, and discovery requires engagement with the real world.

Practically, the pursuit of truth occurs in specialized communities of individuals that share a particular interest and expertise. Each discipline, each area of knowledge or skill, has its own set of standards and methods, and its own unique perspective and contribution to a broader understanding of truth. A more complete picture of reality requires integration of these diverse disciplines. Furthermore, because science is limited to describing only natural phenomena in terms of natural causal agents, a full understanding of reality requires conversations with bearers of knowledge outside of science. Science is not the sole arbiter of truth.

While holding basic presuppositions and interests in common, the members of a discipline community also need to cross boundaries of nationality, race, religious affiliation, culture, sexual identity, etc. Our individual perspectives are informed by our personal experiences and cultural histories, and thus have a limited scope with unrecognized blind spots. A fuller and truer understanding of a topic thus requires the consideration of perspectives other than our own. Isolated individuals or groups are much more likely to fall into serious error. This is as true in the discernment of moral and spiritual truth as it is in seeking knowledge of the natural world.

We must always be aware that our knowledge of the truth is limited and is always subject to correction. We are imperfect beings, and our knowledge is imperfect and incomplete, and always will be. Our understanding of truth (both physical and spiritual) is not static but evolves. There are no "proven" understandings of reality that are not potentially subject to change. We need to hold our understanding of truth with an open hand. Refusal to change one's understanding of what is true is not praiseworthy, if that understanding is in error. Being willing to doubt one's positions and beliefs is not a sign of intellectual or spiritual weakness, but an acknowledgment of our incomplete knowledge. As stated by Os Guinness, "If doubt is eventually justified, we were believing what clearly was not worth believing. But if doubt is answered, our faith has grown stronger still."[8]

The Loss of Trust in the Consensus of Expert Communities

The views of the expert community within a discipline matter. That community is the repository for the body of knowledge in that discipline. Our knowledge is always cumulative; it is built on the observations, insights, and explanatory models that have gone before. Previous understandings of reality are absorbed into the new. Despite the shifts—even dramatic ones—in the accepted models and theories that make sense of our world, there is continuity. Any new consensus view must make sense of all that came before.

Consensus within a discipline is hard won. A community of trained experts is by nature conservative and resistant to change. New ideas must prove themselves by accumulating a persuasive body of evidence in their support that is able to win over the practitioners of a discipline. Consensus does not mean unanimity, but it represents the current best-supported position on the topic of interest. The current consensus may be in error, but it cannot be dismissed. Where there is no consensus on a question, positions should be held more lightly.

The search for truth is a cooperative and community endeavor, and the consensus of that community provides stability and direction to that search. It keeps the research community working together toward a common goal, preventing the fragmentation of that community into numerous groups pursuing unsupported ideas and hypotheses.

This community approach is as critical to the pursuit of theological truth as to truth about the natural world. Theological consensus helps keep the church from being "blown here and there by every wind of teaching" (Eph. 4:14).

Within the scientific community, peer review is an important component of the testing of ideas and claims within a particular discipline. This first step of critical review seeks to evaluate whether an author has followed accepted methods of data collection, processing, and interpretation. Passing peer

review does not promise acceptance by the larger community, but rather, it provides the opportunity to persuade others of the value of the contribution. Articles rejected by peer review, or later retracted, have been used to gain public support for marginal views that conflict with consensus. This can have real, practical, and damaging consequences for the public.[9]

Critical review is needed in the pursuit of any truth, not just in the context of scientific research. Ideas need to be set before the broader community of relevant experts for productive dialogue and critical evaluation. Communication among practitioners within and across all disciplines is necessary to test ideas and discover errors. In pursuit of truth, we should not fear this testing, critique, and challenge of our ideas and beliefs. We are all certainly in error at some points in virtually anything that we accept as true. Those errors will not be found out, if we remain isolated from other perspectives. Our tendency toward confirmation bias makes the interaction with a diverse community even more pressing.

In his essay on the search for theological truth, William Badke wrote as follows:

> An increasing body of research is making it plain that our supposed dispassionate rationalism by which we make decisions based on evidence is in good measure an illusion. We are plagued by a tendency toward confirmation bias, by which we give greater credence to evidence that supports our existing beliefs, and we discount contradictory voices. None of us are immune from such bias. It supports our propensity to fall for fake social media reports that confirm our present views. It also causes us to downplay academic evidence that contradicts our current beliefs, even as we buy into potentially faulty evidence that agrees with our position.[10]

This tendency is manifest in deciding on the veracity of any truth claim.

The proliferation of literature, online resources, and institutions that promote marginal positions that are divorced from critical review by the larger community prevents the proper testing of ideas. Furthermore, false views can gain widespread support if presented to the public without, or in defiance of, criticism and correction. It is in the process of seeking consensus—of having our ideas and beliefs challenged and tested within a diverse community—that our errors and biases can be exposed and corrected.

One of the common misunderstandings about science is that individuals or groups isolated from the larger community of practitioners can successfully do good science and move our understanding forward. As emphasized by Henry Bauer, "If one understands that science is inescapably a cooperative enterprise, one can appropriately view as pseudoscience any claims made from outside the competent, relevant scientific community."[11] Given our desires to see our current views supported, such isolation is an invitation to error. This is equally true within non-scientific disciplines.

Badke emphasizes the importance of expert communities in the search for truth.

> We do need to be searching for truth, defined as what is substantially correct and in agreement with the best evidence. But I don't think it's a simple path in our diverse world. Let me suggest this: We need to return to a world in which we trust the expertise of those who know. … Experts operate within a guild, a consortium of people who share the same kind of expertise and methodology. They critique and judge the contributions of one another according to standards that have stood the test of time. … Just remember that everything experts know is open to challenge by other experts. That is how the best knowledge environment works, ever being tested with new evidence, ever being nuanced with better understanding. When we lose the web of expertise that can make our information properly testable, we lose the very foundation of our society.[12]

The desire to confirm already firmly held views causes people to look to sources of authority outside of the relevant expert communities for information and answers to questions. These authorities are often chosen because they confirm one's views and on the basis of personality, charisma, or personal relationship, whereas the positions of experts that challenge those views are greeted with skepticism or outright rejection. Such alternative authorities have themselves typically not made the effort to understand the basis for positions they dispute, and they often lack knowledge of the topics for which they claim authority. The rise of the Web and social media, and the access to unfiltered information, has made finding such alternative authorities very easy. As stated by Badke,

> It's become common for people to view experts as biased, authoritarian, elitist, out of touch—you name the accusation. The rise of digital access has only exacerbated the problem, leveling knowledge and its creators, so that we are much more likely to

> determine authority on the basis of what sounds right to us.[13]

Furthermore, the vast prevalence of social media has resulted in the tendency for people to accept false claims and disseminate them without first testing.

As stated by Steven Novella, the easy access to unfiltered information

> … creates the powerful illusion of knowledge—I have a world of facts at my finger tips, with no middle-man to get in the way or decide which facts to feed me. Trust in experts and authority has collapsed.[14]

Countering this tendency requires significant personal work. Novella writes:

> That work involves the various processes of critical thinking. We have to evaluate experts, authorities, and claims based upon objective criteria—facts and logic. But more than this (because even flat-earthers think they do this) we need to step back from our beliefs and our own biases and try to chart as objective a path as possible. We have to try to prove ourselves wrong. We need to divorce our own identities and sense of worth and tribalism from any particular conclusion, and take pride instead in the validity of the process.[15]

The Lack of Historical Knowledge

All current knowledge is embedded in a historical context. Our current body of knowledge, theoretical conceptions, and technology is one point on a historical continuum built upon the past and open to the future. It is also a reflection of cultural and social contexts at particular times and places. As stated by Nicholas Rescher,

> Our theorizing about the nature of the real is a fallible estimation, the best that can be done at this time, in this particular state of the art. Our science is a historical phenomenon; it is one transitory state of things in an ongoing process.[16]

Furthermore,

> there is nothing epistemically privileged about the present—any present, our own prominently included. Such a perspective indicates not only the incompleteness of our knowledge but its presumptive incorrectness as well.[17]

What we currently understand as true is the result of a historical process of correction, modification, and expansion. Our understanding of truth, all truth, is dynamic and progressive. The practice of any discipline requires a knowledge of its historical foundations. Time and place matter. Historical context provides a critical foundation for understanding and evaluating current claims. Truth claims do not appear in a vacuum.

An understanding of the history of ideas is the basis for answering critical questions.

- Why do we know what we know?
- Why do we hold the position on a topic that we do?
- What has caused past perspectives or understandings to be replaced?
- What is the context in which a particular truth claim was made?
- What evidence was used to support the claim?
- Was there a particular motive involved (was the claim made in support of a larger argument)?

The answers to these questions provide the context needed to approach the search for truth with humility and openness to correction and change.

History is our teacher, and all disciplines need to be taught in a historical context. Without historical knowledge, our current understandings and beliefs are unanchored. Without it, we don't really know why we believe the things that we do. History provides a foundation for current knowledge which is always the end result of a long process of change, discovery, and correction. Knowledge of the history of ideas guards against being deceived. A historical perspective also brings a certain humility and recognition that our current understandings are incomplete, and in some ways wrong. Loss of historical memory leads to hubris and the repetition of past errors.

History is about remembering, and historical context provides the scaffolding that supports confidence in particular truth claims, while bringing into question others. There is a reason why the prophets in scripture repeatedly call people to remember. God is the God of history and is revealed in history. Remembering helps to guard against repeating previous errors. There is a great wealth of recorded human experience, both good and bad, for us to learn from. We may find answers to our own questions and direction in our own circumstances through the record of the thoughts, questions, struggles, and failures of those before us.

History also helps us understand the influence of culture on what we accept as true. Even our understandings of the physical universe are conditioned by cultural context. As stated by David Livingstone, "... science is not above culture; it is part of culture. Science does not transcend our particularities; it discloses them. Science is not a disembodied entity; it is incarnated in human beings."[18] What is true of science is true of all knowledge. We are all products of our culturally inherited worldviews and histories. Cultural, national, and individual histories all matter.

The dominance of white European perspectives minimizes the contributions and values of other cultures, and it also feeds into caricatures that reinforce racial and cultural biases. As argued by Allison Skinner-Dorkenoo,

> The concentration of power and privilege among white people in the USA means that white people largely write the histories, set the norms and define the values of American society. This centering of white people can be seen in historical narratives, cultural products and cultural beliefs, which can all contribute to the development of individual-level racial biases.[19]

Furthermore,

> the same history and culture can be represented differently depending on who is curating and constructing the representation.[20]

Because our understanding of the world and our approach to understanding it are influenced by our culture, it is important that we listen to the perspectives of those with different worldviews if we are to honestly pursue universal truths. It is especially important to recognize the history and culture of minority and non-western communities. For example, the histories of the Black and indigenous communities provide unique perspectives that can inform our understanding relative to a wide range of questions concerning land stewardship, resource extraction, economics, social justice, and many more. This will be discussed in more detail in the following section.

Isolation from Diverse Perspectives

There are two basic ways in which the pursuit of knowledge has been fragmented. Firstly is the division of knowledge into increasingly highly specialized compartments. At the same time, answers to many of our most pressing problems require broad interdisciplinary efforts. These include climate change and its repercussions, ecological consequences of resource extraction, gene editing and its application and ethics, artificial intelligence development and application, and many others. The lack of collaboration across disciplines becomes a barrier to advancing our knowledge. Collaboration is a necessity, not only between the various scientific disciplines, but also between the science disciplines and all other areas of human knowledge and experience. This includes the perspectives of the arts, philosophy, history, religion, and other disciplines.

The second way in which knowledge has been fragmented is by the lack of productive interaction with individuals who are not part of the white western European cultural inheritance. Multiple expert communities with different cultural, historical, and religious perspectives exist within any particular area of study. Engaging with these diverse perspectives can result in a more complete and fruitful consensus. There is a particular need for the inclusion of the cultural perspectives of marginalized and indigenous communities that have largely been locked out of any meaningful contribution to global institutions of learning and practice.

Indigenous peoples have largely been excluded from contributing to the advancement of knowledge. This is particularly apparent in environmental science and conservation. In their analysis of indigenous contributions, Diana Lewis, Lewis Williams, and Rhys Jones state,

> While it is generally accepted that Indigenous knowledges (IK) hold much significance for climate change strategies, culturally dominant Eurocentric social structures, norms and conventions ensure their marginalization at broader and more influential decision-making levels.[21]

The perspectives of indigenous women are particularly valuable. Furthermore,

> … changes wrought by climate change are generally exacerbating the colonial-rooted inequalities that Indigenous women have historically experienced, yet little research has been conducted from an Indigenous feminist perspective.[22]

Melanie Zurba and Anastasia Papadopoulos similarly state,

> Even though it is widely agreed that indigenous participation and knowledge is critical to effective environmental governance, a frequent commentary

> and position presented from the articles reviewed was that representation of indigenous peoples is often overlooked or outwardly denied in global governance spaces.[23]

At a more individual level, indigenous knowledge and research meets considerable resistance from a scientific community that is trained in an "objective" approach that distances itself from what is studied.

Robin Wall Kimmerer gives voice to this disconnect in her wonderful book Braiding Sweetgrass.

> My natural inclination was to see relationships, to seek the threads that connect the world, to join instead of divide. But science is rigorous in separating the observer from the observed, and the observed from the observer.[24]

Furthermore,

> Getting scientists to consider the validity of Indigenous knowledge is like swimming upstream in cold, cold water. They've been so conditioned to be skeptical of even the hardest of hard data that bending their minds toward theories that are verified without the expected graphs or equations is tough. Couple that with the unblinking assumption that science has cornered the market on truth and there's not much room for discussion.[25]

Amanda Black and Jason Tylianakis have argued that indigenous knowledge can "complement and enhance" the teaching of science and will benefit both students and society in the face of global environmental challenges.[26]

Gender is also an area where there is inequity in the contribution to the advancement of knowledge. Until very recently, women were largely excluded from making important contributions to scientific research. Jane Goodall recounts how her approach to her field studies of chimpanzees ran afoul of the expected detached treatment of her subjects.

> In order to collect good, scientific data, one is told, it is necessary to be coldly objective. You record accurately what you see and, above all, you do not permit yourself to have any empathy with your subjects. Fortunately I did not know that during the early months at Gombe. A great deal of my understanding of these intelligent beings was built up just *because* I felt such empathy with them.[27]

Goodall's work ended up transforming our understanding of primate behavior. Without her breaking through others' expectations, we would not have gained much of our present understanding of primates.

This same problem of excluding minority voices has also influenced biblical interpretation and theological perspectives. The lived history of the African American community has much to contribute to our understanding of scripture and religious practice. As Esau McCaulley argues,

> If our cultures and histories define the totality of our interpretive enterprise, the price of admission can be complete acquiescence to that culture's particularities. This is as true with European domination of the text as it would be if Black culture completely sets the contours for the debate. But if we all read the biblical text assuming that God is able to speak a coherent word to us through it, then we can discuss the meanings our varied cultures have gleaned from the Scriptures.[28]

Drew Hart has similarly emphasized that the experiences of the Black church give it special insight into the teachings of Jesus. Poor, marginalized, and oppressed communities have much to teach the church about the meaning of scripture and the expression of the Kingdom of God.[29]

The easy access to unfiltered information has ironically increased our isolation and polarization by allowing people to stay within their own echo chambers and by preventing communication across divides. This has been accentuated in recent years as social media platforms and polemical programming have gained increasing influence over society. The separation of people into like-minded communities has prevented interaction between people of different races, cultures, sexual orientations, national identities, religious affiliations, political allegiances, educational backgrounds. Consequently, different competing perspectives exist within different communities.

This lack of interaction with people different from us not only deprives us of valuable insights, but also leads to misunderstanding, prejudice, and fear. People often fear what they do not know or understand. Listening to the experience of others is an important beginning in our understanding of the basis for their views and perspectives. It also allows us to be more attentive to how our own cultural, religious, and economic inheritance has shaped our views, both positively and negatively.

The vision of the Kingdom of God is one of ethnic and racial diversity (see Rev. 7:9–10). However, the reality is that congregations tend to be segregated along lines of culture, racial identity, nationality,

education, income, and social status. This segregation has deprived the church of valuable lived experiences, spiritual gifts, and scriptural insights. As Christians, our common ground should be the call to follow the example of the life, ministry, and words of Jesus. This can be done only with the participation of all who claim that call. The church is to be an example of a diverse community seeking and applying truth by valuing and embracing that diversity.

The Unwillingness to Set Aside Personal Egos

In the end, the biggest obstacle to the pursuit of truth is our own ego. As stated by Scott Barry Kaufman, the pressing need is for everyone to quiet their egos. He defines the ego as

> *that aspect of the self that has the incessant need to see itself in a positive light*. Make no doubt: the self can be our greatest resource, but it can also be our darkest enemy. On the one hand, the fundamentally human capacities for self-awareness, self-reflection, and self-control are essential for reaching our goals. On the other hand, the self will do anything to disavow itself of responsibility for any negative outcome it may have played a role.[30]

Furthermore,

> there seems to be this growing belief that the goal is always to win. Not have a dialectical, well-intentioned, mutual search for overarching principles and productive ways forward that will improve humanity—but to just win and destroy.[31]

By contrast,

> a quiet ego is an indication of a healthy self-esteem, one that acknowledges one's own limitations, doesn't need to constantly resort to defensiveness whenever the ego is threatened, and yet has a firm sense of self-worth and competence.[32]

The challenge Kaufman puts before us can be seen as an expression of the humility and love to which we are called as Christ followers. Scripture is clear in pointing out our temptations to pride, selfishness, and tribalism (see 1 Corinthians). Furthermore, we are called to humility in imitation of Christ. "Do nothing out of selfish ambition or vain conceit, but in humility consider others better than yourselves" (Phil. 2:3).[33] The second greatest command to love our neighbor as ourselves requires putting ourselves in another's place (Luke 10:25–37). These and other passages leave little room for taking pride in our presumed correctness, attacking those who disagree with us, or refusing to consider that we may be in error. Love rejoices in the truth even when it means we have been wrong.

Striving for a "quiet ego" will enable us to begin the process of overcoming all of the barriers discussed above. It involves self-reflection, and the ability to set aside our defensiveness and seek to understand, and value, the perspectives of others. In the process, we can grow in our empathy and compassion for each other, and seek the other's good and not just our own.[34] A quiet ego also makes it possible for us to challenge our own confirmation bias. We can be self-critical and skeptical of arguments that would seem to validate our own positions and beliefs. We must always remember that truth is independent of what we believe to be true. The more our personal identities are tied up with particular truth claims, the harder it is to be open to correction and change. We must be willing to pursue truth even it it "hurts."

Summary

I have briefly laid out above what I see as some of the main causes for our divisive and polarized society, and the consequence of an inability to find common ground in the pursuit of truth. Below is a summary list of useful perspectives and actions that can begin to heal those divisions and enable us to pursue truth together.

1. There is an objective physical and spiritual reality (an objective truth) that is accessible to us, but independent of us.
2. Our knowledge of that reality will always be incomplete and subject to error.
3. The consensus conclusions of trained expert communities provide stability and help to guard against error. Alternatives to the consensus positions must prove themselves by providing persuasive evidence.
4. Our understanding of truth is deeply influenced by our history and cultural context.
5. We must break out of our echo chambers and seek engagement across disciplinary and cultural divides.
6. Confirmation bias is a powerful human tendency and must be consciously countered by humility and a willingness to change our views.
7. Above all, we need to "quiet our egos."

Notes

[1]For an extended discussion of the assumptions that underlie scientific inquiry, see Keith B. Miller, "Doubt and Faith in Science and Religion," *Perspectives on Science and Christian Faith* 70, no. 2 (2018): 90–100, https://www.asa3.org/ASA/PSCF/2018/PSCF6-18Miller.pdf.

[2]For a clear and thorough argument for realism, see Hugh G. Gauch Jr., *Scientific Method in Brief* (New York: Cambridge University Press, 2012).

[3]Ibid., 83.

[4]Ibid., 29.

[5]See the following article for a more-detailed discussion of these and other misunderstandings of the nature of science: Keith B. Miller, "The Nature of Science and the Public Debate over Anthropogenic Global Warming," *Perspectives on Science and Christian Faith* 64, no. 4 (2012): 220–29, https://www.asa3.org/ASA/PSCF/2012/PSCF12-12Miller.pdf.

[6]Keith B. Miller, "Countering Public Misconceptions about the Nature of Evolutionary Science," *Georgia Journal of Science* 63 (2005): 175–89, https://digitalcommons.gaacademy.org/gjs/vol63/iss2/8/.

[7]For a thorough discussion of this limitation in the methodology of science, see Keith B. Miller, "The Misguided Attack on Methodological Naturalism," in *For the Rock Record: Geologists on Intelligent Design,* ed. Jill S. Schneiderman and Warren D. Allmon (Berkeley, CA: University of California Press, 2009), 117–40.

[8]Os Guinness, *In Two Minds: The Dilemma of Doubt and How to Resolve It* (Downers Grove, IL: InterVarsity Press, 1972), 16.

[9]Azhar Hussain et al., "The Anti-vaccination Movement: A Regression in Modern Medicine," *Cureus* 10, no. 7 (2018): e2919, https://doi.org/10.7759%2Fcureus.2919.

[10]William Badke, "Fake News, Confirmation Bias, the Search for Truth, and the Theology Student," *Theological Librarianship* 11, no 2 (October 2018): 4–7, https://doi.org/10.31046/tl.v11i2.519.

[11]Henry H. Bauer, "*Scientific Literacy and the Myth of the Scientific Method* (Urbana, IL: University of Illinois Press, 1992), 60.

[12]William Badke, "Evidence and the Search for Truth," *Online* 44 (July 2020): 36–38, https://www.researchgate.net/publication/350740099_Evidence_and_the_Search_for_Truth.

[13]Ibid.

[14]Steven Novella, "Outrage, Bias, and the Instability of Truth," NEUROLOGICA Blog, September 23, 2019, https://theness.com/neurologicablog/index.php/outrage-bias-and-the-instability-of-truth/.

[15]Ibid.

[16]Nicholas Rescher, *The Limits of Science*, rev. ed. (Pittsburgh, PA: University of Pittsburgh Press, 1999), 38.

[17]Ibid., 37.

[18]David N. Livingstone, *Putting Science in Its Place: Geographies of Scientific Knowledge* (Chicago, IL: University of Chicago Press, 2003), 180.

[19]Allison L. Skinner-Dorkenoo et al., "A Systemic Approach to the Psychology of Racial Bias within Individuals and Society," *Nature Reviews Psychology* 2 (July 2023): 395, https://doi.org/10.1038%2Fs44159-023-00190-z.

[20]Ibid.

[21]Diana Lewis, Lewis Williams, and Rhys Jones, "A Radical Revision of the Public Response to Environmental Crisis in a Warming World: Contributions of Indigenous Knowledges and Indigenous Feminist Perspectives," *Canadian Journal of Public Health* 111, no. 6 (2020): 898, https://doi.org/10.17269/s41997-020-00388-1.

[22]Ibid., 899.

[23]Melanie Zurba and Anastasia Papadopoulos, "Indigenous Participation and the Incorporation of Indigenous Knowledge and Perspectives in Global Environmental Governance Forums: A Systematic Review," *Environmental Management* 72 (2023): 84–99, https://doi.org/10.1007/s00267-021-01566-8.

[24]Robin Wall Kimmerer, *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge, and the Teachings of Plants* (Minneapolis, MN: Milkweed Editions, 2013), 42.

[25]Ibid., 160.

[26]Amanda Black and Jason M. Tylianakis, "Teach Indigenous Knowledge alongside Science," *Science* 383, no. 6683 (2024): 592–94, https://www.science.org/doi/10.1126/science.adi9606.

[27]Jane Goodall and Phillip Berman, *Reason for Hope: A Spiritual Journey* (New York: Warner Books, 1999), 77.

[28]Esau McCaulley, *Reading While Black: African American Biblical Interpretation as an Exercise in Hope* (Downers Grove, IL: InterVarsity Press, 2020), 22.

[29]Drew G. I. Hart, *Trouble I've Seen: Changing the Way the Church Views Racism* (Harrisonburg, VA: Herald Press, 2016).

[30]Scott Barry Kaufman, "The Pressing Need for Everyone to Quiet Their Egos," *Scientific American, Beautiful Minds Blog*, May 21, 2018, https://blogs.scientificamerican.com/beautiful-minds/the-pressing-need-for-everyone-to-quiet-their-egos/.

[31]Ibid.

[32]Ibid.

[33]Scripture passage taken from the New International Version of the Holy Bible.

[34]See Heidi A. Wayment and Jack J. Bauer, eds., *Transcending Self-Interest: Psychological Explorations of the Quiet Ego* (Washington, DC: American Psychological Association, 2008).

Timothy Helble

Article

DOI: https://doi.org/10.56315/PSCF9-24Helble

Flood Geology and Conventional Geology Face Off over the Coconino Sandstone

Timothy Helble

Flood geologists have been using the Coconino Sandstone in the Grand Canyon to argue that a global flood reworked much of the planetary geologic record. Flood geologists' arguments may seem convincing at first, but after analyzing their articles and videos as well as the conventional geology literature, it is found that the Coconino does not support a global flood. Flood geologists have been largely directing their efforts toward refuting generalized statements from critics in the popular science literature. By placing so much emphasis on finding data that could be used to refute critics, opportunities were missed to increase scientific understanding of the Coconino. Flood geologists' findings were consistently framed to argue for aqueous deposition, which they implicitly equate to global flood deposition. It is shown that an astronomical difference exists between the two.

Keywords: Coconino Sandstone, global flood, flood geology, aqueous, eolian dunes, crossbeds, fossil trackways, mica, parabolic recumbent folds

In the past few decades, the Coconino Sandstone in the Grand Canyon (fig. 1) became a major cause of flood geologists—young earth creationists who hold that a one-year global flood deposited most of Earth's sedimentary record. To understand why this happened, it is useful to review a little history. In 1934, noted Grand Canyon geologist Edwin D. McKee concluded that the Coconino Sandstone was the product of winds in a desert dune environment.[1] This view that the Coconino formed in a wind-driven or *eolian* environment soon became the consensus view of geologists.

Flood geologists argue that the horizontal layers of the Grand Canyon were deposited by a global flood, and they acknowledge that an eolian layer in the middle of it all poses a problem for their view. But rather than being a response to the consensus view, flood geologists' emphasis on the Coconino was more a reaction to statements by several critics of flood geology in videos and the popular science literature. These critics cited the Coconino as an eolian deposit that clearly invalidates a global flood. Flood geologists viewed these critics' statements as an effort to discredit the Bible.

Flood geologists therefore set out to prove that the Coconino was deposited by water. They published numerous papers on the Coconino in both young earth creationist and conventional geology journals, featured it prominently in the *Is Genesis History?* movies, and addressed it in several videos. In these media, flood geologists levied several "charges" against the conventional geology view, stating that their data "will be difficult for our critics to counter."[2] These efforts were anticipated in my 2011 *PSCF* article "Sediment Transport and the Coconino Sandstone: A Reality Check on Flood Geology":

> Flood geologists are currently involved in multiyear activity known as

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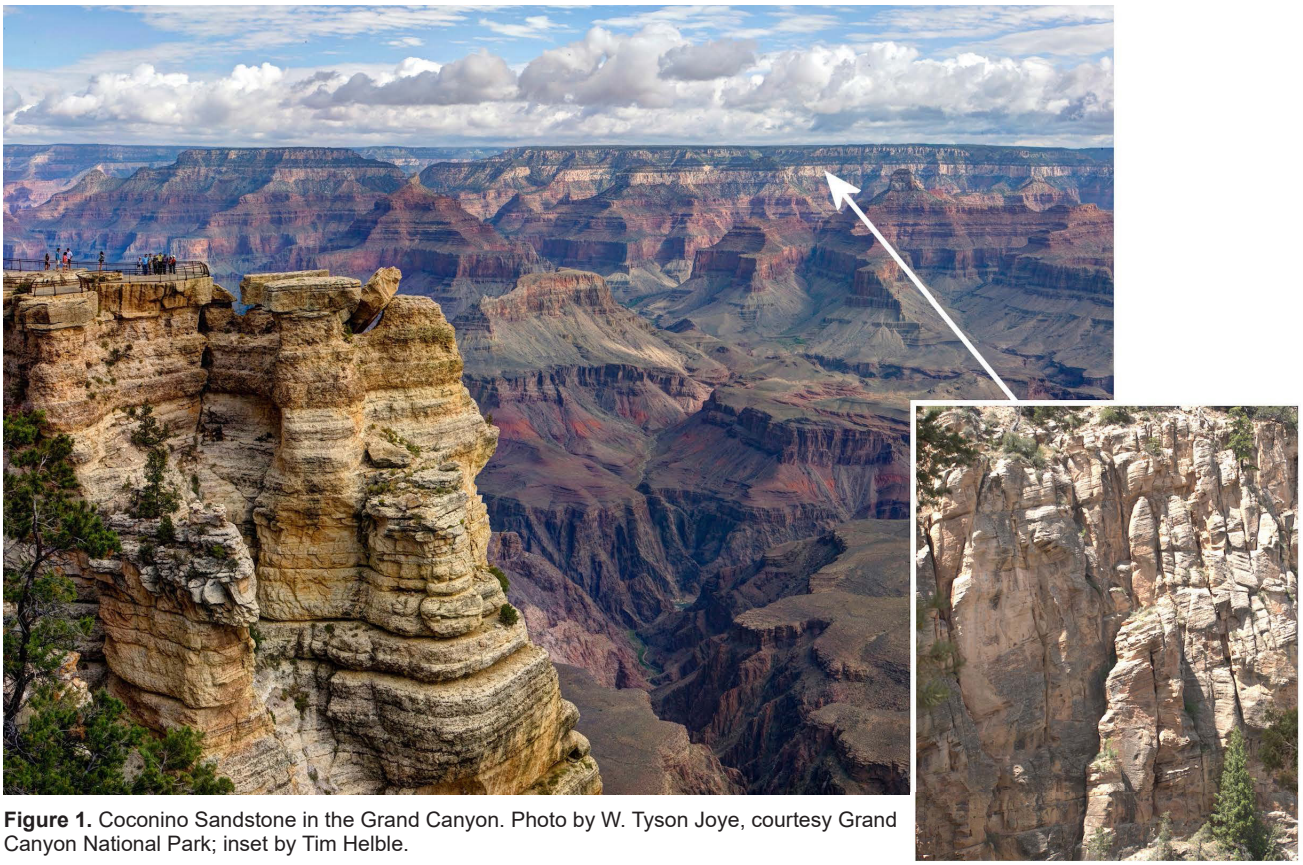

Figure 1. Coconino Sandstone in the Grand Canyon. Photo by W. Tyson Joye, courtesy Grand Canyon National Park; inset by Tim Helble.

> the Flood Activated Sedimentation and Tectonics (FAST) project, with several papers anticipated for publication in the near future. There is no doubt these papers will present more "evidence" for aqueous or catastrophic flood deposition for various sedimentary formations, including the Coconino Sandstone.[3]

Interestingly, while flood geologists undertook an exhaustive, decades-long effort to refute other critics, they ignored the 2011 *PSCF* article and its key finding that sediment transport rates required to deposit the Coconino in a matter of days would be far too high to produce crossbeds and other detailed features, only mentioning that it was written by a "skeptic."[4] Similarly, *The Grand Canyon, Monument to an Ancient Earth* provides over 100 arguments against the flood geology view of the Grand Canyon,[5] but the response from the largest young earth ministry focused on only the introductory and closing chapters, plus two pages from the core seventeen chapters which make the case for an ancient Grand Canyon.[6]

My interactions on social media and anecdotal reports from fellow Christians indicate that flood geologists' Coconino claims are having a significant impact. A book-length document would be required to address all their claims, but that would reach a limited audience. This article will provide a more concise response to flood geologists' main "charges" against the consensus view of the Coconino. But before addressing these charges, it is important to understand what geologists have learned about this massive sandstone formation in northern Arizona. This will make it easier to see if flood geologists' charges are really accounting for the consensus understanding of the Coconino.

Conventional Geology View of the Coconino Sandstone

Earth was dominated by the supercontinent Pangea when the Coconino was formed during the early Permian (299–252 million years ago). The Coconino erg (sand sea) formed 5 to 10 degrees north of the equator on the western edge of Pangea (fig. 2).[7] Large transcontinental river systems drained westward from the early Appalachian Mountains. This long mountain range had peaks comparable to the

Figure 2. Western part of Pangea during the early Permian, 280 million years ago, representing conditions 275–282 million years ago, just before the main part of the Coconino was deposited. Note the boundaries of South American and African countries in the lower right portion of the map. Paleogeographic map by Ron Blakey ©Colorado Plateau Geosystems, Inc., License #90922.

modern Rockies and formed with the collision of Laurentia (North America) and Gondwana (Africa/South America/Antarctica).

A continental arch prevented the transcontinental rivers from reaching the ocean. This forced the rivers to dump their sediment loads in a vast region known as the Western Interior Desert. Numerous alternating layers of sandstone, siltstone, mudstone, evaporites, halite, and anhydrite extending from central Canada into the Midwest and mountain states testify to the large terminal lakes that once existed in this vast desert during late Mississippian to middle Permian time.[8]

The region had a monsoonal climate with strong northwesterly seasonal winds. Sediments from the Western Interior Desert and local mountain sources were blown to the west and southwest. Sands reaching the ocean were transported southward by longshore currents. Sands may have been incorporated into sedimentary rock one or more times before being recycled into the Coconino.[9] The Ancestral Rocky Mountains in what is now Colorado were being eroded down to hills, depositing large stores of sediment in adjacent basins.

The region where the Coconino was deposited was near sea level and surrounded by water on three sides. Before the Coconino was formed, siltstones, mudstones, and very fine-grained sandstones of the Hermit Formation were deposited in a coastal plain crossed by shallow streams draining the Ancestral Rockies and related nearby uplifts. Increased aridity took hold over the wider region when Hermit deposition tapered off. A time gap on the order of hundreds of thousands of years elapsed, with sands from the north just blowing across the Hermit surface in the area where the Grand Canyon is today. Further south where crustal subsidence was greater, a thick, reddish mixture of eolian and marine sediments accumulated on top of the Hermit as the Schnebly Hill Formation.

Tectonic forces buckling the crust began creating more space for sand accumulation in the area where the Grand Canyon is today. Sands blown from the northwest or from beaches by onshore winds formed various types of dunes. Sometimes, dunes built up until sand avalanched downward, forming beds at what is known as the angle of repose (about 33° for dry sand). Strong winds often blew sands into the air which settled away from steeper dunes in lower-angle beds. Mica and other dust from the Western Interior Desert were blown thousands of feet high into the atmosphere and settled hundreds of miles downwind over the dunes. Lighter winds often formed migrating wind ripples. In some places, very high sand hills known as megadunes formed, which were so massive that they contained smaller dune forms superimposed over larger dunes. These megadunes sometimes had heights in the hundreds of feet and lengths in the tens of miles. The main body of large megadunes migrated southward a few centimeters per year, truncating previous dune deposits and leaving complicated bounding surfaces.[10]

Fossil footprints and invertebrate burrows at different levels show that conditions were stable enough for animals to roam around and hunt. Oases, which were especially active areas of animal activity, existed in some interdune areas.[11] Sporadic, short-duration showers left raindrop imprints and various soft sediment deformation features indicate that water was sometimes present. Eolian sands interfingered with marine sediments in surrounding shoreline environments. Deposition of the Coconino ended when it was covered over by the Toroweap Sea.

How Was the Age and Depositional History of the Coconino Determined?

The time frame for deposition of the Coconino was determined using multiple lines of evidence in the geologic record. Indirect methods were used because no datable volcanic material has been found directly above, in, or below the Coconino. Fossil footprints discovered in the Coconino in the early 1900s provided the first clue.[12] The same kind of footprints was known to exist in other parts of the world along with certain fossils known to be Permian. Radiometric dating techniques, developed later, allowed numerical ages to be assigned to the Permian and other geologic periods.

Fossils in the underlying Hermit Formation and overlying Toroweap Formation allowed the relative age of the Coconino to be narrowed down further. Fossils of a plant, several species of pine trees, and a wing from a meganeurid, an extinct insect resembling modern dragonflies, indicated that Hermit deposition ended during the early Leonardian age of the Permian period.[13] Several bryozoan species indicated a late Leonardian age for the Toroweap.[14] These established a middle Leonardian age for the Coconino.[15] The Leonardian age, a subdivision of the Permian **used** in southwestern North America, is now known to span from about 280 to 271 million years ago.

A technique refined during the 1980s and 1990s known as detrital zircon geochronology provided a trove of new data for deciphering Earth's geologic history. This technique takes advantage of the durability of zircon crystals, uranium-lead dating, and laser ablation technology to provide the "age spectrum" of grains in a sandstone. Knowing the age of basement and other igneous rocks across the continent, detrital zircon analysis allows geologists to decipher source regions for any sedimentary unit

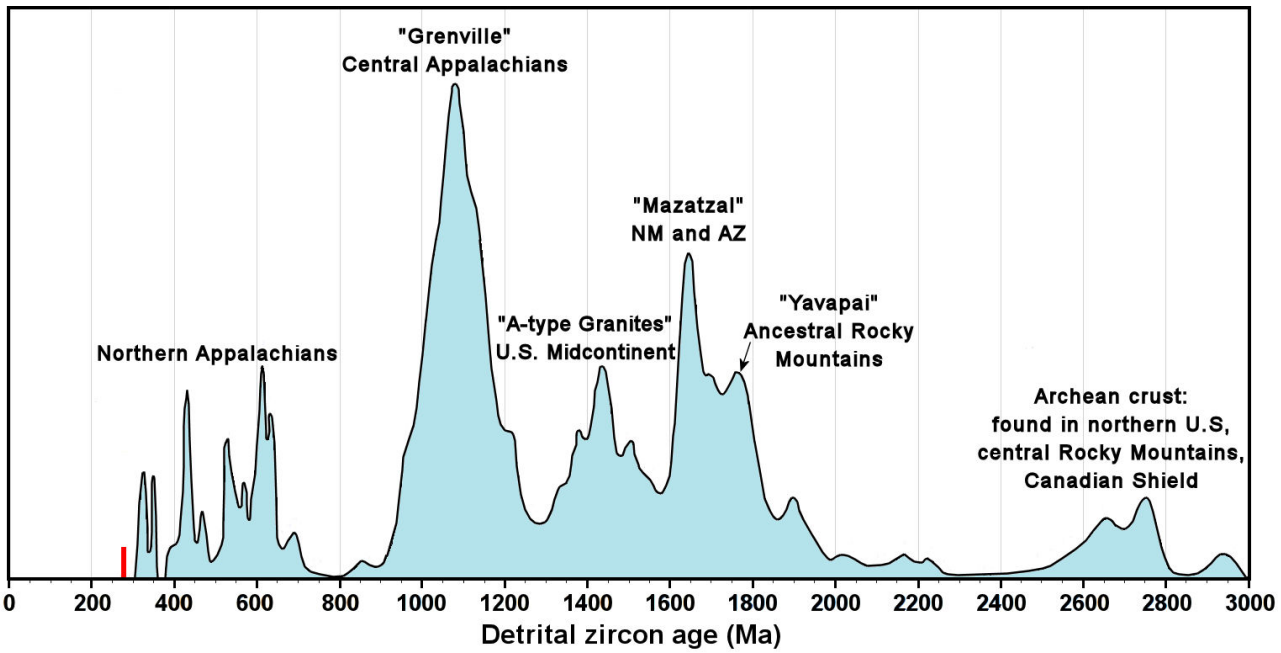

Figure 3. Distribution of zircon ages (Ma, or millions of years ago) from Coconino samples at two locations. The unlabeled vertical axis is a statistic indicating the frequency of zircons found at various ages: the higher the peak, the more zircons were found of that age. Bar at the far left, bottom, indicates the estimated age of the Coconino. Modified from Gehrels et al., 2011.

containing zircons. It also allows the maximum depositional age of a sedimentary unit to be determined, because the rock cannot be older than its youngest zircons. Figure 3 shows a detrital zircon distribution for the Coconino annotated with selected source areas.[16] Note how the youngest zircons are about 300 million years, corroborating the Coconino age using fossil evidence.

Detrital zircon analysis of the Coconino, other Grand Canyon formations, and rocks in the surrounding region, coupled with detailed stratigraphic studies at thousands of locations across North America, allowed the regional geologic history to be pieced together into paleogeographic maps such as figure 2. Similar maps have been produced for times throughout the Paleozoic era.[17]

As indicated in figure 3, Coconino zircons came from a variety of nearby and distant source areas. For distant sources such as the Appalachians, geologists proposed that massive volumes of sand were transported westward by transcontinental rivers as shown in figure 2. Evidence for one of these rivers has been found at the Permian level in West Virginia.[18] The stratigraphy of Pennsylvanian and Permian layers in central Canada and the US Midwest/mountain states indicates that these rivers dumped their sediment loads in a vast, arid region.[19] These sediments may have been recycled from older Pennsylvanian and Permian rocks to the north in Utah, Wyoming, and Montana before reaching the Coconino.[20]

Eolian processes then brought sands further west and southward. Sands blown into the ocean were transported southward via longshore currents. The zircon evidence indicates that significant amounts of sand also came from local uplifts such as the Ancestral Rocky Mountains, which were in process of being eroded down to low hills during the Permian. Some evidence of water transport from local uplifts has been found in parts of the Glorieta Sandstone to the east of the Coconino.[21] Interestingly, flood geologists acknowledge that "the zircon evidence is compelling and does suggest a distant origin for some of the Coconino sand,"[22] yet many of them have published articles, books, and videos arguing that radiometric dating cannot be trusted.[23]

Flood Geology Coconino Arguments

Crossbed Angles

The Charge: *Coconino crossbed dip angles support the underwater deposition view.*[24]

Response: Flood geologists' changing arguments on this issue imply that the Coconino cannot be eolian in origin because all crossbed dips are not at the

angle of repose, which is about 33° for land dunes. They initiate their case by mischaracterizing critics as saying that all Coconino crossbeds are near the angle of repose.[25] They then set out to disprove this characterization by measuring Coconino crossbed dips, eventually sampling over 200 locations in quarries and along trails and streams. They found that bed angles ranged from 2 to 32°, with the highest number of beds at 24° and a mean of about 20° (fig. 4). The lee slopes of marine sand waves are typically less than 20° but are reported to reach more than 30°, so they argue that some marine sand waves are comparable to those in the Coconino.

A fact obscured by flood geologists is that all crossbeds do not have to be near 33° for the Coconino to be an eolian sandstone. Beds formed by sand avalanching are steep at the top, but often flatten out at the base, producing a concave-upwards profile. Exposed beds in modern dunes reveal a mix of dip angles (fig. 5), because they are formed in several ways. Strong winds often blow sand far away from steeper dunes (suspension), which falls in beds at a variety of angles. Flood geologists assert that the Coconino is completely "dominated by avalanche deposits," but the Coconino does not follow such "one size fits all" rules. Some parts are mostly avalanche (grain flow) deposits while other areas are mostly suspension (grain fall) deposits.

It would probably be accurate to say that crossbed angles by themselves cannot be used to argue for either the eolian or aqueous view. A flood geologist recently admitted that having few crossbed dip angles in the 30s does not prove subaqueous origin.[26] His main argument now is that the distribution of crossbed dips in modern dunes have a wider statistical spread than ancient sandstones; therefore, "the sandstones probably all formed in similar non-eolian settings." Presumably "non-eolian" means marine, but how that conclusion logically follows from the premise is not explained. Comparing statistics on crossbed dips in modern dunes to those for sandstones is an apples-to-oranges exercise. This is due to the fact that modern sand dunes have high crests separated by wide, lower areas with few steep beds. In contrast, sandstones are of uniform thickness because all the low areas have been "filled in" through various dune processes such as migration and suspension. Also, angles vary with dune type, wind regime complexity, and other factors. When comparing modern dunes to ancient sandstone, one cannot presume to know the precise dune types and wind regime existing in the past.

Flood geologists have made misleading claims about crossbed angles. In *Is Genesis History?*, one stated that "these crossbeds are always 15 to 25°,"[27] but left out that 14% of measured crossbeds are more than 25°. Another claimed that the book *The Grand Canyon, Monument to an Ancient Earth* says Coconino crossbed dips are "near the angle of repose,"[28] when it actually uses the words "maximum angles" or "reaching" in conjunction with references to the angle of repose."[29]

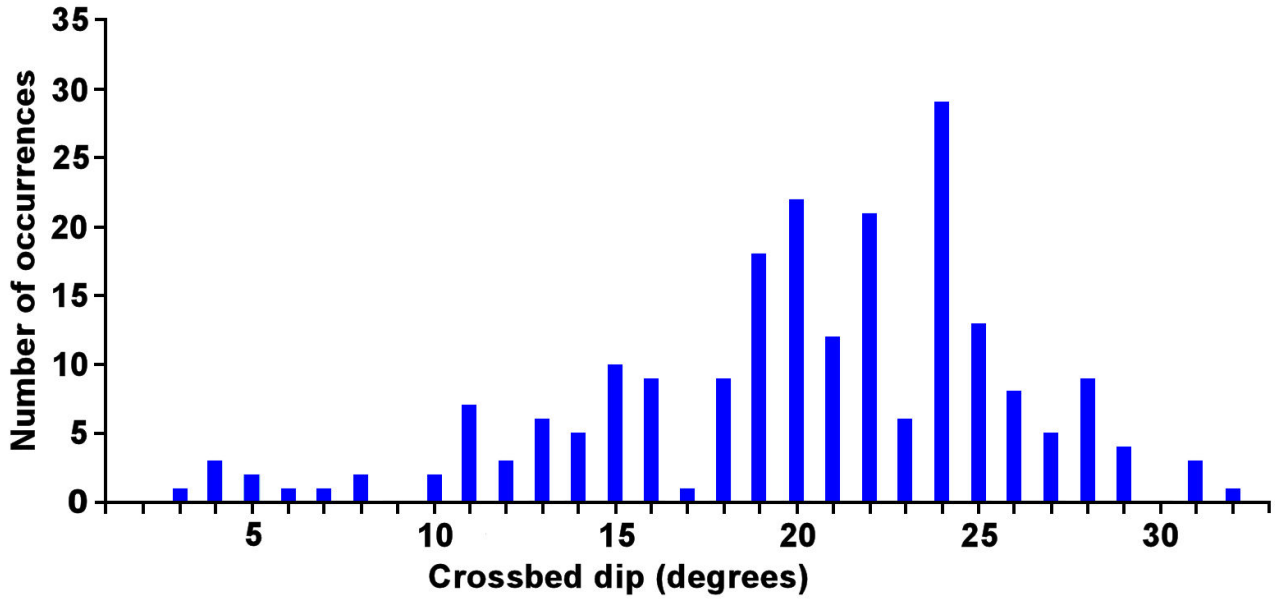

Figure 4. Compilation of 214 crossbed dips measured by flood geologists in the Coconino Sandstone. Modified from Whitmore and Garner (2018).

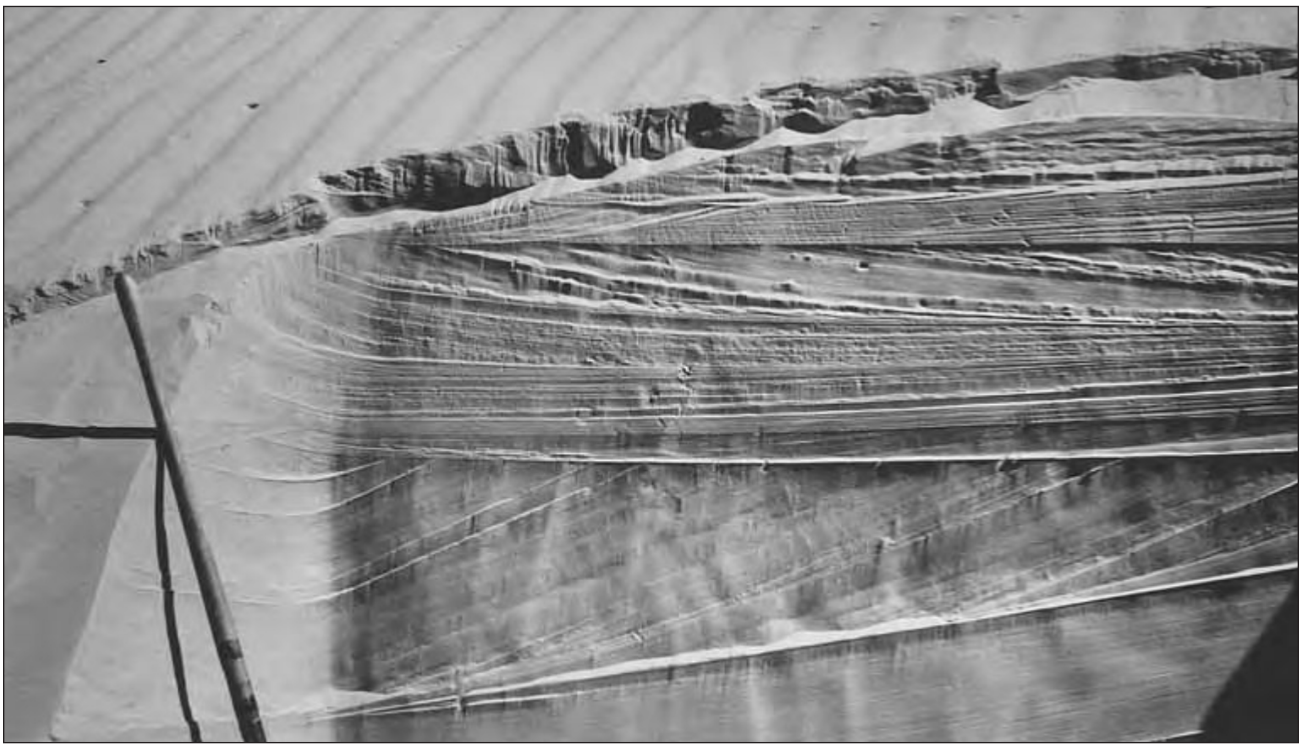

Figure 5. Eolian crossbeds exposed in a pit dug into the Algodones Dunes, California, showing that all beds are not near 33°. Note shovel handle on the left and wind ripples at the surface (see next section). Photo by John S. Shelton, courtesy University of Washington Special Collections.

Ripples

The Charge: *Ripples on exposed surfaces of the Coconino (fig. 6) could be formed underwater.*[30]

Response: Ripples in the Coconino have small heights (amplitude) compared to their wavelength. Such ripples do not form underwater except in some beach swash zones. Ripples are often characterized using a ripple index (RI), where RI = length between wave crests divided by the height of crests. In 1917, geologist Edward Kindle found that wind ripples have RI greater than 10 to 15 while RI for water ripples is less than 10 to 15.[31] Kindle's criteria are now widely accepted, with acknowledgement that some variation exists with grain size and wind velocity.[32] In 1945, Edwin McKee applied these criteria to 21 Coconino specimens and found that their RI ranged from 17 to 98, with fairly even distribution between the extremes.[33] This placed all 21 of McKee's Coconino specimens solidly in the high-index, wind ripple category.

Flood geologists John Whitmore and Paul Garner cite a 1968 paper by J. Houbolt to argue that "these kinds of ripples are known to occur in similar style on various sand waves and related subaqueous features."[34] However, Houbolt never stated anything of the kind. He was studying large-scale sand waves on the bottom of the North Sea, not small-scale ripples. The analog echo sounding technology that he used in the 1960s to scan the ocean bottom had no way to resolve small ripples.[35]

Flood geologists acknowledge that "low-amplitude" ripples exist in the Coconino and refer to them as "called 'wind ripples' by some," but avoid their significance as eolian indicators. They compiled statistics for crossbed angles, grain sorting, grain rounding, and grain size, but nothing for ripple index as done by McKee 80 years ago. Not including such data suggests an intent to only provide information which can be used to argue for aqueous deposition.

Rounding and Sorting

The Charge: *Sand grains in the Coconino are neither well rounded nor well sorted.*[36]

Response: Flood geologists effectively refuted generalizing statements from their critics, but the science had already advanced well past a narrow focus on "one size fits all" rounding and sorting criteria for sand dunes. Some flood geologiy critics cited well-

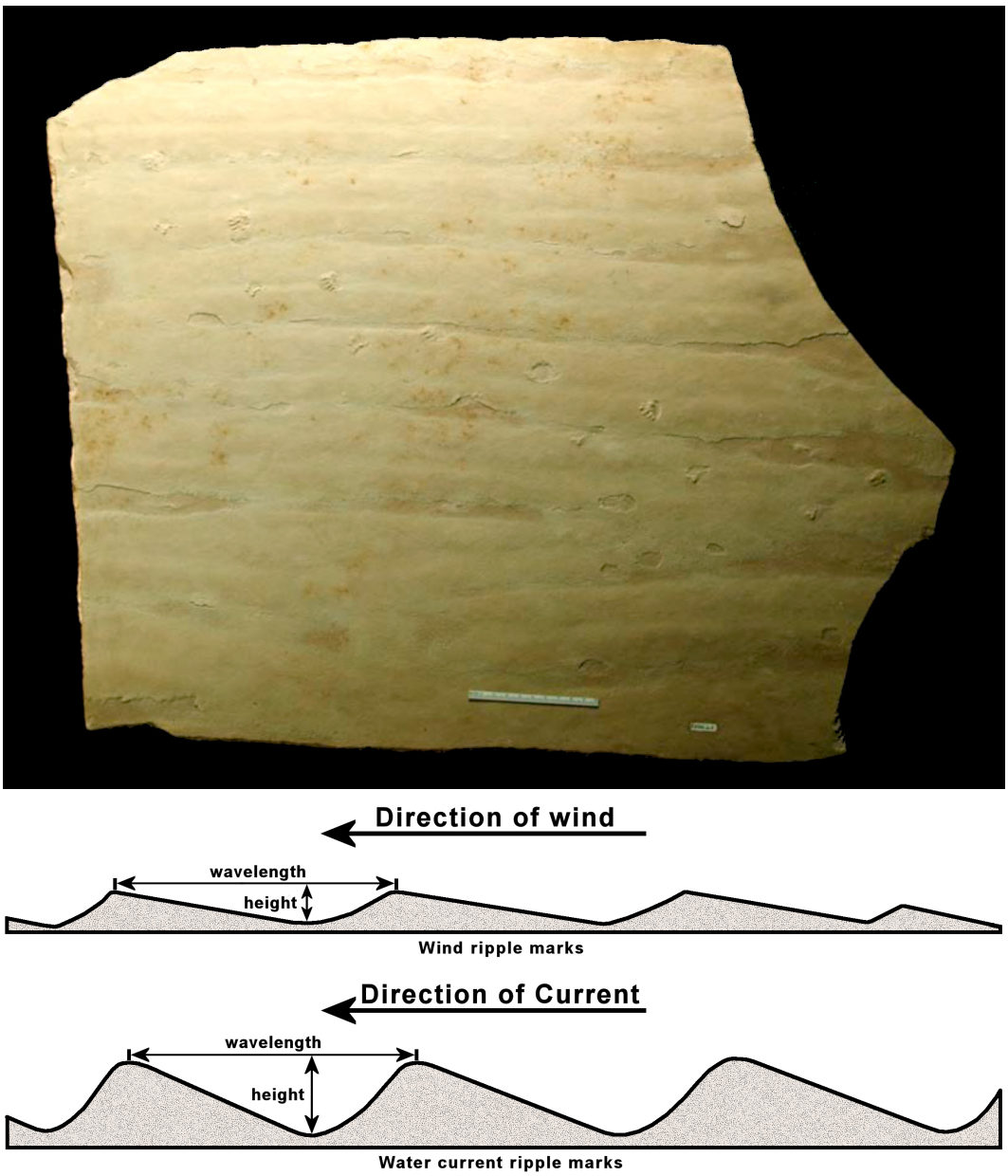

Figure 6. (Top) Coconino Sandstone slab with wind ripples (and a few footprints). Courtesy Science Museum of Minnesota. (Bottom) High-index wind ripples compared to low-index water ripples. Based on Pye and Tsoar, 1990.

rounded and well-sorted sand grains in Colorado Plateau sandstones as evidences for eolian origin of the Coconino.[37] Flood geologists then evaluated Coconino thin sections taken from several locations and found that sand grains were sub-angular in northern Arizona and sub-rounded in central Arizona. They also found that sorting and overall grain size in the Coconino is slightly different from modern eolian dunes that they sampled. They argue that these findings are more consistent with aqueous depositional processes.

It is now known that grain rounding in eolian sand dunes is more complicated than earlier thought. In 1995, geomorphologist Nicholas Lancaster stated:

> Although early workers suggested that aeolian sands were rounded or well-rounded in shape, more recent investigations indicate that, in aeolian sands, true roundness in the dominant 125–250 μm size group is rare and most grains are sub-angular to sub-rounded in shape.[38]

In 1981, Andrew Goudie and Andrew Watson noted that grains from different sand seas cluster around distinctive grain roundness characteristics that reflect their specific sand source and transport pathways.[39]

It has also been known for several decades that inland dunes have a range of sorting values. In 1979, McKee stated:

> Comparison of 291 coastal dune sand samples with 175 inland dune sand samples shows several differences. The coastal dunes are composed almost totally of very well sorted fine sand … Inland dune sand samples, by contrast, show a much greater range in mean grain size and sorting values.[40]

It should be apparent that grain morphology in sand dunes (and eolian sandstones) cannot be forced to follow a fixed set of rules. Finding "rule violations" in flood geology critics' generalizing statements does not constitute evidence for aqueous deposition.

Sand Injectites

The Charge: *Liquified Coconino sands were injected downward into cracks in the Hermit Formation (fig. 7).*[41]

Response: The evidence found by flood geologists that the sands were liquified when injected into the Hermit is likely correct, but they did not evaluate all options for how and when this occurred. In the article which they successfully published in the journal *Sedimentary Geology*, flood geologists offered only two possible causes and time frames for the cracks: desiccation shortly after the Hermit was deposited, or earthquakes on the Bright Angel Fault[42] some 250 million years later. (Of course, flood geologists do not accept a 250-million-year time span—they were using conventional geology terminology so that their article could be published in a "secular" journal.) They correctly noted several features of the cracks that are inconsistent with desiccation such as tapering in an upward direction and splitting and rejoining. Flood geologists easily rejected their second option—the sands could not have been injected during earthquakes on the Bright Angel Fault—because "the fault was relatively inactive between the Precambrian and the Laramide deformation."[43] The Coconino is currently estimated to be about 275 million years old, and the Laramide Orogeny took place from about 70 to 40 million years ago. They concluded that if the cracks did not form until the Laramide Orogeny, the Coconino would have to remain uncemented for "an excess of 250 million years."[44]

Flood geologists effectively refuted two explanations which they implied were the only options for conventional geology, but failed to consider a third option. The sand injectites could have formed sometime between Coconino deposition and the Laramide Orogeny in the conventional geology time scale, but much closer to the former time than the latter. Lithification (the process of becoming rock) of the Hermit muds would require at least several centuries,[45] and the Hermit was obviously hardened rock when the cracks formed. Tectonic forces could slowly deform a lithified crust upward when the overlying Coconino sands were still a relatively recent deposit and saturated below a water table (or the sea). At some point, the Hermit "snapped," cracks formed, and sand rushed in. This deformation could be related to where the Bright Angel Fault is today, but was not necessarily caused by the fault. Also, "relatively inactive" does not mean zero earthquakes on the fault for 250 million years.

Sand injectites in less permeable rock layers such as mudstone have been extensively documented in the research literature. Liquefaction—a breakdown of the support structure of sand grains to the point where they are temporarily dispersed in the fluid that fills their pores—is recognized as integral to their formation.[46] Flood geologists do not consider the possibility that this could occur in the conventional geology time frame under saturated

Figure 7. Contact between the Coconino Sandstone (top) and the Hermit Formation (bottom), showing where sand was injected several meters downward into a crack in the Hermit. Photo by Tim Helble.

conditions below a water table. Saturated conditions would also exist when marine waters covered the eolian Coconino as the overlying Toroweap and Kaibab Formations were deposited.

The sharp Hermit/Coconino contact poses a huge problem for flood geology which has been largely overlooked. Flood geology cannot explain how the silts and clays of the Hermit Formation could rapidly dewater, compact, and lithify within hours such that a sharp boundary could exist between it and the overlying Coconino. A deep, saturated layer of Hermit muds that was deposited just hours earlier would not be able to support Coconino sands that were rapidly piled on top at a tens of feet per day rate. Geotechnical failure would occur and the two would just intermix, making it impossible to distinguish Hermit sediments from the Coconino.[47]

Vertebrate Footprints

The Charge: *Fossil footprints in the Coconino were made underwater.*[48]

Response: Fossil trackway research has advanced considerably beyond flood geologists' early papers, and flood geologists' water tank experiments never demonstrated that underwater footprints could be made under conditions that were remotely close to a global flood. In 1979, Leonard Brand described trackways in the Coconino at 15 locations along the Hermit Trail in Grand Canyon within a 50-meter (165 feet) vertical span. At just one of those locations, he found tracks at six different levels within 60 cm (2 feet). He then observed the footprints made by newts in calm water tank experiments and argued that his results show that fossil footprints in the Coconino "should not be used as evidence for eolian deposition by dry sand."[49]

In 1991, Leonard Brand and Thu Tang described experiments with newts videotaped while scrambling against a 0.2 mile per hour current in 1.5-inch deep water. When a newt was washed sideways, its feet were pointed at almost a right angle to the direction it was drifting. They noted similar foot orientations in some Coconino trackways where an animal briefly traveled sideways from its intended direction. They argued that this points to subaqueous deposition.[50] Brand and Tang provided drawings of the newts' foot positions in the flowing tank experiments, but no actual photos. Brand recently stated that they could see where the animal put its feet down, but could not provide any details as to how deep or distinct the prints were or how they compared to the deep prints found in the Coconino.[51] An ichnologist commenting on Brand and Tang's paper pointed out that Coconino trackways indicate the strides of non-drifting tetrapods. He also stated that if the current in their water tank had been increased to 0.45 miles per hour, the sand would show (low index) current ripples. However, no water current ripples have been found on thousands of square meters of Coconino specimens.[52] High-index wind ripples are often seen in the Coconino.

Simulated current speeds over the continents produced in flood geologists' recent models of a global flood are 30 to 45 miles per hour.[53] Such speeds would send trackmakers swirling in the water. Proposals that animals left the tracks during low-tide breaks in the flood violate the principles of hydraulics, because deep water over broad regions cannot recede in a few hours like tides on the sea shore. A few flood geologists are beginning to recognize that trackways pose a problem because they reflect an increase in frequency and species diversity as one moves higher through the rock record, when animal life should have been wiped out by day 150 of the flood as specified in Genesis 7:23–24.[54]

In a 1996 paper, Brand found that the best toe prints were produced in wet mud exposed to the air, which was a significant retreat from his subaqueous interpretation.[55] Several studies going back to a classic paper by Lionel Brady (1947) demonstrate how modern arthropods and vertebrates can make tracks remarkably like those in the Coconino in damp/moist (not subaqueous) sand.[56] Preservation of subaqueous tracks is a problem, as very saturated substrates lack the cohesion necessary to preserve well-formed tracks like most of those seen in the Coconino. If tracks were made on sand which was then covered by water, they would be quickly erased. The characteristics of ridges behind each footprint impression indicate that fossil trackways were made on dry sand, and it is even possible for scientists to use the impressions to make good estimates of the animal's weight. The mechanism for preservation of such footprints is currently being studied.

More recently, Brand acknowledged that "at present, it is not clear what the ultimate conclusion from this research will be."[57] Ichnologists have observed fresh lizard trackways on sand dunes and noted that individual tracks pointed uphill even where the animals

moved sideways across the dune face.[58] Some surfaces of the Coconino and other sandstones with fossil trackways also have high-index wind ripples, not low-index current ripples, indicating that they were made on land, not underwater (fig. 6, top). Also, Coconino trackways have been found which go in all four directions and even make a U-turn (fig. 8).[59]

Raindrop Imprints

The Charge: *So-called raindrop imprints in the Coconino really are not raindrop imprints.*[60]

Response: Flood geologists have not offered a viable explanation for the depressions and fail to seriously evaluate an obvious interpretation that runs against the flood geology view. They offered three arguments against the raindrop imprint interpretation: (1) raindrops in sandy substrates form a mottled surface rather than distinct craters like what is sometimes seen in the Coconino, (2) the "raindrop" prints in the Coconino typically occur in linear zones, not in randomly scattered patterns as one would expect, and (3) some depressions that look like raindrop prints are probably burrows or some other feature because the structures vertically penetrate up to 1 cm into the sand.

The deepness and spacing of depressions would depend on the size and number of raindrops and the nature of the surface. Raindrop imprints appear to be in rows because rain fell on wind-rippled dune surfaces (fig. 9), which flood geology cannot allow for. Differential erosion then slightly eroded the higher parts of some ripples, making the imprints appear to be in rows. Burrows do indeed exist in the Coconino, but these indicate animals living in a stable environment, not one where sediment was piling on at astronomical rates required by flood geology.

Soft Sediment Deformation

The Charge: *Large contorted beds in the Coconino, like the ones in Lizard Head near Sedona, Arizona (fig. 10), could only be formed by strong water currents.*[61]

Response: Water was indeed involved when these contorted beds were formed, but it happened through a mechanism that was very different from the overturning of crossbeds by strong water currents as envisioned by flood geologists. Three sets of crossbeds can be seen in the top photo of figure 10: an upper set, a middle set containing the contorted

Figure 8. Coconino specimen RAM 244 with numerous, deep footprints traveling in multiple directions. Photo by Tim Helble, courtesy Raymond Alf Museum.

Figure 9. Raindrop imprints on a Coconino specimen, most visible in the troughs of wind ripples. Courtesy Science Museum of Minnesota.

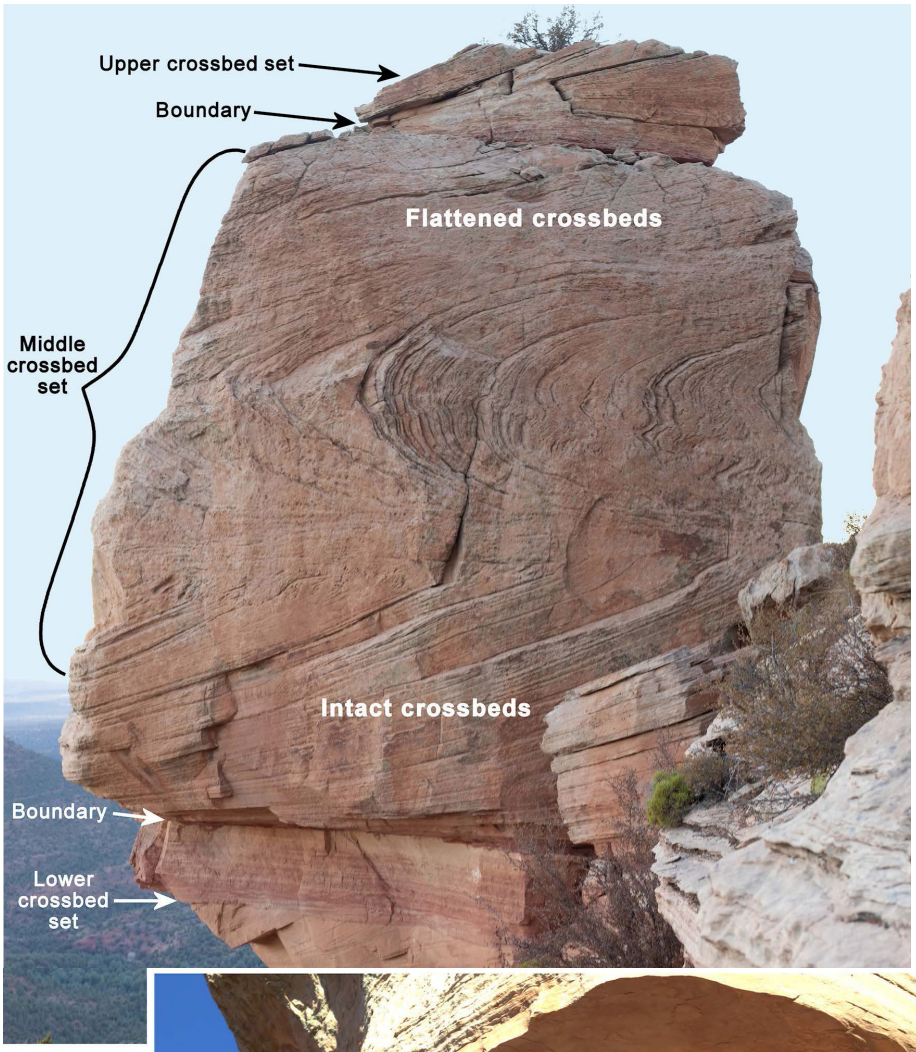

Figure 10. (Top) Contorted beds within the middle crossbed set of Lizard Head. The horizontal pseudo beds below the contorted beds are right in the middle of the photo.

(Bottom) High index wind ripples on the underside of Lizard Head, indicating that the lower crossbed set was deposited by wind processes, not water. Note how more "sheets" of laminae have fallen away near the tip, but all layers have wind ripples. Photos courtesy Gerald Bryant.

beds, and a lower set. Within the middle set, the original crossbed dip was maintained above and below the deformation. This indicates that the deformation was internal to the middle crossbed set. Even if it were physically possible for currents to overturn the middle crossbed set, at this location it would require the current to reverse direction from that which formed the crossbeds. There is no evidence here or elsewhere in the Coconino for such flow reversals.

An unstated assumption of flood geologists is that water has no role in a desert. But deserts do occasionally experience heavy rainfall. Many deserts have high water tables and surface water in localized areas. A more viable explanation for the contorted beds within the middle crossbed set is that downward dune collapse occurred into a zone of saturated sand which then underwent liquefaction. Such dune collapses could occur in slopes where the bedding structure of sands made them inherently unstable. Collapses could be triggered by local earthquakes associated with fault reactivation in basement rock which was adjusting to new sediment loads. When the collapsing sand impacted saturated beds at the bottom, internal forces acting parallel to the crossbed dip were initiated, causing a bulge in the crossbeds along an underlying shear surface. Fluid then escaped along a permeability barrier indicated by horizontal pseudo-bedding produced by the shear movement. This flat pseudo-bedding can be seen just below the contorted beds in the middle set.[62]

Evidence in the beds at Lizard Head indicates that they formed in an eolian environment that was later saturated by water. The upper set seen in figure 10 (top) consists of normal crossbeds. The crossbeds in the middle set above the contorted beds were slightly flattened when the collapse and subsequent contortion occurred. Crossbeds in the middle set which are below the contorted beds and pseudo-bedding were left intact, as were the crossbeds in the lower set. Crossbeds in the lower set now exposed on the underside of Lizard Head (fig. 10, bottom) are topped by strata that reveal a clear indicator of eolian processes—high-index wind ripples. Geologist Gerald Bryant measured these ripples to have a wavelength of about 150 mm and an amplitude of 3 mm (ripple index = 150/3 = 50), so they are clearly wind ripples.

Mica

The Charge: *Mica was found in the Coconino. Mica disappears in eolian transport, so it could be there only if the Coconino was deposited underwater.*[63]

Response: Some key information was left out in using mica to argue for underwater deposition. After a critic suggested that the Coconino has no mica,[64] flood geologists found mica sandwiched between sand grains in thin sections of the Coconino.[65] They then conducted experiments to test how well mica survives in simulated eolian and aqueous environments. The first experiment involved placing a small amount of muscovite-rich sand in a gallon pickle jar and running a propeller inside the lid at a speed that caused a small "dune" to migrate around the bottom. After four days, all mica flakes were abraded down to between 0.2 and 0.5 mm in size. By twenty days, all flakes were between 0.12 and 0.2 mm.[66] These numbers were provided in a 2017 *Aeolian Research* article, which is behind a paywall, but not in media targeted for lay audiences. They conducted a second experiment which involved tumbling mica and sand in a jar with water. After a year, mica flakes could still be seen. They concluded that aqueous processes could transport mica much greater distances than eolian processes.

When describing the results of their first experiment in talks, videos, and publications targeted for lay audiences, flood geologists state that the mica "disappears" in two (or four) days.[67] Clearly, reducing mica flakes to somewhere between 0.2 and 0.5 mm is not the same as disappearing. Furthermore, close-up photos of Coconino sand grains in flood geologists' articles show mica flakes between 0.1 to 0.3 mm except for one that is about 0.4 mm.[68] Thus, mica from their first experiment, a simulated eolian environment, was essentially the same size as mica they found in the Coconino.

Another point not mentioned by flood geologists is that Saharan mica flakes similar in size to those in the Coconino are routinely blown at least 570 miles offshore to the Cabo Verde Islands and even 2,700 miles into the Atlantic (fig. 11).[69] The flood geologists' pickle jar experiment may be a good analog for abrasion of mica in deserts such as the Namib, where sands are blown long distances inland from a beach. However, the Saharan dust plumes show that mica would not have to bounce great distances across the land together with sand to reach the Coconino erg. Strong winds in the Western Interior Desert or the even closer region surrounding the Ancestral Rockies could easily loft mica thousands of feet into the atmosphere, which later settled over the Coconino and was soon buried or leached into the sand with rain water. Flood geologists concede that mica exists

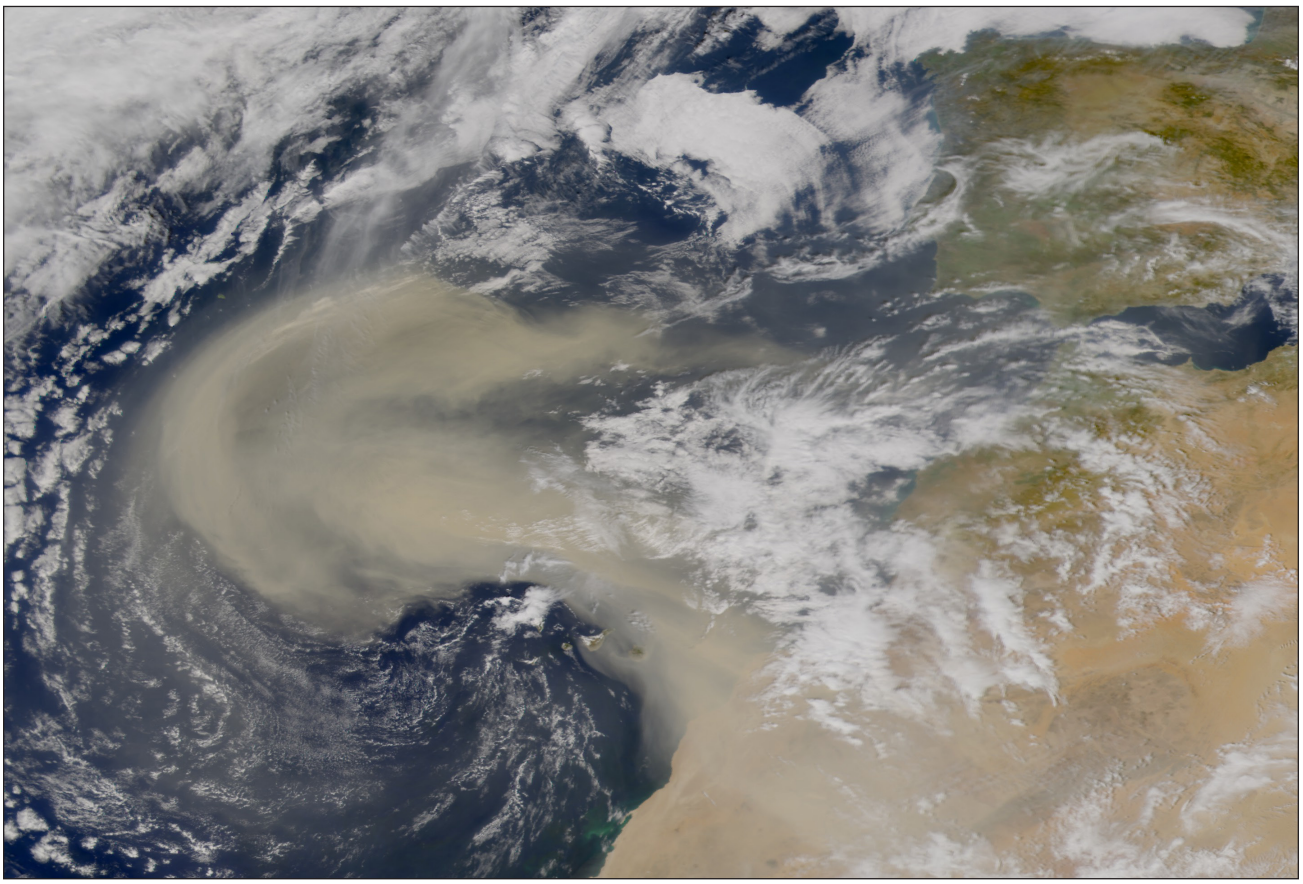

Figure 11. Saharan dust plume over the Atlantic Ocean. Courtesy NASA.

in modern sand dunes that are close to a source, but they never discuss airborne transport or identify possible nearby sources for the Coconino.[70]

Dolomite, Marine Minerals, and Angular Feldspar

The Charge: *Dolomite, marine minerals, ooids, and angular feldspar have been found in the Coconino, indicating a marine depositional environment.*[71]

Response: Formations like the Coconino do not have neat, clean edges and are not made of just one type of sediment, even when their name (e.g., "sandstone") suggests otherwise. Sediment from one depositional environment with an associated set of characteristics known as facies will transition to, or interfinger with, sediments of neighboring environments. This happened more than once to the Coconino with sea level changes and subsidence/uplift. It is not surprising that dolomite interfingers with northern parts of the Coconino, since the Coconino was surrounded by the sea on three sides at the time of deposition. As an aside, the mineral structure of dolomite requires it to form in time frames consistent with the geologic time scale in coastal and evaporative environments rather than after rapid and deep burial, which by itself argues against flood geology.[72] Geologists realize that eolian sands in a shoreline area can be reworked in shallow sea waters.[73] Indeed, Karl Krainer et al. found marine microfossils (forams) in a Coconino equivalent to the east known as the Glorieta Sandstone and concluded that the eolian sands were reworked in a shallow marine setting.[74] This does not mean the entire Glorieta was marine; rather, it indicates that some parts of it are eolian and some are marine.

Ooids form when small nuclei like sand grains are coated with concentric layers of calcite or other minerals. This happens in strong currents or agitated water with high saturation levels of calcium bicarbonate, such as those at a tropical beach. Flood geologists argue that eolian transport "is difficult to envisage bearing in mind the fragility of these ooids."[75] However, the ooids found by flood geologists were in the top part of the Coconino and north of the Colorado River. Both flood and conventional geologists acknowledge that the Coconino is overlain

by a marine deposit—the Toroweap Formation. Flood geologists acknowledge that the Toroweap interfingers with northern parts of the Coconino, but ignore the impacts that the sea would have as it advanced inland and reworked upper parts of the Coconino. Also, it has been observed that marine carbonate grains can be blown appreciable distances inland and the Coconino was never that far from the sea.[76]

Flood geologists state that it is difficult to understand how angular K-feldspars could survive in an eolian environment without becoming rapidly rounded unless there was a nearby fluvial (stream) or bedrock source. They acknowledge that feldspar concentration is greater in northern parts of the Coconino. But then they fail to consider the possibility that sources existed close to the northern Coconino, such as deposits of sediment eroded from the Ancestral Rockies or even closer uplifts.

Sand Grain Frosting

The Charge: *The frosting of sand grains in the Coconino did not occur by ballistic collisions of grains in an eolian environment as some have imagined.*[77]

Response: Flood geologists are correct that sand grain frosting was not caused by collisions. However, researchers have known for several decades that frosting has other causes. In 1962, Kuenen and Perdok stated that "frosting of quartz grains is thought to be due in minor degree to mechanical action (1) by wind and (2) by water, but mainly to chemical action (3) by corrosive solutions and (4) by alternate solution and deposition of matter, especially in desert areas."[78] In 1978, Robert Folk pointed out that in dunes of the Simpson Desert of Australia, silica is precipitated as scabby, "turtle-skin" crusts on sand grain surfaces, and is re-precipitated as water evaporates deeper within the dunes.[79] The recycling of sands from earlier sedimentary rocks into the Coconino could also have played a role in the frosting process.

Thickness

The Charge: *Modern sand dunes are not as thick as the Coconino, and the Coconino could not have been deposited in a slowly subsiding basin because it crosses through many ancient basins.*[80]

Response: The argument makes the unsupportable assumption that multiple basins could not form gradually in the same deep time frame. Differing crust characteristics on a regional or continental scale and sideways tectonic forces slowly deforming the crust could allow this to happen before and/or while the Coconino was deposited. Surveyed elevations and compiled regional stratigraphic data show that basins did indeed provide abundant space for Coconino sands to accumulate, especially south of an upward deformation in underlying rock known as the Sedona Arch (fig. 12).

Sand Waves

The Charge: *Large sand waves comparable to those in the Coconino have been found in many marine settings.*[81] *The Coconino was deposited by sand waves during the global flood "in a matter of a few days."*[82]

Response: Flood geologists use several diagrams developed by conventional geologists which depict crossbed patterns that can be produced by under-

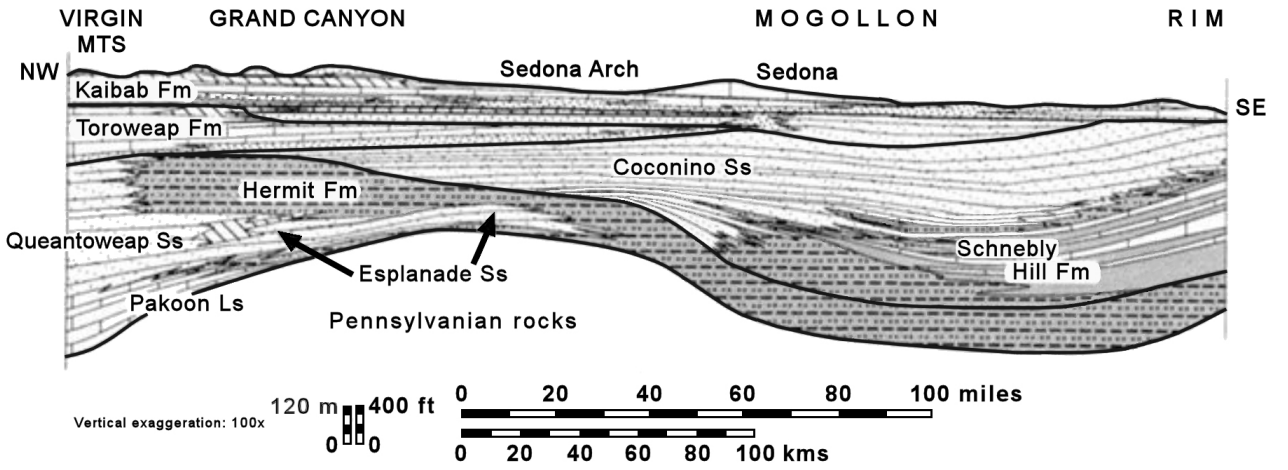

Figure 12. Northwest-southeast cross section of Permian formations in northern Arizona. Courtesy Ron Blakey.

water sand waves. However, they obscure the fact that depositing the Coconino by such normal processes would take at least hundreds of years.[83] As described in the next section, depositing the Coconino in a matter of days would require the equivalent of regional-scale slabs of sand sliding in each day that were dozens of feet high—an impossible environment for sand wave formation.

Is Aqueous Deposition the Same as Global Flood Deposition?

Flood geology articles targeted for lay readers depict Coconino crossbeds as being formed by the washing of sand grains over the top of underwater dunes.[84] Such normal sediment transport processes are known to produce underwater sand dunes, as shown in flood geology videos and presentations.[85] But even if the previously discussed flood geology "charges" were correct, only normal underwater sediment transport processes would be indicated. Conventional geology accepts that many sedimentary formations were deposited in a variety of aqueous environments, but these involved plausible geomorphological processes—some gradual, some catastrophic—that are consistent with the continuity principle and laws of physics. Flood geologists must make an astronomical jump to equate normal water deposition to global flood deposition and then hope this will go unnoticed.

The vast difference between normal water deposition and global flood deposition was addressed in my 2011 *PSCF* article. Deposition of the Coconino in a matter of days was shown to be the equivalent of thick sediment slabs advancing across a multi-state region each day. But flood geologists are not only arguing that the Coconino was deposited by the global flood. They also maintain that most of the continental sedimentary record was deposited in less than a year. Since the Coconino is part of the 150,000 square mile Colorado Plateau, this larger region can be used in another reality check. The layers in this plateau said to have been deposited by the flood average over three miles thick. This means about 480,000 cubic miles of sediment would have to be transported into the region in less than a year. This volume can be represented by a box that is 390 miles by 390 miles by 3.2 miles deep (fig. 13). The implications of what would be required to fill this enormous box with sediment in less than a year, as depicted in figure 13, are rarely considered. Note that subsequent late- or post-flood erosion of these layers is not being addressed here.

Assuming flood sediments were instantly compacted and dewatered during deposition (this is obviously physically impossible for silts and clays), they would have to pile up in the plateau region at a rate of about 75 feet per day.[86] Alternatively, the equivalent of a 75-foot-thick slab of sediment would have to slide in sideways at about 16 mph and cover the plateau each day. The time frames for flood sedimentation proposed by many flood geologists require even thicker "daily slabs." With such astronomical transport rates, a global flood would not be able to produce sand waves and crossbeds, let alone a fantastically complicated global sedimentary record

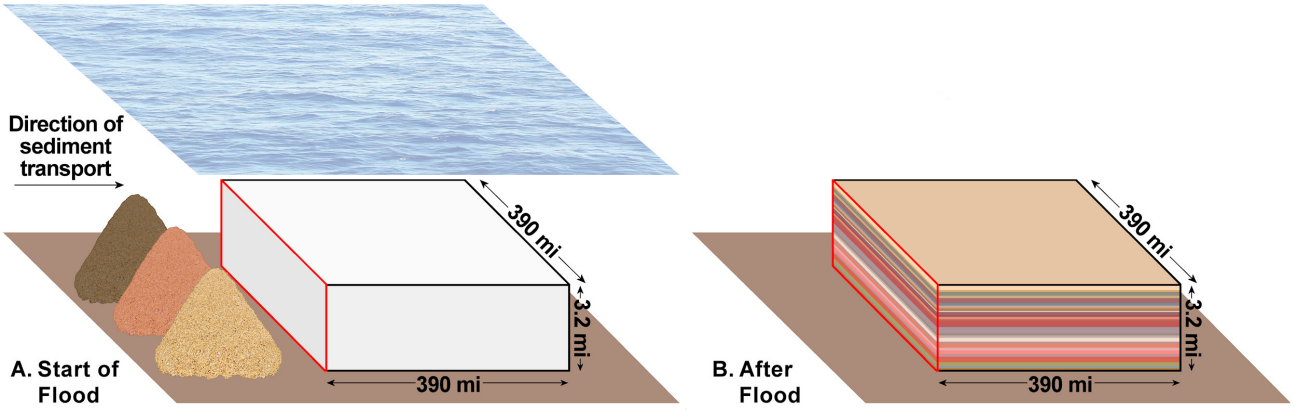

Figure 13. Schematic representation of Colorado Plateau sedimentation by the global flood. A: Situation at start of flood showing pre-flood sediment accumulations totaling 480,000 cubic miles located immediately "upstream" from the empty "box" where they will be deposited as the Colorado Plateau. Different shades (colors) represent discrete types of sediment that will be deposited in different layers. All sediment will have to pass through the left side of the box. B: Situation after deposition of 480,000 cubic miles of Colorado Plateau layers (before erosion).

with innumerable facies changes, trace fossils, body fossils, and a host of other detailed features.

When flood geologists argue that the Coconino is part of a much larger regional sand sheet covering all or parts of fourteen western US states,[87] they make the sediment transport problem even worse. They provide maps and charts attempting to link dozens of different formations across these states. Obscured in this effort is the fact that these formations are not all linked in one "sheet" as implied and not all are pure "sandstones" that originated in the same depositional environment. Also, the larger the area, the more astronomical the lateral sediment transport rate must be to deposit the "flood layers" in that area during the flood year. It can be shown using simple math that each time the area of a region like the one in figure 13 is doubled, the sediment transport rate (volume/time per unit length of line crossed) required to fill it must increase by a factor of the square root of 2. Thus, what initially appears to be a solid argument for a global flood turns out to be an argument against it.

Conclusion

In the final analysis, deposition of the Coconino Sandstone by wind over a long period of time and not a one-year global flood is indicated by (1) the presence of wind ripples, even in places where flood geologists tried to use features to argue for aqueous deposition; (2) the presence of animal trackways which were clearly produced at numerous different levels and times in sediment exposed to the air; (3) the sharp boundary between the Coconino and underlying Hermit Formation at most locations, indicating that Hermit muds had at least multiple centuries to dewater, compact, and lithify before sands were added on top; and (4) the astronomical deposition rates that a global flood would require to deposit the entire Coconino in a matter of days, which would preclude existence of any kind of detailed features, including ripples, animal trackways, sand waves, and crossbeds.

Some of the findings presented by flood geologists about the Coconino Sandstone may have the positive effect of spurring future researchers to collect more data and develop an improved hypothesis. However, in placing so much emphasis on refuting their critics and seeking to frame their data to support aqueous deposition, flood geologists missed opportunities to increase scientific understanding of the Coconino. In setting out to present data which they believe refutes their critics, flood geologists limit themselves to the older research tradition—cataloging features and characteristics. The newer approach in conventional geology distinguishes process from features and characteristics, seeking an understanding of how all the data fits together through processes known to operate in the real world (actualism). Thus, conventional geologists can accept that data obtained in formation A points to one or more aqueous processes and the data for neighboring formation B points to eolian processes. They then seek to develop a viable process-response model which explains how both could be true across a varied region over time. With flood geology, the predetermined goal is to persuade people that both formations A and B point to aqueous processes.

Flood geologists' Coconino Sandstone arguments may seem convincing at first to those unfamiliar with the earth sciences, but can be addressed after careful research of both flood and conventional geology sources. As exhibited by how results of the pickle jar experiment were characterized as "the mica disappears after two (or four) days," flood geologists must shoehorn their findings into a mold shaped by their own narrative and leave out the data and explanations that do not fit. Christians are offered a false choice—either accept this approach as good science or you "don't evidently believe God's Word is true."[88] Perhaps it is time to consider that God operated over long eons of time in ways that are more difficult to comprehend than explanations supposedly required by so-called "literal interpretations" of the Bible.

The young-earth ministries have become very proficient at using articles, videos, and presentations to frame features like the Coconino Sandstone in ways that convince Christians who are unfamiliar with the complexities of geology, that science really supports a global flood. Many Christians have unwittingly accepted the idea that it is just a matter of "same data, different conclusions" or "there are PhD scientists on both sides of the issue." What gets lost when trying to shoehorn the observational evidence to support a young earth is that the Christian faith, and the overwhelming consensus among geologists that the earth is very ancient, are both true.

Acknowledgment

The author would like to thank Drs. Gerald Bryant and Spencer Lucas for their reviews and comments on this article, Dr. Ron Blakey for providing graphics and answering many of my questions, Dr. Ricky Bartlett for his update on current trackway research, Daniel Gibson for lining up key geologic experts to assist in this project, and the anonymous reviewers and editor of *PSCF*. Any errors in the text or graphics are my responsibility and not that of any reviewer or contributor.

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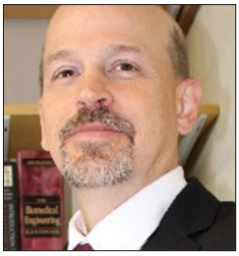

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DOI: https://doi.org/10.56315/PSCF9-24Hall

Toward a Theology of Sustainable Aquaculture: Wisely Producing Safe Abundant Seafood While Enhancing Fruitfulness of Aquatic Creatures

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Aquaculture, commonly conceived as "fish farming," includes the culture of animals, plants, or other species in water. Although about 70% of Earth's surface is covered by water, aquaculture often uses much smaller spaces such as tanks, ponds, raceways, or aquatic enclosures to grow aquatic food, fiber, and other resources. Theologically, humans are called to "protect and serve" (Gen. 2:15), and throughout the Bible, there are calls to good stewardship and cultivation while allowing for fruitfulness of other creatures. Biblically, fish are seen as God-created aquatic creatures, often used as food, with implications for wise stewardship (e.g., Psalm 8).

At the present, many fisheries around the world are overfished. Sustainable aquaculture should address environmental, economic, and health concerns, and it could help reduce the stress on natural fisheries. As the fastest-growing protein sector, aquaculture now produces more seafood than the wild harvest of all the world's oceans (now approximately 120 million metric tons per year). This promising and expanding field (approximately 6–8% growth per year over the last 50 years) includes extremely efficient converters of protein, micro- and macro-algae (seaweeds) that can absorb unwanted wastes and clean the water, and filter feeders such as oysters and clams that clear the water of algae and other particles, simultaneously contributing various ecosystem services and habitat. Ongoing problems include pathogenic and related disease issues, environmental pollution in surface waters, food safety, increasing automation utilization, potential genetic concerns, and the relatively recent start of modern aquaculture (most aquaculture growth has occurred since 1970). This article addresses each of these hurdles, identifies areas of theological and ethical concern, and clarifies matters of interest to Christians and others, suggesting possible ways forward in this fast-growing but challenging field.

Keywords: aquaculture, automation, food safety, seafood, water quality, ethics, theology, sustainability

"And God said, 'Let the water teem with living creatures … so God created the great creatures of the sea and every living thing with which the water teems and that moves about in it.'" (Gen. 1:20–21, NIV)

"Then God said, 'Let us make mankind in our image, in our likeness, so that they may rule over the fish in the sea …'" (Gen. 1:26a)

"The Lord God took A'dam *(earthling) and put him in the Garden of Eden to* shmar *(protect) and* abad *(serve) the garden." (Gen. 2:15)*

"Lord our Lord, how majestic is Your name in all the earth ... You care for (human beings) … You have made them rulers over the fish in the sea, all that swim the paths of the sea …" (Ps. 8:1,6–8)

"Taking the five loaves and two fish and looking up to heaven, Jesus gave thanks and broke them. Then he gave them to the disciples, and the disciples gave them to the people. They all ate and were satisfied." (Matt. 14:19b–20a)

Definition of Sustainable Aquaculture

Aquaculture is the culture of aquatic organisms for food, fiber, and other resources.[1] It has developed quickly in recent decades, producing only a few percent of total fish consumed in 1970, but now providing roughly as much biomass as wild harvest from all the world's oceans (albeit in a much smaller total area) and is worth roughly $160 billion.[2] Fish and shellfish currently represent over 17% of all animal protein consumed globally, providing high quality protein

for the growing middle class as well as low cost protein for the world's poor.[3] It is also the fastest-growing modern protein source on the globe.[4] There is evidence of historic culture of carp in China, of floating plant/fish systems in Mexico, of historic fish ponds in Europe, and of indigenous farming of fish from coastal embayments in historic Hawaii, among others.[5] These systems appear to have been relatively small and fairly sustainable. However, concerns about sustainability of modern aquaculture for large populations raise questions on how to minimize adverse effects on the environment, enhance production efficiency, and optimize health;[6] each of these may be considered for their ethical and theological implications.

A truly sustainable aquaculture would minimize environmental effects and provide safe, ethical, and healthy products while utilizing the ability of finfish to convert feed very effectively, ideally allowing wild fish stocks to recover from their currently depleted status. Modern aquaculture is only a few decades old (see fig. 1) but is likely to continue to grow, so we explore a theology of sustainable aquaculture.

Seafood includes finfish, crustaceans, fish eggs, marine mammals, mollusks, aquatic plants, and algae. Consumer demand for seafood has increased due to its perceived health benefits and abundance.[7] With global fish production (wild caught plus aquaculture raised) now approaching 170 million metric tons, and with seafood making up 17 percent of all animal protein consumed by the global population (in 2020), seafood safety and sustainability is critical.[8]

A report by the Food and Agriculture Organization of the United Nations (FAO) indicates that Americans now eat about 16.5 pounds of seafood per year compared to the 10 pounds consumed in the 1980s.[9] Aquaculture, in particular, is rapidly increasing production, while capture fishing has remained stagnant.[10] Although aquacultural systems do rely on significant capital and energy, it has been noted that the edible meat yield in fish is usually high compared to livestock, both in terms of feed conversion ratio and meat yield per total animal weight.[11] Despite the productivity and growth of aquaculture, obstacles remain and must be addressed to move toward sustainability. Some of the most important questions have ethical or theological aspects: How can we provide for fruitfulness of both humans and other creatures? How can we care for God's good creation, including aquatic creatures and environments?

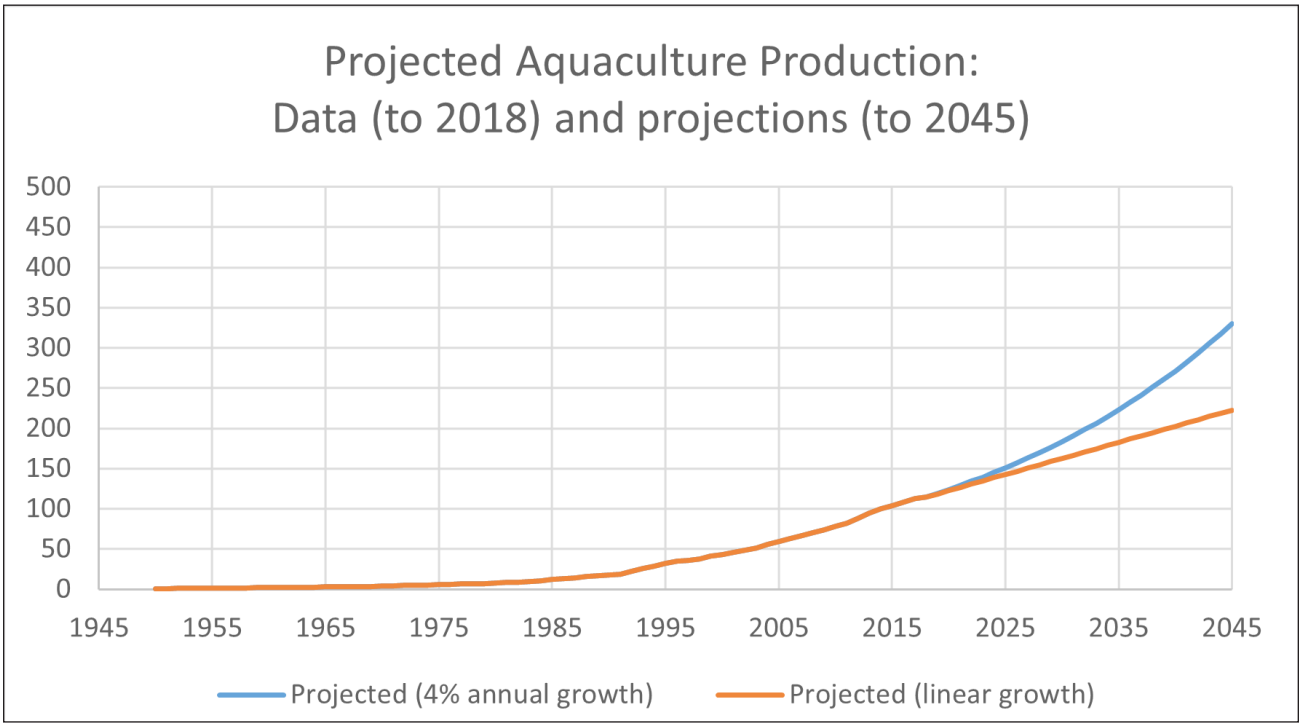

Figure 1. Growth of aquaculture has now surpassed all wild caught seafood (based on data from FAO 2020). About 40% of aquatic production is macroalgae or seaweed. The long-term growth has been 6–8% per annum for several decades. Units are millions of metric tons (MMT) of annual production.

Harmful Results of Aquaculture

Thirty percent of regional fish stocks are overexploited, and a majority of fisheries are at or beyond their sustainable limit.[12] The ramifications of overfishing on global fisheries include coastal pollution, diseases, genetic introgression, and human and animal health.[13] Recent work argues that the world's oceans have been substantially affected and that aquaculture has not yet provided enough fish to reduce the stress on the world's natural fisheries.[14] However, without continued growth of aquaculture to feed growing populations, can we hope to provide protein for millions of poor or hope for the world's depleted fisheries to be restored?[15] Conversely, can the growth of aquaculture continue, and if so, at what cost?[16] How might we move aquaculture onto a more sustainable path, providing high quality protein for today while stewarding our oceanic and freshwater resources for the future?[17] What special contributions and considerations come from a theological perspective? These questions are central to providing a vision for future development of aquaculture that not only protects the oceans but ideally also contributes to restoring marine fisheries and other aquatic habitats while providing healthy, efficient protein for the world.

Implications of Aquaculture on Wild Stocks

While the hope has been that aquaculture might reduce the stress on wild stocks, at least two major areas remain as significant considerations. First, carnivorous fish cultured in tanks or cages still require a high-protein diet, and fish meal is part of that diet. This fish meal often comes from wild bycatch and drives up demand for wild caught fish. Parallel to this is another large and growing field: the demand for fish in animal diets, including pets. Cats in particular need protein in the diet, and fish is often considered a desirable part of cat diets. Finally, the "farming" of some fish such as tuna is often dependent upon catching wild fish and then fattening them in ocean cages.[18] This is yet one more demand on wild stocks.

How can we reduce these outcomes? Johann Bell and coauthors suggested ways to sustain Pacific Island economies which are dependent on tuna harvest.[19] Others have addressed ways to advance tuna culture, but at the same time reduce adverse effects on wild stocks by breeding and culturing tuna in captivity.[20] These efforts require more work before they will be useful in solving the concurrent problems of the wild fisheries.

Another example of aquaculture's influence on wild fish stocks has involved the farming of Atlantic salmon from Norwegian stock. These fish have escaped at times and interbred with the local populations (typically relatively small in eastern Canada and the US); the resulting hybridization between farmed and wild stocks, and genetic changes in the overall wild population, are causes for concern. As recently as 2018, substantial occurrences of "large escapes" of domesticated Atlantic salmon "unambiguously" diminished populations in seventeen of eighteen rivers sampled.[21] These circumstances are limiting the fruitfulness of wild fish (contrary to Genesis 1) and damaging the environment. Dis-covering methods to mitigate the effects on wild stocks is crucial for advancing toward a more sustainable aquaculture.

Pollution, Wasted Resources, and Environmental Impacts

The presence of excess nutrients both from land-based human farming and industry and also from aquaculture in and near coastal areas has been documented in various "dead zones" and related phenomena. Some of this is directly attributed to excess feed and feces from aquaculture farms. Growth may exacerbate this, but more-sustainable practices (in the case of seaweed and filter feeders like oysters) might improve water quality. However, at present, numerous studies have noted ongoing pollution in areas near and often several hundred meters from aquaculture feeding operations.[22] Clearly, as aquaculture grows, these consequences will escalate unless efforts are made to minimize feeding operations or to manage them differently. Michael Timmons and Brian Vinci suggest recirculating aquaculture systems (RAS) with fish tank culture to manage wastes more effectively.[23]

Atlantic Sapphire, whose website boasts an entire section on sustainability, grows oceanic fish including Atlantic Salmon in recirculating systems "better for fish, for people and for the planet we all share," and claims to "skip the fish wastes, escapees, hormones, parasites, and antibiotics used in some sea-based fish farming."[24] These are fairly idealistic

claims which do not acknowledge the significant capital and operating costs of most land-based RAS or other complexities that may be posed in these more controlled environments. While technology may be deployed to sustain or harm, sustainable activities must consider the laws of physics and biology and work with them, not against them. We also have the task of maintaining humility, a fundamentally theological approach. At the core of a theology of sustainable aquaculture lies the balance between biology and ecology.

Ecosystems can also be affected by aquaculture. For some time, mangrove ecosystems were destroyed for shrimp farming, leading to loss of protection from tsunamis and coastal storms.[25] More recently, Rosamond Naylor et al., in 2021, note that "destructive habitat conversion, particularly by shrimp farming in mangrove ecosystems raised in the previous review has declined markedly since 2000" and cite studies from China and Vietnam.[26] However, they also note that ongoing serious consequences include "pathogens, parasites and pests," as well as environmental pollution which may lead to harmful algal blooms and may be exacerbated by changes in climate. These problems at the ecosystem level may be further exacerbated by biological limitations of aquaculture.

Biological Problems: Genetic Introgression, Diseases, and Invasive Species

Escapees from cage-based ocean aquaculture systems (or pond systems during flood events) can contribute to genetic introgression, genetic changes from cultured fish that may reduce survival, and genetic diversity of wild stocks. Diseases can be transmitted and may develop more quickly in high-density fish farms, either in the ocean or in tanks or ponds. Parasites may grow on fish; in ocean cages, they can be transmitted to wild animals nearby. Sea lice (parasites found on salmon) have been documented to infest wild fish in the vicinity of cage-based fish farms, posing a problem costing over $100 million annually. Similar dilemmas are encountered in land-based farming, and they significantly influence the potential sustainability in the aquaculture sector. Furthermore, they tend to be inflated as operations grow.

This article is not the first to tackle topics concerning sustainability or even theology and sustainability. In fact, the literature on both sustainable agriculture and sustainability in aquaculture (the culture of food, fuel, and fiber in aquatic environments) has grown in recent decades. Rex Caffey addressed sustainability in modern aquaculture just over two decades ago.[27] Since that time, there has been much scientific work and possibly even more popular activism both for and against aquaculture and its sustainability.[28] The genetics of aquatic systems, introduced species, and disease proliferation within and beyond high-density aquaculture systems are some aspects requiring future research and attention.

The genetic understanding of aquaculture species, compared to other forms of agriculture, is relatively nascent. For example, several species of animals were cultivated (and genetically selected) in biblical times, so we are likely thousands of generations into these genetic selection processes. Most aquaculture species are, at most, a few decades removed from the wild. For example, modern catfish (a $400 million per year industry in the southeastern United States) have been genetically managed for perhaps twenty generations, while striped bass are only on generation eight.[29] Compared to land-based agriculture, aquaculture is very early in its development, but this also allows consideration of how to wisely manage genetic and biological resources.

To date, there has been limited genetic engineering in aquaculture. There has been modest work on triploid (sterile) oysters and tilapia, but this does not introduce any other species' DNA into either oysters or tilapia. One exception is the AquAdvantage salmon (with inserted genetics from other species), which has been viewed positively as a "pioneering application of biotechnology in aquaculture"[30] and negatively with concerns that parallel those about genetically modified organisms (GMOs) in land-based plants and animals. GMOs have now entered the pet trade, including "GloFish." On land, many of our cultivated plant species are now genetically modified (e.g., corn is now over 90% GMO across the United States), whereas this has not yet happened as extensively in aquaculture. Serious concerns include growth hormones and "playing God," unknown consequences of these techniques on the environment, and food safety. In 2015, the FDA approved the AquAdvantage salmon and declared it safe to eat.

Whether and when other species may be introduced is not clear. There has been significant resistance to GMOs.

Furthermore, concerns regarding invasiveness arise with the introduction of an entire species. Invasive species may be presented unintentionally in new habitats where there are few predators to keep them in check. Introduced species (aquatic species native to one area, introduced to another) are common. For example, Atlantic salmon (non-GMO) are grown on the west coast of the United States (US) and Canada, as well as Norway and Chile. Washington state raises five different cultivated species of oysters: the majority are native to other regions, including the Atlantic Eastern oyster *Crassostrea virginica* and the Pacific oyster *Crassostrea gigas,* native to the western Pacific. So far, it appears that these species have not displaced native species excessively, but there are well-founded concerns.

The nutria, or swamp rat, *Myocastor coypus*, was introduced to the Gulf coast from South America to cultivate for fur, but it escaped and has done considerable damage to coastal wetlands. Attempts to control this invasive pest have included paying bounties for trapping, turning them into dogfood and sausage, and reinvigorating the native predator *Alligator mississippiensis* population.

Another example of invasive finfish species is the jumping carp or silver carp, *Hypophthalmichthys molitrix*, slowly invading the US Midwest. Ironically, it is threatened in its native China and Siberia.[31] One solution would be to utilize native species to compete with invasive counterparts. A second approach would be to include biosecurity techniques to reduce the spread of invasive species. These are concerns that must be addressed as aquaculture expands.

Health and Safety

Animal and human health are both concerns. Fish is generally acknowledged as high-quality protein, but questions about health of fish may be tied to pathogens. Biosecurity can help, but it is acknowledged that a mix of practices can be found worldwide.[32] Human health concerns with wild caught finfish include substances that may be bioaccumulated such as mercury and other heavy metals. Generally, cultured seafood should minimize this risk, as feed is controlled and bioaccumulation is minimized in cultured systems, where feed conversion is very efficient.

While filter feeders such as oysters, clams, and mussels help clean the water and algae can extract nutrients from the water, food safety in raw seafood is still a concern to safely enjoying these products. We see in the scriptures that eating animals and using agriculture for food has always been an integral part of humanity's function on Earth. In Leviticus 11, God invites the Israelites to consume aquatic animals with fins and scales. At that time, however, shellfish and other sea creatures were regarded as unclean.

After the death and resurrection of Jesus Christ came the introduction of a new covenant between God and those who obey him. A result of this new covenant was the inclusion of Gentile believers in the family of God. This is demonstrated in Acts 10 when God spoke to Peter through a vision. God placed before Peter animals that were previously viewed by Jews as unclean and told him to kill and eat them. Peter refused, but God told him, *"Do not call anything impure that God has made clean"* (Acts 10:15). While God used this vision to call Peter to share the good news of the gospel with non-Jews, a dual meaning regarding a change in food consumption can be understood from the text. Paul explains this new freedom in his letter to the Corinthians. He urged them to realize that *"… food does not bring us near to God; we are no worse if we do not eat, and no better if we do"* (1 Cor. 8:8). However, Paul urges the believers not to be stumbling blocks to brothers and sisters who feel that eating certain foods is sinful. He said, *"Therefore, if what I eat causes my brother or sister to fall into sin, I will never eat meat again, so that I will not cause them to fall"* (1 Cor. 8:13). Even our Lord declared all food clean: *"'Are you so dull?' he asked. 'Don't you see that nothing that enters a person from the outside can defile them? For it doesn't go into their heart but into their stomach, and then out of the body.' (In saying this, Jesus declared all foods clean.)"* (Mark 7:18–19). Knowledge of these scriptures should compel us to give thanks and delight more fully in the food we eat, especially seafood.

Aquaculture is proving a viable source of seafood protein for humanity. Along with the production of seafood, however, comes the responsibility to provide safe seafood for consumers. Food safety is a

looming challenge for food, agricultural, and aquacultural industries. During pre-harvest, processing, distribution, and after consumer purchase, careful consideration is taken to make food safe for human consumption. The risk of illness as a result of eating seafood is more likely than consumption of non-seafood meat due to the fact that seafood products are either eaten raw or processed in ways that may not completely kill harmful organisms.[33] In aquacultural systems, safety can be ensured by proper screening and monitoring of juvenile fish and mollusks to ensure no contaminants are introduced into the system. After the animals are matured and prepared for market sale, systems to clean shellfish can be employed to aid in the further reduction of physical, microbiological, and/or viral contaminants.

Technology may, on the one hand, increase safety; but on the other hand, have unexpected harmful results. Automation is expanding in many different industries—from manufacturing to customer service. The aquacultural industry has also employed automation via the use of automated feeders, sampling devices/vehicles, and monitoring systems.[34] An autonomous system can describe any system that gathers information, generates a solution, and then executes an action implementing the solution.[35] While autonomous systems are an exciting area of technology and one that will almost certainly become more necessary in large-scale aquaculture, these systems can have unintended consequences—both technical and human—involving interaction, intentions, and capabilities.

Combinations or teams of vehicles may work in collaboration to collect multi-perspective data and/or to provide vehicle task assistance.[36] These systems are now being developed and implemented within various fields, from the military to environmental monitoring, and can be configured in various ways based on vehicle type, quantity, and collaborative structure.[37] Collaboration is dependent on the type and amount of interaction on the human-robot interface and the methods of vehicle communication.[38] The shared goal of these systems is to make tasks less expensive, safer, and more efficient in order to expand data collection possibilities, minimize risk, and optimize productivity.[39]

Serious ethical and theological implications are linked with autonomous systems—humans are still responsible for these "autonomous" systems, which may be parallel to "ruling over" other creatures (Gen. 1:26). Damage from autonomous agents might be considered in the same light as responsibility for domestic animals in Exodus 21:28–30. The owner of such a system bears responsibility. Theology should be considered regarding the dynamic relationship between humans and their autonomous systems. This goes beyond aquaculture, but the same principle applies: to enhance fruitfulness of creation, to maintain safety, and, ideally, to enhance human life.

A More Sustainable Path

Sustainability has become a significant part of the conversation concerning how to manage our planet and humanity's stewardship of it, especially over the last few decades. Sustainable development, sustainable agriculture, and sustainable aquaculture have been the focus of many publications, with considerations of social, environmental, and economic aspects, sometimes popularly referred to as "people, planet, and profits."[40] Aquaculture is growing; if managed well, it may help reduce pressure on wild fish stocks while providing high quality protein for billions. A theology of sustainable aquaculture will be biblically based and will consider environmental and social conditions while presenting a vision of fruitfulness and responsible stewardship of creation.

One hope is to grow aquaculture enough to allow for a reduction in the stress on worldwide ocean fisheries and restoration of depleted wild fish populations. This would allow for human and aquatic flourishing. Figure 2 suggests possible scenarios based on current wild harvest and aquaculture production levels and growth rates of aquaculture that may allow wild fisheries to begin a restoration process with reduced catch. Based on this, production of aquaculture will likely exceed 200 million metric tons (MMT) by 2050 (using a conservative linear trend based on growth since 2010); wild fishery harvest can be reduced from recent harvests over 90 MMT to a more sustainable 80 MMT, still providing food for a growing world population (estimated growth approximately 2–3 billion additional people during this period).[41]

Total harvest (wild plus aquaculture) is expected to be nearly 300 MMT in 2050, roughly correlating with an increase in world population, but still minimizing negative effects on the oceans. In a more

extreme scenario, if aquaculture continues to grow at the historic rate of about 6%, this could lead to over 500 MMT of aquaculture production alone by 2050. Further growth in aquaculture that does not harm oceans, biological stocks, or water quality will be an ongoing task. Continued efforts to reduce wild catch to sustainable levels should be made in concert with increasing well-managed aquaculture production. Theological and values approaches, as well as physical (e.g., engineering, management) and biological techniques used to produce this volume of food, could be what separates a largely sustainable future from one that tragically degrades creation.

One example of an aquaculture success that also helped with restoration is alligator culture. These endangered species were reinvigorated substantially through parallel aquaculture and restoration activities. According to practices overseen by regulators, a certain percentage of alligators are released to the wild at 4 feet (1.2m) in length, when they are likely to survive. As a result of this wisely managed aquaculture and related regulations, wild populations have been substantially increased over four decades and the predation of wild alligators has reduced invasive nutria populations and helped reinvigorate the marsh ecosystem.[42] Simultaneously, a multimillion-dollar business in alligator production has grown up in Louisiana, with a similar-size industry in Florida, indirectly helping pay for restoration efforts.

Various authors address sustainability in three areas: environmental, economic, and social.[43] There seems to be agreement on the belief that sustainability is not simply good but necessary for future society.[44] Such beliefs imply values and ethics. A Christian theology of sustainability must be focused on Christ, his atoning work, and the restoration of humans and all creation that is ongoing. Christian values—including truth and grace—must be at the center of such a theology. Our action originates with Christ's love and flows out to his created order with our desire to care for those he loves. This will result in an emphasis on caring for creation wisely and faithfully while providing for people and other creatures with compassion, both now and in future generations. This, as it turns out, sounds similar to "sustainability."

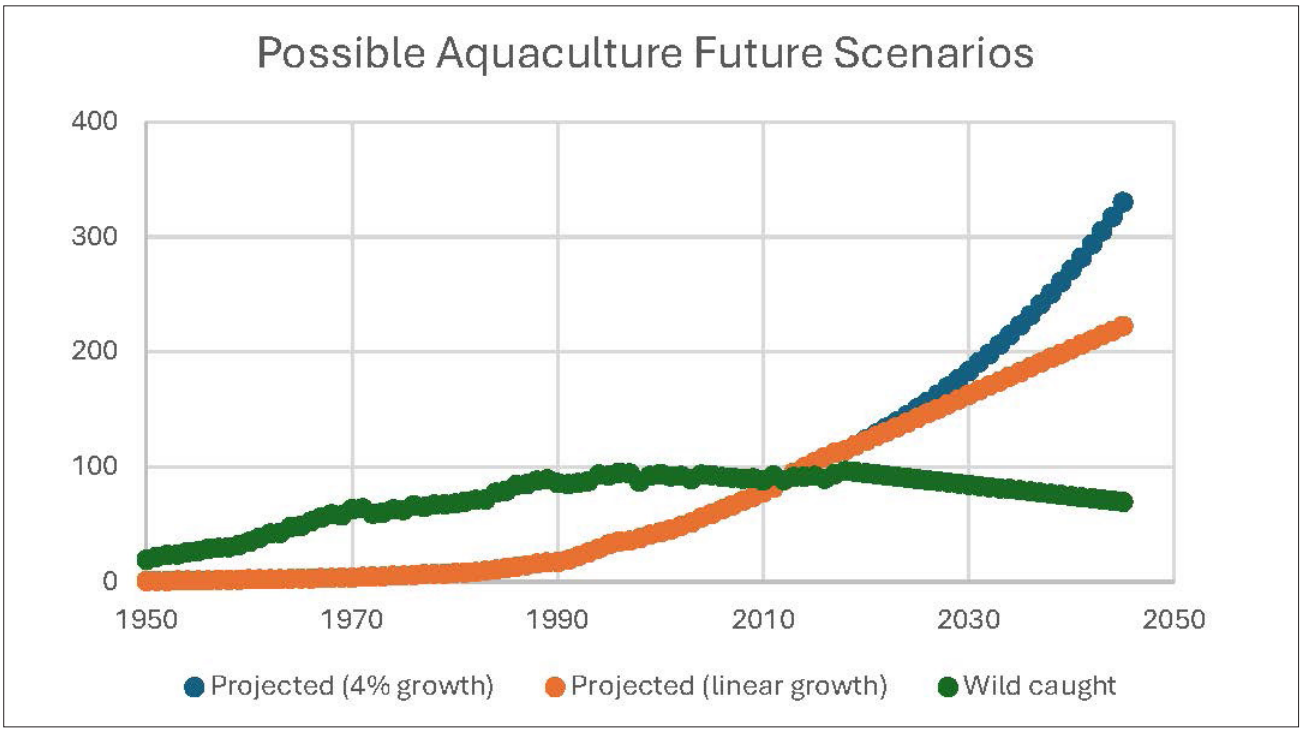

Figure 2. Actual history through the present, and projections based on current levels of wild caught and aquaculture production with conservative linear growth (middle line) based on linear trends from the last decade; and long-term growth rate (upper line) of 6% per year, consistent with aquaculture growth since 1950). Data based on FAO 2020 Fishstat at http://www.fao.org/fishery/statistics. Given past aquaculture growth and expected future trends, wild fisheries could at least partially recover while aquaculture could provide more total protein (aquaculture plus wild fisheries) per person for expected increasing population. The middle (linear growth) model provides more fish protein per person than current totals from aquaculture and wild fisheries, while the higher (6% growth) curve roughly doubles that number by 2045. Units are millions of metric tons (MMT) of annual production.

Long-term sustainability requires each aspect—environmental sustainability (creation care/restoration), sufficient economic return (appropriate use of talents, fair wages), and social and community features (loving our neighbor, thankfulness to God, caring for those in need)—to support a population that can cultivate (Gen. 2:15) and manage resources in a beneficial way. Certain characteristics of sustainability on land are still controversial, but sustainable aquaculture is even earlier in development.[45] Sustainability in aquaculture may mean farming on lower trophic levels by using more plants or algae as feed and less fish meal, or by growing valuable seaweed that cleans the water by absorbing nutrients that could otherwise cause detrimental environmental effects;[46] aquaponics contributes to these desirable outcomes by growing edible plants and fish in parallel systems that increase productivity and minimize environmental pollution.[47] While some cultured species are carnivorous (e.g., salmon, trout), and current models still include their production due to economic demand, these species require more protein—often wild fish—in feed than species lower on the trophic order. Fish such as tilapia and carp can be fed largely plant-based diets, reducing inputs of protein, while filter feeders such as oysters and clams remove algae and other particles from the water column, thus enhancing water quality. In fact, aquaculture's largest production by mass is already aquatic plants: macroalgae or seaweed.[48]

Humans are called to "rule over the fish of the sea" (Gen. 1:26), but the implication is stewardship and caring for these creations—allowing for the fruitfulness of aquatic creatures, not the destruction of aquatic ecosystems. Considering aquaculture as substantially focused on caring for creation and the poor would lead us to harvest this food and also find ways to maintain the fruitfulness of oceanic and aquatic resources. What kind of aquaculture minimizes damage to ocean resources or even helps stressed fisheries recover? How can we avoid overexploitation or damage to the oceans and fisheries, and how can we enhance overall sustainability in aquaculture? A theology which addresses these matters from a biblical standpoint can help undergird a more truly sustainable aquaculture.

Parallels: Sustainability in Agriculture and Aquaculture

Steven Hall proposed a theology of sustainable agriculture in which he suggested that agriculture might include both culture on land (terraculture) and in the water (aquaculture).[49] His main focus was on parallels between the Bible, written across many centuries in nomadic and settled agrarian societies, and our current age, in which we have indeed been fruitful but are now reducing the abundance of other species. There are both secular organizations (e.g., FAO; UN Sustainable Development Organization; Sierra Club) and Christian organizations (e.g., A Rocha, ECHO, Au Sable Institute) which address some of these concerns,[50] but primarily those concerning land-based food and natural systems. As we consider aquaculture, the fastest growing protein sector (fig. 3),[51] and the growth of food, fiber, and other products in the water, some new theological observations as well as technological innovations are worth considering. Underlying each of these technologies are implications for economic, environmental, or social stability. At a theological level, considerations of stewardship of the environment, compassion toward workers and other creatures, and stewardship to provide for ongoing abundance both for humans and for other creatures, are central themes.

What unique contributions can scientists and theologians offer that enhance our current approach to sustainability? In particular, definitions of sustainable development (e.g., of societies) include, at least partially, an ethical aspect—often normative.[52] One ethical requirement is that such development must not impose an undue burden on future generations. In agriculture and aquaculture,[53] the ability to maintain productivity, by both the producer and the region, is a parallel requirement. Sustainability also implies harvesting at a rate that allows the ecosystem to regenerate in a reasonable time period.[54]

As noted, Hall aimed at addressing practical and theological questions concerning sustainability of agriculture. He addressed ethics, the concept of stewardship, economics, communities, and intergenerational equity and justice for the poor, and he concluded with suggestions on redeeming and restoring God's creation and the practice of agriculture. He also cited a handful of references to aquaculture[55] and the statement: "Aquaculturists need to consider how their production impacts the

water, native fish stocks, and other aspects of their environment,"[56] acknowledging Dayton Roberts and Paul Pretiz's *Down to Earth Christianity*, and Wes Jackson, Wendell Berry, and Bruce Colman's *Meeting the Expectations of the Land*, which have theological and values aspects.[57]

Hall included insights from both the "book of scripture" and the "book of nature" point of view and acknowledgment of long-standing theological traditions that address sustainability. Some of these, such as the concept of Sabbath for the land found in the book of Leviticus, are still relevant today, albeit in a somewhat changed physical and cultural environment. Other perceptions are generally accepted tenets of theology with applications to sustainability, especially with the production of food. Finally, there are prophetic passages, both challenging (e.g., "*those who destroy the earth shall be destroyed,*" Rev. 11:18) and optimistic ("*I saw a renewed Heaven and a renewed Earth …,*" Rev. 22:1) about the future. Christians are called to follow the Lord, to care for the least of these, and by extension, to care for both people and creation. In the case of aquaculture, this means focusing on specific ways we can steward and manage aquatic resources to provide food for growing populations while also providing for a prosperous creation and future generations. Some specific areas are critical to consider and should address theology and sustainability in aquaculture.

One hope of this article is to suggest a path forward. This path should be universal in that the broad notions should be acceptable to all reasonable people. It should also be of specific interest to Christians, and hopefully, it will encourage them to address enhanced methods to feed the world's people, especially the poor (*"whoever feeds the least of these feeds me,"* Matt. 25:40). It should describe ways to be fruitful while also allowing God's good creation to do the same. A truly biblical vision should focus on restoring or enhancing the abundance and productivity of the waters, not only from the point of beneficial human use but also from the point of natural biodiversity, ecosystem health, and general stewardship of natural aquatic systems.

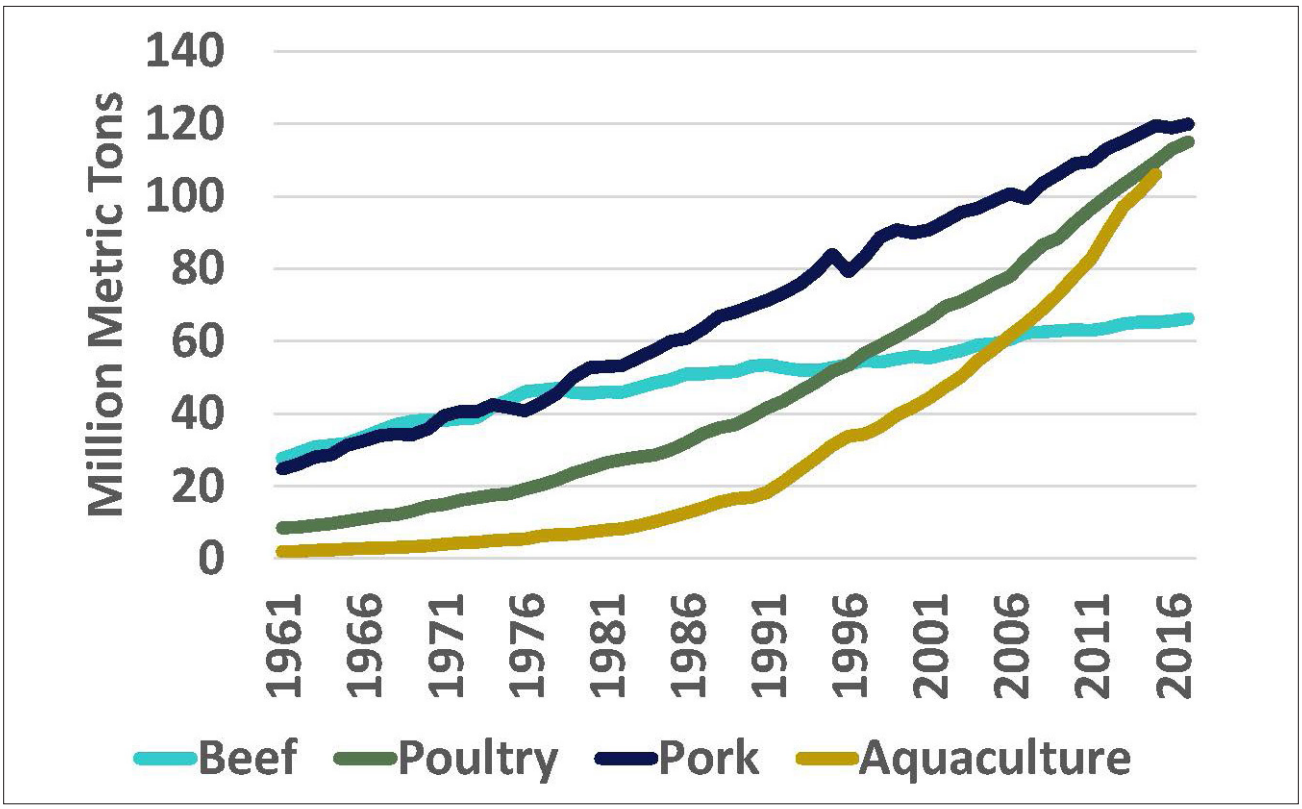

Figure 3. Aquaculture has now passed beef as a source of protein worldwide and is approaching the production of poultry and pork (FAO). Fish are known to be fundamentally good converters of protein, in some cases producing nearly a pound of fish per pound of feed. The support of the water allows less energy to go to building a skeleton and more to biomass. Fish are also poikilotherms, so they do not expend energy maintaining body temperature in most cases. However, despite these efficiencies, concerns about water quality, food quality, natural fisheries, and outcomes on traditional fishing communities are each important to consider (data from UN FAO 2018).

Aquaponics (see fig. 4) is a historic technology that has been modernized and effectively used, not just to survive, but to thrive.[58] This technology has been the subject of much research in the past few decades and offers immense potential in terms of productivity, conservation, waste valorization, and resource use efficiency that can be influential in overall sustainability. It combines the production of fish and plants in one system in which the plants, fish, and nitrifying bacteria develop a symbiotic relationship that creates a micro-ecosystem which makes it sustainable. The modularity of aquaponics allows its application or operation even in urban areas; such a system could bring it closer to the consuming population and eventually reduce carbon footprint.[59]

Another biological concern focuses on the desire to raise carnivorous species from salmon to tuna, impling that we are feeding one species of fish to raise another, clearly not encouraging the recovery of stressed fisheries. Efforts toward feeding more plant-based food to these fish, that is, raising herbivorous fish or even filter-feeding bivalves such as oysters and clams, could address this area. One little-known fact is that the top aquaculture product worldwide is seaweed or aquatic plants.[60] The aquatic plant sector could expand, increasing the output of aquaculture while minimizing environmental damage, or, if carefully managed, it could be used to help clean water and restore ocean health.[61] One practical and ethical challenge is that the value of seaweed is often lower than that of carnivorous fish, pushing producers to focus more on less-sustainable salmon and less on macroalgae, for example. Finding ways to enhance the value or to provide payments for the ecological value of removing nutrients might help encourage farmers to focus more on sustainable plant products.

Some of these techniques to reduce stress on the ocean focus on growing aquatic species low on the food chain, such as plants, algae, and filter feeders—for example, shellfish that filter algae and other material in the water, all of which can enhance water quality, provide habitat, and still produce aquatic food. Improving our understanding of reef systems, microalgae, and macroalgae (seaweed) could help enhance productivity of the oceans while maintaining or perhaps restoring some species and ecosystems.[62]

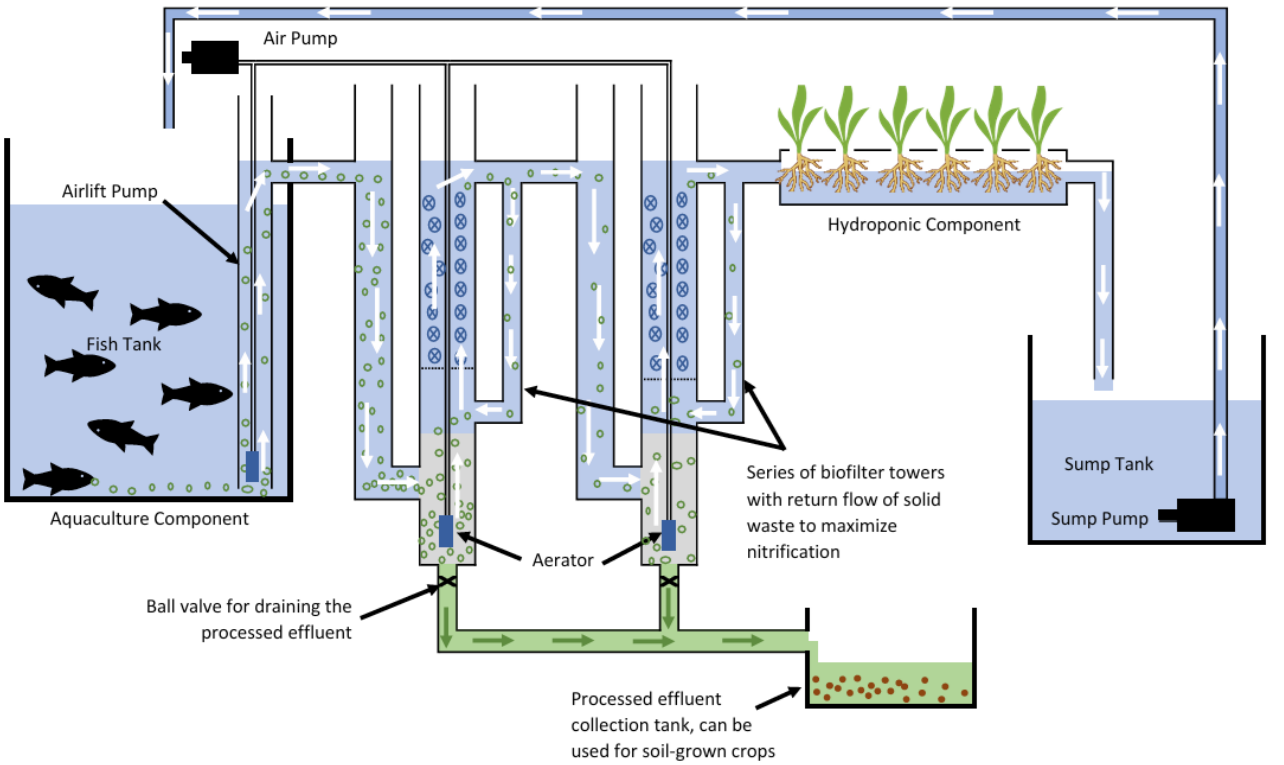

Figure 4. Flow diagram of a recirculating aquaponics system with series of biofilter towers to optimize the nitrification of ammonia into nitrite and nitrate. The nitrified nutrient is readily used by plants and cleans up the water before returning to the fish tank. This design uses an airlift pump and submersible pump to recirculate the water. The airlift pump also helps to maintain the dissolved oxygen and disperse carbon dioxide. An aerator is provided at the bottom of the biofilter tower and acts as "mechanical digester" to extract nutrients from the effluent. The collected solids will then be drained out and can be used as fertilizer and soil enhancer for soil-grown crops.

There is potential to responsibly use enhanced design techniques for shellfish culture systems to improve water quality and to grow food. However, responsible management of technology has theological and ethical dimensions which extend beyond the purely biological. Specifically, automation and autonomous systems are technological sectors that are growing fast, with substantial automation already used and more use of autonomous systems expected; the theological and praxis aspects of these technologies should be considered carefully.

Technology in Service to Sustainability

The goal of any kind of innovation is to reduce current problems and avoid future ones. This is especially true for sustainable aquaculture. Unpiloted surface vehicles (USVs) are being used to collect water quality data to evaluate existing or potential aquaculture operation sites.[63] Autonomous underwater vehicles (AUVs) are traveling beneath the surface to inspect and manage net pens.[64] Even unpiloted aerial vehicles (UAVs) have been made capable to estimate chlorophyll *a* concentrations to help monitor the health of a body of water.[65] Open-ocean aquaculture is expensive in terms of labor and maintenance costs, and therefore many researchers and aquaculture businesses are moving in the direction of autonomy.[66] This progression toward autonomy can have profound effects on the industry.

Autonomy in aquaculture has the ability to greatly reduce cost, man-hours, and risks to safety. Ingrid Bouwer Utne et al. claim that there is limited focus in research on health and safety in aquaculture.[67] There were over 1,400 injuries from 1988 to 2013, and approximately 33 fatalities from 1982 to 2013, in Norway alone.[68] The Code of Ethics for Engineers, written by the National Society of Professional Engineers, states that "engineers shall hold paramount the safety, health, and welfare of the public."[69] Sharkey makes the contention that "public and international discussion is vital in order to set policy guidelines for ethical and safe application before the guidelines set themselves."[70]

Many questions relate to purpose—of devices and of human beings. Human qualities include the fruits of the spirit (Gal. 5:22), which culminate in love. How can we create and guide automated and autonomous systems that encourage people in these fruitful and loving directions? Proponents of sustainable aquaculture by automation must consider how to address these problems on the future inclusion of autonomous vehicles and systems.

Food Safety and Added Value

Keeping food safe to eat is critical to human health. Depuration is a processing method in which filter-feeding organisms harboring contaminants are allowed to filter feed in a clean water source, thus allowing for the natural purging of contaminants from the organism.[71] These systems can even be enhanced by manipulating key depuration parameters such as processing time, water temperature, water flow rate, and water salinity. For example, A. M. Larsen et al. found that high salinity was an effective component in reducing *Vibrio parahaemolyticus* and *Vibrio vulnificus* in live oysters during depuration.[72] Cooking seafood is always a suggested method of reducing food pathogens, but cooking often alters food product quality. Application of processing methods that do not change the notable characteristics of seafoods, but effectively eliminate human pathogens, is a problem that research is actively addressing.

Aquatic animals intended for food, including bottom dwellers and filter feeders in particular, are strongly affected by their environment. The long-term approach to food safety involves acknowledging and responsibly stewarding water resources. Among other steps implied by this approach is the willingness to manage water quality, which implies societal responsibilities upstream. Specifically, proper treatment of human and livestock wastewater is essential, and industries and individuals must act responsibly to reduce toxic effluents in surface waters. These waters hold consequences for us all, with downstream communities, both human and aquatic, experiencing more-pronounced effects.

Parallel to the concept of food safety is the idea of adding value to seafoods by various forms of healthy handling and processing. As consumers of seafood, it is imperative that we take on a greater responsibility in the stewardship of aquatic life. Currently, we see that aquaculture can provide an excellent alternative source of protein for humans. The majority of fish feed is turned into energy for the growing fish, so waste is minimal if systems are planned well.

Aquaculture also has the potential to relieve stresses on lands that have been over-tilled and depleted of nutrients. Seafood waste can contribute to fertility or serve other useful purposes. For example, recycled oyster shells may be one method of sustainable carbon sequestration, while algae can be used for renewable biodiesel production.[73] Similarly, hydroxyapatite, beneficial for medical bone reconstruction, has been produced from components of fish bones.[74] Current and future research continues to make use of aquatic systems and seafood and their subsequent waste.

Theological and ethical considerations regarding value-added seafood encompass both safety and quality, emphasizing high protein content, low fat, and desirable nutrition. Fundamentally, aquaculture should be a way to maintain good quality, as the feeds are often provided and controlled more than for wild fish. However, mislabeling can be unethical,[75] and the health benefits of aquatic products can be reduced by processing that diminishes nutrition content or adds unhealthy calories (e.g., breading or frying). By recognizing the value of various aquatic organisms and the value of their various components, not only can we more fully utilize but also appreciate and enjoy the bounty the Lord provides.

We should understand, in modern times, that God wants us to enjoy his creation and celebrate his goodness by consuming aquatic animals and plants. For example, Jesus, before his ascension in Luke 24, ate a piece of broiled fish. He and the disciples often fished for food since seafood was a vital food source in ancient Jewish culture. Ultimately, we should be reminded that human consumption of seafood, along with responsible stewardship of the planet's waters, aquatic life, and seafood byproducts, not only contributes to the growth of the seafood and aquaculture industry, but it also allows us, as stewards, to participate in a plan for humanity that traces back to the beginning (see Gen. 2:15, where *A'dam* is instructed to "protect and serve" creation).

Conclusions and Best Practices

Aquaculture is the fastest-growing protein sector. With a growing world population expected to add more than 2 billion people worldwide by 2050, it is critical and ethical that we produce healthy, efficient food such as fish and aquatic plants. However, various technological, ecological, and social complications remain; a theology of sustainable aquaculture must address these as they emerge and are introduced. Biblically, we are stewards with responsibility to care for God's creation. We can enjoy seafood, whether wild caught or cultured, but should do so wisely, and in such a way that water quality and fisheries, as well as the communities tied to these resources, remain healthy or are restored to productivity and are preserved for future generations.

Some practical conclusions are appropriate. Scientists, regulators, businesses, coastal communities, and consumers—all can learn and act wisely.[76] Regulators can consider long-term implications of development choices, infrastructure placement, and restoration/conservation of aquatic resources. Businesses are encouraged to prioritize the production of valuable products (aquatic foods, fuels, and fibers are indeed valuable) in a sustainable way, as we have suggested. Coastal communities can consider further development in light of scientific findings and wisely invest (or defer investment) in ways that can sustain and protect both human communities and the ecosystems they depend on. Consumers can be aware that aquatic products are generally healthy and efficient sources of protein, whether cultured or wild caught. They can choose more aquatic plants (e.g., seaweed and related products), filter feeders (e.g., mussels, oysters, clams), and finfish and shellfish that are herbivorous or omnivorous (e.g., tilapia, pangasius, herring, anchovies), and limit the amount of large carnivorous fish (e.g., tuna, salmon) that require more net resources and may also bioaccumulate undesired toxins (these are often marked with a warning to limit consumption).

All of this is presented humbly, as consistent with current knowledge and subject to further investigation and interpretation, but we hope this encourages conversation about how to make aquaculture more sustainable by applying both scientific and theological insights. Theologically, we are still looking forward to a fully renewed earth that explicitly includes aquatic systems as referenced in Revelation:

> *Then the angel showed me the river of the water of life, as clear as crystal, flowing from the throne of God and of the Lamb down the middle of the great street of the city. On each side of the river stood the tree of life, bearing twelve crops of fruit, yielding its fruit every month. And the leaves of the tree are for the healing of the nations.* (Rev. 22:1–2)

As children of God, we are called to steward his creation, including water ecosystems, humans, and other creatures. In short, aquaculture is expanding, and will continue to grow worldwide. We are called to manage the growth of aquaculture in a way that glorifies God and continues to provide a fruitful (and restored) planet with healthy aquatic ecosystems and creatures.

About the Authors

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Laura Newsom is an undergraduate researcher under the mentorship of Steven Hall and Christopher Pascual. She is currently pursuing a bachelor's degree at North Carolina State University in chemical engineering with a concentration in sustainable engineering, energy, and the environment.

Notes

[1]Food and Agriculture Organization of the United States (FOA), "The State of World Fisheries and Aquaculture 2020," https://www.fao.org/state-of-fisheries-aquaculture/2020/en/, https://www.fao.org/3/ca9229en/ca9229en.pdf, hereafter FAO 2020.

[2]Ibid. This report includes graphs and figures attesting to the dramatic increase in aquaculture over the last 50 years. Fish consumption is now greater than beef consumption worldwide.

[3]World Bank, "Fish to 2030: Prospects for Fisheries and Aquaculture. Agriculture and Environmental Services," Discussion Paper 03 (Washington, DC: World Bank Group, 2013), Report number 83177-GLB, http://documents.worldbank.org/curated/en/458631468152376668/Fish-to-2030-prospects-for-fisheries-and-aquaculture. This document analyzes global fisheries (wild fish) and aquaculture, noting that fish are perhaps the most efficient form of protein production to feed growing world populations. As a note, some fish are relatively inefficient or expensive (note sturgeon caught or farmed for caviar, sold for many dollars per ounce), while others are quite hardy, efficient, and typically "low trophic level"—e.g., primarily plant eaters, omnivores, or filter feeders. These are the fish (think catfish, tilapia, or perhaps oysters) that may actually "feed the poor."

[4]FAO 2020.

[5]A number of authors have explored the history of aquaculture in various cultures. Aquaculture was generally at a very local level: e.g., ponds in Europe or Hawaii; coupling of fish with plants and other livestock in historic China. See, e.g., Fangzhou Hu et al., "Development of Fisheries in China," *Reproduction and Breeding* 1, no. 1 (2021): 64–79, https://doi.org/10.1016/j.repbre.2021.03.003. Modern aquaculture has expanded in both scale and complexity, using advanced genetics, filtration, feeding, and management.

[6]Rosamond Naylor et al. reviewed data at that time which revealed a number of problems, specifically, that bycatch from (wild) marine fisheries was often used to make fish feeds, and since these fish stocks were often over exploited, they suggested biological limits. This work set the aquaculture industry to move toward algae, plant, and other "lower trophic level" feeds and to limit wild fish meal in aquaculture. Rosamond L. Naylor et al., "Effect of Aquaculture on World Fish Supplies," *Nature* 405 (2000): 1017–24, https://doi.org/10.1038/35016500.

[7]Martha Iwamoto et al., "Epidemiology of Seafood-Associated Infections in the US," *Clinical Microbiology Review* 23, no. 2 (2010): 399–411, https://doi.org/10.1128%2FCMR.00059-09.

[8]FAO 2020.

[9]FAO 2020; The National Oceanic and Atmospheric Administration (NOAA) yearly publications also provide additional (primarily US) information. Especially see, "Fisheries of the United States, 2005," *NOAA Fisheries*, January 24, 2006, last updated January 24, 2018, https://www.fisheries.noaa.gov/feature-story/fisheries-united-states-2005; and "Fisheries of the United States, 2018," *NOAA Fisheries*, February 21, 2020, https://www.fisheries.noaa.gov/feature-story/fisheries-united-states-2018.

[10]Colin G. Scanes, "Animal Agriculture: Livestock, Poultry, and Fish Aquaculture," in *Animals and Human Society*, ed. Colin G. Scanes and Samia R. Toukhsati (Cambridge, MA: Academic Press, 2018), 133–79, https://doi.org/10.1016/B978-0-12-805247-1.00007-1.

[11]Jonathan Shepherd, "The Lessons from Intensive Livestock Development for Aquaculture," in *Global Trade Conference on Aquaculture: 29–31 May 2007—Qingdao, China*, ed. Richard Arthur and Jochen Nierentz (Rome, Italy: FOA, 2007), 249–57. This article recognizes some of the unforunate results that have occurred with land-based animals, including pollution, disease, and animal treatment.

[12]FOA 2020 acknowledges both the growing population and reduced fisheries (85% of fish stocks worldwide are fully fished or overfished).

[13]Naylor et al., "Effect of Aquaculture on World Fish Supplies."

[14]Stefano B. Longo et al., "Aquaculture and the Displacement of Fisheries Captures," *Conservation Biology* 33, no. 4 (2019): 832–41, https://doi.org/10.1111/cobi.13295, argue that aquaculture should help reduce stress on wild fisheries, but despite efforts to reduce the use of fish meal, the total volume of aquaculture has not yet enhanced wild fisheries. George S. Lockwood, in his book *Aquaculture: Will It Rise to Its Potential to Feed the World?* (San Francisco, CA: Blurb, 2017), asserts that "Aquaculture is the most environmentally sustainable means to feed the population boom that threatens the planet" (book back cover). He addresses a series of concerns including regulations, public image, and various business and practical implications. The jury is still out on whether aquaculture will have a net negative or positive effect on wild fisheries. Rosamond L. Naylor et al., "A 20-Year Retrospective Review of Global Aquaculture," *Nature* 591 (2021): 551–63, https://doi.org/10.1038/s41586-021-03308-6, addressed some further changes, noting some improvements and some additional setbacks.

[15]In some ways, the physics and biology are limiting factors, but addressing these is a values or ethics question, and will require both individual (farmers, fishers) and group (governments, policy, NGO, business) actions.

[16]Both Naylor and Longo, in their writings, asked but did not fully answer questions about what effects aquaculture may have long term. Longo ran seven models trying to predict these and did not get convincing answers either way.

[17]Amos O. Arowoshegbe, Emmanuel Uniamikogbo, and Olufemi O. Gina, "Sustainability and Triple Bottom Line: An Overview of Two Interrelated Concepts," https://www.researchgate.net/publication/322367106_SUSTAINABILITY_AND_TRIPLE_BOTTOM_LINE_AN_OVERVIEW_OF_TWO_INTERRELATED_CONCEPTS look at the "triple bottom line" of social, environmental, and economic sustainability. Other authors apply these concepts directly to aquaculture. See, for example, Mahfuzur Shah et al., "Microalgae in Aquafeeds for a Sustainable Aquaculture Industry," *Journal of Applied Phycology*, 30, no. 1 (2018): 197–213, https://link.springer.com/article/10.1007/s10811-017-1234-z.

[18]Rubén Vita and Arnaldo Marín, "Environmental Impact of Capture-Based Bluefin Tuna Aquaculture on Benthic Communities in the Western Mediterranean," *Aquaculture Research* 38, no. 4 (2007): 331–39, https://doi.org/10.1111/j.1365-2109.2007.01649.x, described the "classic" capture of tuna to fatten them in cages and noted not only that this affects wild tuna, but also that the wastes from the sea cages stressed other animals in a radius of at least 200 meters around the structure.

[19]Johann Bell et al., "Pathways to Sustaining Tuna-Dependent Pacific Island Economies during Climate Change," *Nature Sustainability* 4 (2021): 900–910, https://doi.org/10.1038/s41893-021-00745-z, noted that a number of these economies are dependent on wild capture and sale of tuna species, and suggested ways to enhance sustainability via various management techniques.

[20]Gorana Jelić Mrčelić et al., "An Overview of Atlantic Bluefin Tuna Farming Sustainability in the Mediterranean with Special Regards to the Republic of Croatia," *Sustainability* 15, no. 4 (2023): 2976, https://doi.org/10.3390/su15042976, acknowledged the challenges of tuna capture and fattening, and addressed the need for "future sustainable closed-cycle tuna farming …"

[21]Brendan F. Wringe et al., "Extensive Hybridization Following a Large Escape of Domesticated Atlantic Salmon in the Northwest Atlantic," *Communications Biology* 1 (2018): 108, https://doi.org/10.1038/s42003-018-0112-9, noted that hybrids between cultured and wild salmon accounted for 27% of salmon sampled; they were found in 17 out of 18 rivers sampled, suggesting a large genetic change in the area. It is not clear what the long-term repercussions may be.

[22]For example, Naylor et al., "Effect of Aquaculture on World Fish Supplies"; Naylor et al., "A 20-Year Retrospective Review of Global Aquaculture"; and Mrčelić et al., "An Overview of Atlantic Bluefin Tuna Farming Sustainability."

[23]Michael B. Timmons and Brian J. Vinci, *Recirculating Aquaculture, 5th ed.* (Ithaca, NY: Ithaca Publishing, 2022).

[24]Atlantic Sapphire website, quotations from Sustainability, Our Mission: Better for All of Us; and Sustainability, Innovation: Ocean Safe, accessed April 6, 2024, https://atlanticsapphire.com/sustainability/.

[25]Naylor et al., "Effect of Aquaculture on World Fish Supplies."

[26]Naylor et al., "A 20-Year Retrospective Review of Global Aquaculture"; Lucia S. Herbeck et al., "Decadal Trends in Mangrove and Pond Aquaculture Cover on Hainan (China) since 1966: Mangrove Loss, Fragmentation and Associated Biogeochemical Changes," *Estuarine Coastal and Shelf Science* 233 (2020): 106531, https://doi.org/10.1016/j.ecss.2019.106531; and H. Q. Nguyen et al., "Socio-Ecological Resilience of Mangrove-Shrimp Models under Various Threats Exacerbated from Salinity Intrusion in Coastal Area of the Vietnamese Mekong Delta," *International Journal of Sustainable Development and World Ecology* 27, no. 7 (2020): 638–51, https://doi.org/10.1080/13504509.2020.1731859.

[27]Rex Hall Caffey, "Quantifying Sustainability in Aquaculture Production," PhD diss., Lousiana State University, 1998, https://repository.lsu.edu/gradschool_disstheses/6809, focused on sustainability in aquaculture; and Rex H. Caffey, Robert P. Romaire, and J. W. Avault Jr., "The Sustainability of Crawfish Aquaculture," *World Aquaculture* 27, no. 2 (1996): 18–23. Both papers recognize that sustainability is critical for aquaculture to flourish. While not explicitly theological, value statements consistent with a Christian worldview are explored in these works.

[28]Longo et al., "Aquaculture and the Displacement of Fisheries Captures," is one example of a work questioning the sustainability of current aquaculture practices.

[29]Personal communication, Benjamin Reading, North Carolina State University Department of Applied Ecology, 2020, claims that the domesticated striped bass at the base of the now $100 million plus hybrid striped bass industry is only on its eighth generation, while Terry Tiersch, Lousiana State University Renewable Natural Resources, has worked with catfish to "modernize" the industry but acknowledges the whole catfish industry is genetically "very young."

[30]One positive view of AquAdvantage Salmon (owned by AquaBounty Technologies) is Henry Clifford, "AquAdvantage Salmon—A Pioneering Application of Biotechnology in Aquaculture," *BMC Proceedings* 8, suppl. 4 (2014): O31, https://doi.org/10.1186%2F1753-6561-8-S4-O31. He notes that these (Atlantic with some inserted transgene from Chinook salmon) salmon reach market size in half the time and will be available only as "all female, sterile fish." They will further be required to be maintained in a freshwater, land-based, biosecure system. An alternative viewpoint is represented by Rebecca Voelker, "New on the Menu: Genetically Modified Salmon," *Journal of the American Medical Association* 315, no. 1 (2016): 20, https://doi.org/10.1001/jama.2015.17339. She notes that the FDA has approved this animal, but that it "meets the definition of a drug" (due to added growth hormones and activators). The fact that this fish also includes genetics from the pout fish is also more apparent in this article than in the article by Clifford.

[31]This threat includes two problems: that of invasive species, and that of genetic changes, as explained further in Carol A. Stepien, Matthew R. Snyder, and Anna E. Elz, "Invasion Genetics of the Silver Carp *Hypophthalmichthys molitrix* across North America: Differentiation of Fronts, Introgression and eDNA Metabarcode Detection," *PLoS One* 14, no. 3 (2019): e0203012, https://doi.org/10.1371/journal.pone.0203012.

[32]Naylor et al., "A 20-Year Retrospective Review of Global Aquaculture."

[33]Iwamoto et al., "Epidemiology of Seafood-Associated Infections in the United States."

[34]Jens G. Balchen, "Automation in Fisheries and Aquaculture Technology," in *Control Systems, Robotics and Automation* 19, in *Encyclopedia of Life Support Systems (EOLSS),* developed under the auspices of the UNESCO (Paris, France: Eolss Publishers, 2002), https://www.eolss.net/sample-chapters/c18/E6-43-35-05.pdf.

[35]Mike Salem addresses basic definitions of autonomy in "What Is an Autonomous System?," *Udacity,* September 24, 2018, 3-min. read, https://www.udacity.com/blog/2018/09/what-is-an-autonomous-system.html, while Noel Sharkey discussed some of the ethical questions in these areas in "The Ethical Frontiers of Robotics," *Science* 322, no. 5909 (2008): 1800–1801, https://www.science.org/doi/10.1126/science.1164582.

[36]Yong Ma et al. explored how multiple vehicles can communicate effectively in "Cooperative Communication Framework Design for the Unmanned Aerial Vehicles-Unmanned Surface Vehicles Formation," *Advances in Mechanical Engineering* 10, no. 5 (2018): https://doi.org/10.1177/1687814018773668, while Man Zhu and Yuan-Qiao Wen addressed engineering design of collections of vehicles in an aquatic environment in "Design and Analysis of Collaborative Unmanned Surface-Aerial Vehicle Cruise Systems," *Journal of Advanced Transportation* 2019 (January 14, 2019), https://doi.org/10.1155/2019/1323105.

[37]Zhu and Wen, "Design and Analysis of Collaborative Unmanned Surface-Aerial Vehicle Cruise Systems"; and Eduardo Pinto, Pedro Santana, José Barata, "On Collaborative Aerial and Surface Robots for Environmental Monitoring of Water Bodies," in *Technological Innovation for the Internet of Things*, DoCEIS 2013. IFIP *Advances in Information and Communication Technology*, vol. 394, ed. Luis M. Camarinha-Matos, Slavisa Tomic, and Paula Graça

(Berlin, Heidelberg: Springer, 2013), 183–91, https://doi.org/10.1007/978-3-642-37291-9_20; and Joshua N. Weaver, A. A. Arroyo, and E. M. Schwartz, "Collaborative Coordination and Control for an Implemented Heterogeneous Swarm of UAVs and UGVs" (unpublished PhD diss., 2014). Each address the computer codes required for such collaborative coordination and control of multiple vehicles. However, they only hint at the ethical or theological implications of multiple different types of highly autonomous robots in the environment.

[38]Arthur Zolich et al., "Survey on Communication and Networks for Autonomous Marine Systems," *Journal of Intelligent & Robotic Systems* 95, no. 3-4 (2019): 789–813, https://doi.org/10.1007/s10846-018-0833-5, provide a recent update, noting that the field of autonomous marine systems is expanding substantially for both resource extraction and security reasons. Steven G. Hall, Daniel D. Smith, and Troy Davis, "Design of a Communications System between Multiple Autonomous Vehicles," paper presented at the American Society of Agricultural and Biological Engineers Annual International Meeting, Reno, NV, June 21–24, 2009, https://www.researchgate.net/publication/271420802_Design_of_a_communications_system_between_multiple_autonomous_vehicles. This paper does acknowledge the possibility of using groups of autonomous vehicles for aquatic- and aquaculture-related activities.

[39]Sierra Young et al., "Robot-Assisted Measurement for Hydrologic Understanding in Data Sparse Regions," *Water* 9, no. 7 (2017): 494, https://doi.org/10.3390/w9070494 address the use of autonomous vehicles for water-related work, specifically in remote areas.

[40]James L. Anderson et al., "The Fishery Performance Indicators: A Management Tool for Triple Bottom Line Outcomes," *PLoS One* 10, no. 5 (2015): e0122809, https://doi.org/10.1371/journal.pone.0122809; Arowoshegbe, Uniamikogbo, and Gina, "Sustainability and Triple Bottom Line," and others acknowledge the "triple bottom line."

[41]FAO 2020; OECD-FAO Agricultural Outlook 2014–2023: FISHERIES—OECD-FAO Agricultural Outlook 2014–2023 provides data which were used (along with other projections) to create figures 1–3. Data used was from FAO; this and other data is now available at OECF Data Explorer, https://data.oecd.org/.

[42]Mary Nickum et al., "Alligator (*Alligator mississippiensis)* Aquaculture in the United States," *Reviews in Fisheries Science and Aquaculture* 26, no. 1 (2018): 86–98, https://doi.org/10.1080/23308249.2017.1355350, provide a more complete history of the aquaculture industry (now valued at over $70 million in Louisiana alone), and the parallel work to restore and maintain healthy wild alligator populations. There is tension, especially in areas where human development encroaches on habitat. Alligators or other species that are released need healthy environments to live in.

[43]Peter Glavič and Rebeka Lukman, "Review of Sustainability Terms and Their Definitions," *Journal of Cleaner Production* 15, no. 18 (2007): 1875–85, https://doi.org/10.1016/j.jclepro.2006.12.006, created "sustainability axes" to try to map specific concerns and look at optimization or acceptable balances between different aspects of sustainability. This implies some level of tension in sustainable production.

[44]Julia Moore et al., "Developing a Comprehensive Definition of Sustainability," *Implementation Science* 12 (2017): article 110, https://doi.org/10.1186/s13012-017-0637-1, noted that there are many definitions of sustainability that approach from different angles. Herman Daly, in *Beyond Growth: The Economics of Sustainable Development* (Boston, MA: Beacon Press, 1997); and later with coauthor Joshua Farley, in *Ecological Economics: Principles and Applications*, 2nd ed. (Washington, DC: Island Press, 2010), recognized one of these limits to sustainability: the physical limit of the earth's ecosystem to handle waste from our society. While the physical statements made are generally not in doubt (e.g., rising carbon dioxide levels in the air, increasing levels of long-lasting chemicals in the water, and increasing amounts of plastics in the environment), the field of ecological economics continues to clash with the ruling neoclassical economics that focuses on growth, often at the expense of sustainability.

[45]Anderson et al., "The Fishery Performance Indicators"; and Danis Maulana, Merlin Dyah Wati, and Mirza Safitri Agatha Putri, "Optimization of Small Fisheries Enterprise with Fishery Performance Indicators through Triple Bottom Line," *Jurnal Entrepreneur dan Entrepreneurship* 6, no. 2 (2017): 71–78, https://doi.org/10.37715/jee.v6i2.642, argue that the business side is important, and that environmental and social aspects should be brought into the business model of fisheries and aquaculture.

[46]Geddie and Hall focused on developing siting tools for siting macroalgae farming. As the industry develops, other tools will be needed. Alexander W. Geddie and Steven G. Hall, "Development of a Suitability Assessment Model for the Cultivation of Intertidal Macroalgae in the United States," *Science of the Total Environment* 699 (2020): 134327, https://doi.org/10.1016/j.scitotenv.2019.134327.

[47]James E. Rakocy, "Aquaponics: The Integration of Fish and Vegetable Culture in Recirculating Systems," paper presented at the Caribbean Food Crops Society 30th Annual Meeting, St. Thomas, Virgin Islands, July 31–August 5, 1994, https://doi.org/10.22004/ag.econ.258746.

[48]FAO 2016, FAO 2018, and FAO 2020 provide substantial data including much of the data presented in this article. Extensive discussion of fisheries and aquaculture is provided in these reports, whereas we present data to help consider ethical and theological perspectives on this practical and growing field.

[49]Steven Hall, "Toward a Theology of Sustainable Agriculture," *Perspectives on Science and Christian Faith* 54, no. 2 (2002): 103–07, https://www.asa3.org/ASA/PSCF/2002/PSCF6-02Hall.pdf, addressed this unique intersection. Few authors before or since have tackled sustainability of aquaculture from a theological perspective.

[50]A Rocha, https://www.arocha.us/, accessed February 2000, has a broad array of environmental activities and is worldwide, with a tagline "Living God's call to care for creation"; Au Sable Institute, https://www.ausable.org/, provides educational and research experiences for K–12, undergraduate, and the public, with a current tagline "Serve. Protect. Restore," accessed April 2024; and ECHO is Educational Concerns for Hunger and has strongly applied international sustainable agriculture aspects, with a tagline "Hope Against Hunger," https://www.echonet.org, accessed April 2024. Regent Professor Emeritus Loren Wilkenson and team have produced a video series focusing on sustainable agriculture and food,

called Food Forethought, https://www.regentaudio.com/products/food-forethought, with consideration of theological implications of agriculture, food choices, and related topics.

[51]FAO 2020, fig. 3.

[52]See Remigijus Ciegis, Jolita Ramanauskiene, and Bronislovas Martinkus, "The Concept of Sustainable Development and Its Use for Sustainability Scenarios," *Engineering Economics* 62, no. 2 (2009): 28–37; David W. Pearce and Giles D. Atkinson, "Capital Theory and the Measurement of Sustainable Development: An Indicator of 'Weak' Sustainability," *Ecological Economics* 8, no. 2 (1993): 103–08, https://doi.org/10.1016/0921-8009(93)90039-9.

[53]See Gordon R. Conway and Edward B. Barbier, *After the Green Revolution: Sustainable Agriculture for Development* (London, UK: Routledge, 1990).

[54]Johan Rockström et al., "Planetary Boundaries: Exploring the Safe Operating Space for Humanity," *Ecology and Society* 14, no. 2 (2009): 32, http://www.ecologyandsociety.org/vol14/iss2/art32/, focus on carrying capacity from both an ecological and a human density point of view.

[55]Hall, "Toward a Theology of Sustainable Agriculture," included the following references: Caffey, Romaire and Avault, "The Sustainability of Crawfish Aquaculture"; Claude E. Boyd and Craig S. Tucker, "Sustainability of Channel Catfish Farming," *World Aquaculture* 26, no. 3 (1995): 45–53, both took a cautiously optimistic view; while Naylor et al., "Effect of Aquaculture on World Fish Supplies," focused on challenges to sustainability in aquaculture at that time. More recently, Claude E. Boyd et al., "Achieving Sustainable Aquaculture: Historical and Current Perspectives and Future Needs and Challenges," *Journal of the World Aquaculture Society* 51, no. 3 (2020): 578–633, https://doi.org/10.1111/jwas.12714, revisited both advances in the field and future needs and challenges toward a more sustainable aquaculture.

[56]Hall, "Toward a Theology of Sustainable Agriculture," 107.

[57]W. Dayton Roberts and Paul E. Pretiz, eds., *Down to Earth Christianity: Creation Care in Ministry* (San Jose, Costa Rica: AERDO, 1999); and Wes Jackson, Wendell Berry, and Bruce Colman, eds., *Meeting the Expectations of the Land* (Berkeley, CA: Northpoint Press, 1986).

[58]Scott Jones, "Evolution of Aquaponics," *Aquaponics Journal* 6, no. 1 (2002), https://aquaponics.com/wp-content/uploads/articles/evoluton-of-Aquaponics.pdf.

[59]C. Somerville et al., *Small-Scale Aquaponic Food Production: Integrated Fish and Plant Farming* (Washington, DC: Food and Agricultural Organization of the United Nations, 2014).

[60]FAO 2020 reveals that over 30 million metric tons of seaweeds are harvested using culture systems annually, probably reducing nutrients and helping enhance water quality in these areas.

[61]Alexander W. Geddie and Steven G. Hall, "An Introduction to Copper and Zinc Pollution in Macroalgae: For Use in Remediation and Nutritional Applications," *Journal of Applied Phycology* 31 (2019): 691–708, https://doi.org/10.1007/s10811-018-1580-5; and Geddie and Hall, "Development of a Suitability Assessment Model for the Cultivation of Intertidal Macroalgae in the United States," look at growing macroalgae for possible food or feed and optimal siting of macroalgae cultivation in the United States. Currently, most macroalgae is grown in Asia.

[62]Matthew D. Campbell and Steven G. Hall, "Hydrodynamic Effects on Oyster Aquaculture Systems: A Review," *Reviews in Aquaculture* 11, no. 3 (2019): 896–906, https://doi.org/10.1111/raq.12271, addressed oyster aquaculture and noted parallels with reef systems, and the possibilities with good design to grow more food, use less energy, and potentially enhance the environment.

[63]Daniela Sousa et al., "Self-adaptive Team of Aquatic Drones with a Communication Network for Aquaculture," in *Progress in Artificial Intelligence: 19th EPIA Conference on Artificial Intelligence, EPIA 2019, Vila Real, Portugal, September 3–6, 2019, Proceedings, Part II* (Lecture Notes in Computer Science), ed. Paulo Moura Oliveira, Paulo Novais, and Luís Paulo Reis (Cham, Switzerland: Springer, 2019), 569–80. At this conference, some presenters discussed not only communication but also various ethical issues with these vehicles.

[64]Jianhua Bao et al., "Integrated Navigation for Autonomous Underwater Vehicles in Aquaculture: A Review," *Information Processing in Agriculture* 7, no. 1 (2019): 139–51, https://doi.org/10.1016/j.inpa.2019.04.003, include use of autonomous submarines for inspecting ocean aquaculture cages.

[65]Anny Keli Aparecida Alves Cândido et al., "Water Quality and Chlorophyll Measurement through Vegetation Indices Generated from Orbital and Suborbital Images," *Water, Air, and Soil Pollution* 227 (2016): article number 224, https://doi.org/10.1007/s11270-016-2919-7 .

[66]Erich Luening, "Scientists See Role for Robots in Mariculture," *Aquaculture North America* (March 3, 2016), https://www.aquaculturenorthamerica.com/scientists-see-role-for-robots-in-mariculture-1603/, addresses this issue further; while the National Society of Professional Engineers Code of Ethics for Engineers (2019) includes an ethical code for professionals in the engineering field, https://www.nspe.org/resources/ethics/code-ethics, hereafter NSPE 2019. Discussions are ongoing as to the implications for autonomous vehicles and systems.

[67]Ingrid Bouwer Utne, Ingrid Schjølberg, and Ingunn Marie Holmen, "Reducing Risk in Aquaculture by Implementing Autonomous Systems and Integrated Operations," paper presented at the European Safety and Reliability Conference, ESREL 2015, held September 7–10, 2015, in Zurich, Switzerland, published in *Safety and Reliability of Complex Engineered Systems: ESREL 2015*, ed. Luca Podofillini et al. (London, UK: CRC Press, 2015). NTNU (Norwegian University of Science and Technology) Ocean Week 2015 held May 4–7, 2015, in Trondheim, Norway, addressed both fixed and moving automated systems, https://www.ntnu.edu/documents/919518/1262417150/Ocean+Week-program+final.pdf/5ea39bd7-7381-44a3-b3d0-0c5189fb4179.

[68]Utne et al., "Reducing Risk in Aquaculture."

[69]NSPE 2019.

[70]Sharkey, "The Ethical Frontiers of Robotics," 1801.

[71]Vashti M. Campbell, Alexander Chouljenko, and Steven G. Hall, "Depuration of Live Oysters to Reduce *Vibrio parahaemolyticus* and *Vibrio vulnificus*: A Review of Ecology and Processing Parameters," *Comprehensive Reviews in Food Science and Food Safety* 21, no. 4 (2022): 3480–506, https://doi.org/10.1111/1541-4337.12969.

[72]A. M. Larsen et al., "Temperature Effect on High Salinity Depuration of *Vibrio vulnificus* and *V. parahaemolyticus* from the Eastern Oyster (*Crassostrea virginica*),"

International Journal of Food Microbiology 192 (2015): 66–71, https://doi.org/10.1016/j.ijfoodmicro.2014.09.025.

[73]Costanza Baldisserotto et al., "Biological Aspects and Biotechnological Potential of Marine Diatoms in Relation to Different Light Regimens," *World Journal of Microbiology and Biotechnology* 35, no. 2 (2019): article number 35, https://doi.org/10.1007/s11274-019-2607-z, provide one perspective on the technological approach to value-added processing for seafood. For a more "consumer-friendly" angle, see Andy Nelson, "Demand for Value-Added Seafood Surges," *Supermarket Perimeter* (April 17, 2019), https://www.supermarketperimeter.com/articles/3465-demand-for-value-added-seafood-surges, which acknowledges that convenience foods are marketable. This may be good for the economy but provides one more area where an ethical approach is critical.

[74]Many recent and ongoing studies are focused on adding value to various biological and especially aquatic materials. Jutika Boro, Dhanapati Deka, Ashim J. Thakur, "A Review on Solid Oxide Derived from Waste Shells as Catalyst for Biodiesel Production," *Renewable and Sustainable Energy Reviews* 16, no. 1 (2012): 904–10, https://www.sciencedirect.com/science/article/abs/pii/S1364032111004618, focused on use of shells as part of more-sustainable energy production while M. Boutinguiza et al., "Biological Hydroxyapatite Obtained from Fish Bones," *Materials Science and Engineering: C* 32, no. 3 (2012): 478–86, https://doi.org/10.1016/j.msec.2011.11.021, focused on biomedical applications. Yu-Fong Huang et al., "Microwave Calcination of Waste Oyster Shells for CO_2 Capture," *Energy Procedia* 152, (2018): 1242–47, https://doi.org/10.1016/j.egypro.2018.09.176, considered how to process some of these materials to address another "grand challenge," excess carbon dioxide in the atmosphere. Each of these are at base simply "value added" (e.g., purely economic based), but actually have substantial ethical and theological implications in terms of caring for creation and wisely stewarding aquatic resources.

[75]See Matthew Morris, "Naming as a Form of Stewardship: A Case Study on Fraudulent Fishes Sold in Calgary, Alberta, Canada," *Perspectives on Science and Christian Faith* 72, no. 3 (2020): 151–66, https://www.asa3.org/ASA/PSCF/2020/PSCF9-20Morris.pdf, for a much more serious discussion of this deception.

[76]Calvin DeWitt, "Science and Ethics in Practice of Earth Stewardship," *in all things*, October 13, 2016, https://inallthings.org/science-and-ethics-in-practice-of-earth-stewardship/, addresses what he terms the "Science-Ethics-Praxis" triad. Scientists, he suggests, need to share their scientific but also ethical knowledge with practitioners. He talks about two ecosystems, each with water relations: first the desert, which has little water; and then Bald Cypress swamps, something much nearer to aquacultural work. In both instances, he notes tragic consequences of action without wisdom, and urges Christians and scientists (as well as practitioners) to share their knowledge and move toward wiser actions.

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DOI: https://doi.org/10.56315/PSCF9-24Clements

Reconciliation Ecology in the Anthropocene

David R. Clements

Call for Papers

Readers are encouraged to take up one of the insights or questions spurred by the following invitation essay and its endnotes, or maybe a related one that was not yet mentioned, and draft an article (typically about 5,000–8,000 words) that contributes to the conversation. This can be sent as an attachment to David Clements at clements@twu.ca. An abstract should be included in the text of both the email and the essay. The best essays will go on to peer review, with the potential for publication in a theme issue of *Perspectives on Science and Christian Faith*, or independently in a variety issue of *PSCF*.

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Looking forward to learning from your contributions,

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

Ten years ago Gordon College ecologist Dorothy Boorse called for submissions to Perspectives on Science and Christian Faith *in recognition of the many new findings in environmental science.*[1] *This ever-increasing knowledge of the environment, while, simultaneously, environmental change is occurring as part of the "Great Acceleration," was said to alert humanity that the new Anthropocene age is upon us.*[2] *A decade on from Boorse's invitation, I likewise invite Christian scholars to encourage believers to put Christian faith into action in the face of Anthropocene-level challenges and with the promise of reconciliation ecology.*

Keywords: reconciliation ecology, call for papers, Anthropocene, restoration ecology, Indigenous values, United Nations, decade of restoration, creation care, Colossians

Although some may doubt the ability of humankind to influence global processes such as climate, much evidence has been assembled to show that human influence on our planet is so overwhelming as to have ushered in a "scene change." Many now argue we are no longer in the Holocene period, but have entered a new geological age best termed the Anthropocene.[3] The Anthropocene is the name given to the period that began when human activity became the dominant influence on climate and the environment. Dutch meteorologist Paul Crutzen, credited with popularizing the term, said,

> It's a pity we're still officially living in an age called the Holocene. The Anthropocene—human dominance of biological, chemical, and geological processes on Earth—is already an undeniable reality.[4]

How does God call us to respond to environmental changes arising due to such sweeping levels of human influence on creation? In Colossians 1:19–20, the apostle Paul points to the reconciling work of Christ in creation:

> For God was pleased to have all his fullness dwell in him, and through him to reconcile to himself all things, whether things on earth or things in heaven, by making peace through his blood, shed on the cross.

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It is also evident from Romans 8:19–21 that we, as God's redeemed image bearers, are not merely spectators but rather are clearly part of the process:

> For the creation waits in eager expectation for the children of God to be revealed. For the creation was subjected to frustration, not by its own choice, but by the will of the one who subjected it, in hope that the creation itself will be liberated from its bondage to decay and brought into the freedom and glory of the children of God.

Restoration ecology is a discipline that attempts to navigate the difficult interface between ecological science and ethics, where the goalposts are sometimes hard to see clearly. Yet the game is on, as the United Nations has declared the current decade (2021–2030) as the United Nations Decade on Ecosystem Restoration.[5] The stated purpose of this initiative is to "prevent, halt and reverse the degradation of ecosystems on every continent and in every ocean."[6] As the goalposts come into greater focus at this critical time, combining restoration ecology with the reconciling work of Christ promises to provide a clearer vision of humanity's goals for healing and restoration amidst the onslaught of environmental problems we face in the Anthropocene.

A New Epoch: Is the Anthropocene for Real?

Geological periods are designated according to major shifts in the Earth's system, often tied to climate shifts as read in the geology. For example, the beginning of the era of the dinosaurs occurred as the climate went from "icehouse" conditions in the late Paleozoic to "greenhouse" conditions in the Mesozoic.[7] The next major transition is probably the best known, with evidence showing that the sudden extinction of the dinosaurs was precipitated by a meteor approximately 10 km in diameter striking the Gulf of Mexico leaving a distinct geological signature, although other factors were involved in the extinction itself.[8] The Mesozoic era was followed by the Cenozoic era, the era we are currently still in, but the question has become, if we properly divide the Cenozoic into epochs, should it include a newly emerging epoch, the Anthropocene?[9] The Pleistocene epoch was characterized by a series of ice ages. The Holocene epoch is said to begin 11,700 years bp (before present), as defined by a sharp boundary in the Greenland ice core marked by a spike in deuterium, also corresponding to the end of the last ice age.[10] Can a similar geological signature be identified to mark the beginning of the Anthropocene?

Not all major human changes to Earth's environment qualify as a change to a new *geologic* epoch, something that must be evaluated in rock strata.[11] The international organization charged with naming these periods is the International Commission on Stratigraphy.[12] The commission sets the boundaries by identifying Global Boundary Stratotype Sections and Points (GSSPs).[13]

As of October 2021, there were 12 candidate GSSP sites scattered around the globe, including Crawford Lake, located near Milton, Ontario (fig. 1).[14] At a news conference in Berlin, July 11, 2023, the Anthropocene Working Group announced that Crawford Lake was chosen to be the golden spike of the new epoch—the Anthropocene.[15]

Why Crawford Lake? Part of the reason is that Crawford Lake is unusually deep for its size. Less than 300 m wide at its widest, it reaches 24 m in depth. Whereas most lakes experience mixing of lower layers with upper layers, with the lake extending that deep, it is termed meromictic, meaning that the bottom layers do not mix with the upper layers. According to lake researcher Francine McCarthy, the bottom of the lake is "completely isolated from the rest of the planet, except for what gently sinks to the bottom and accumulates in sediment."[16] Furthermore, the lake is nestled in limestone, and white annual layers form as calcium carbonate crystals precipitate, allowing organic particles such as pollen and microorganisms to be read from these layers that form a varved sediment (layers with contrasting colors).[17] This is known as varved succession, whereby "varve couplets of organic matter capped by calcite precipitated each summer in alkaline surface waters reflect environmental change at global to local scales."[18] This allows many different indicators of importance to be read from the sediments, including biotic indicators such as diatoms or pollen, or inorganic geochemical signals, and the ability to capture information at various scales, namely, local, regional, and global.[19]

Climate scientists have embraced the Anthropocene as reinforcing their observations and predictions of atmospheric changes on a massive scale, hitherto unprecedented over the ages of human civilization. Still, it is fair to ask, is the Anthropocene for real?

Key related questions are the following:

1. Is the magnitude of change comparable to transitions between previous geological epochs?
2. Are the changes associated with the Anthropocene manifested in a multitude of ways? and
3. Can these changes be pinned on us?

One phenomenon that has been helpful in trying to define the Anthropocene is the "Great Acceleration," a term first used at a workshop in 2005 as participants poured over figures produced under the International Geosphere-Biosphere Programme showing dramatic increases in many indicators of human influence on the Earth's system since 1950.[20] These indicators point to 1950 as a starting point for the Anthropocene, and also coincide with distinct changes observed in the layers of Crawford Lake at the same point in time.

Major drivers of the Great Acceleration since 1950 include global human energy consumption, global productivity (as measured in GDP), and global population (fig. 2).[21] Because these drivers have increased at an accelerated rate since 1950, there are many other measurable indices to indicate the sheer magnitude of the impact humanity has had on the planet. The accelerated CO_2 emissions, now at 17.5X 1900 levels, along with an accompanying increased energy production largely via fossil fuels, have fortunately resulted in only 1.4X as much atmospheric CO_2 as in 1900; yet this 1.4X increase still has dire consequences as discussed below. (It is only thanks to a massive increase in the net land[22] and the ocean carbon sinks[23] that the rate of atmospheric CO_2 increase has been relatively low.) Furthermore, huge

Figure 1. One of the field trips at the 2023 ASA/CSCA Annual Meeting in Toronto, Ontario, led by Bob Geddes (third from the left) visited Crawford Lake, Ontario. This lake was nominated by the international Anthropocene Working Group as the Global Boundary Stratotype Sections and Points to mark the beginning of the Anthropocene Epoch. The unique characteristics of the lake allow scientists to see recent Earth's system changes in the varved annual layers formed in the lake bottom. Photo by Vicki Best.

increases in production of commodities such as copper and steel create impacts on unprecedented scales (fig. 2).

Even considering the production of a single commodity, cement, the acceleration is mind boggling. In 1900, annual cement production was 5 Mt (Megatonnes). It rose to 130 Mt in 1950 and then increased 32-fold from that point to reach 4180 Mt in 2015, representing an 836-fold increase from 1900.[24] The growth of the concrete jungle that humans are erecting across the planet has many implications for planetary health. These include increased CO_2 emissions both from cement production and from energy required to mine it, along with the many harmful results of the immense structures (e.g., many large dams as highlighted in fig. 2) that are built from this annual production of 4180 Mt of the material.[25] Cement production is also indicative of the staggering impact of *acceleration* in many such indicators—the amount of cement produced in the previous decade (2010–2019) exceeded the amount produced in the entire twentieth century.[26]

Resource exploitation has accelerated along with increasing human population and wealth since 1950, as indicated by fossil fuel consumption (and by association production), plastic production, and steel production among many other resources tapped to an ever-increasing degree.[27] By 2015, plastic production had increased to 315 Mt annually, up from 2 Mt in 1950. A large portion of this plastic must also be disposed of each year, with a lot of it in the "single use" plastics category. Plastic inevitably accumulates in unwanted places, such as in the massive North Pacific Garbage Patch which covers 1.6 million square km and weighs about 100,000 t.[28]

Many other indicators of the Great Acceleration show up in the sediments at the bottom of Crawford Lake. Nuclear bomb testing showed up as a spike in plutonium in the lake bottom from 1950 to 1968. Fortunately, the acceleration of radioactive material leveled off in the 1980s, corresponding to reduced global nuclear testing.[29] A sharp rise in fossil fuel consumption also begins in the 1950s, as indicated by the increasing number of spheroidal carbon particles (SCPs) in the lake sediment layers. Many of the indicators are best evaluated by looking at the siliceous organisms (diatoms and relatives) identified in the varve layers in the lake bottom; these can be used to track the increasing levels of radioactivity,

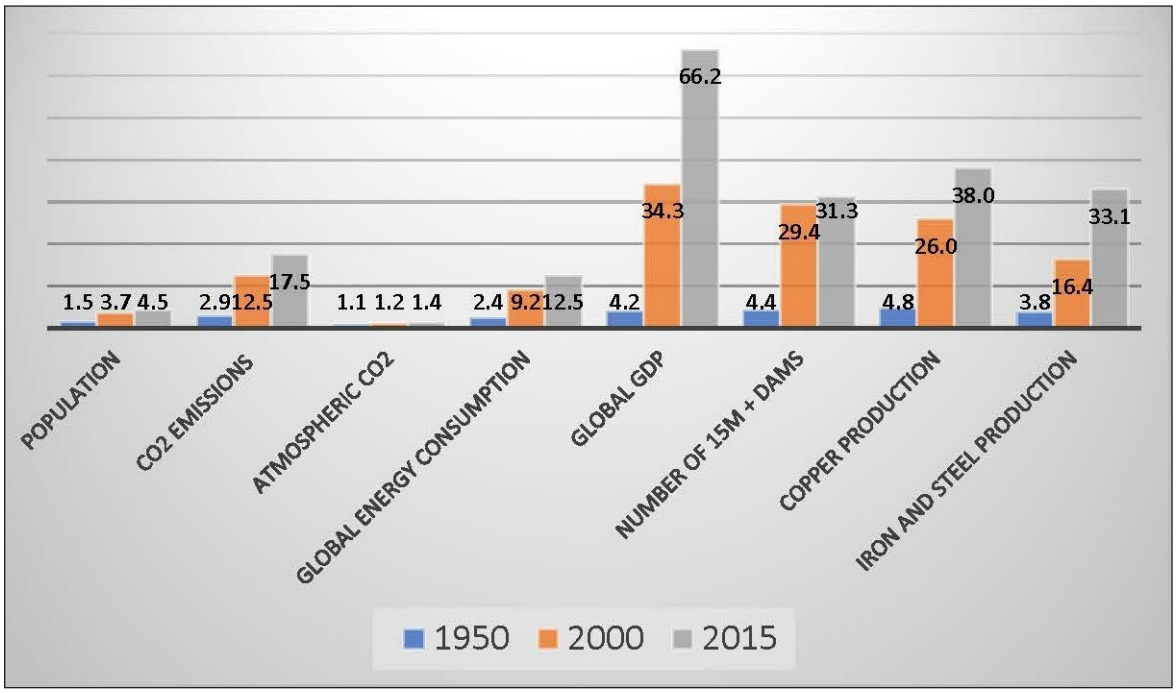

Figure 2. Increases in various indicators of the "great acceleration" from 1900 according to the factor by which the parameter increased compared to 1900; e.g., the global human population in 1950 was 1.5 times the population in 1900, then 3.7 times the 1900 population in 2000, and 4.5 times the 1900 population in 2015. The parameter "15m + dams" signifies dams 15m or more in elevation from the substrate. Data used to create the figure are from Jaia Syvitski et al., "Extraordinary Human Energy Consumption and Resultant Geological Impacts Beginning Around 1950 CE Initiated the Proposed Anthropocene Epoch," *Communications Earth & Environment* 1, no. 1 (2020): 32, http://dx.doi.org/10.1038/s43247-020-00029-y.

SCPs, and another notable substance, δ15N, with the latter tied to local steel production not far from the Crawford Lake site.[30]

Despite the efforts by geologists to try to establish the beginning of the Anthropocene epoch as 1950, it seems for now that there will be no official geological Anthropocene epoch. On March 4, 2024, the International Union of Geological Sciences (IUGS) voted against the proposed epoch, and there is apparently no way of appealing the decision.[31] Outside an official geological designation, it is clear the concept will live on, given the multitude of indicators showing that the earth's ecology has changed.[32]

The consequences of staggering increases in the production of concrete, energy, and other commodities are measured via the climate impacts of rising atmospheric CO_2. Current levels of atmospheric CO_2 exceed 400 ppm, when pre-industrial levels were never higher than 300 ppm.[33] When global average temperature trends are plotted alongside these rising CO_2 levels, the picture that emerges is that post-1950, the global temperature barely dips below the long-term average (1850–2019),[34] and continues upward on average from the 1970s, with the world seeing the warmest years ever recorded post-2010, including 2023 as the warmest year ever recorded.[35]

An optimist might believe that lowering CO_2 levels would reverse climate change trends, making the Anthropocene merely a blip, rather than a genuine geological epoch. Alas, the way the Earth's system works, the ocean possesses a great deal of momentum, and the recent high levels of CO_2 absorbed by the ocean will be released back to the atmosphere for some time. Likewise, glacial melt and sea-level rise create a great deal of inertia.[36]

With the accelerated rise in global temperatures comes an acceleration in extreme weather events, as we have witnessed since 1950. Climate models predict increases in both the frequency and intensity of extreme climate events such as heat waves, downpours, hurricanes, flooding, and wildfires, which is exactly what we have been seeing in the news over the past few years.[37] Data from reputable agencies such as NOAA (National Oceanic and Atmospheric Administration) and other agencies accurately validate the increasing trend in these extreme events.[38]

As well as the severe and often terrifying consequences of the extreme storm events for humanity, there is also the "perfect storm" of runaway species extinction levels associated with the Anthropocene.[39] Anthropogenic forces combining to create this perfect storm of biodiversity loss include climate change, habitat loss, pollution, invasive species, and over-exploitation, placing the current extinction rate as approaching that of the five great past extinctions events.[40] It is argued that the Anthropocene extinction has not yet reached the same level of these previous mass extinctions, but this does not excuse us from sounding the alarm.[41]

The case for the reality of the Anthropocene epoch is predicated on the assumption that the various indicators of the abrupt disjunction are evidence that humans have caused planetary change. However, many Christians, and evangelical Christians in particular, have resisted this notion. In evangelical Christian circles, particularly in the United States, these conflicting views have sometimes stymied efforts to support attempts to reduce our human carbon footprint. The hesitancy for some evangelical Christians to accept humanity's role in the climate crisis is well represented by the 2005 Cornwall Declaration on Environmental Stewardship, which includes the statement: "Some unfounded or undue concerns include fears of destructive man-made global warming, overpopulation, and rampant species loss."[42] In his critique of the Cornwall Declaration, Thomas Ackerman, Executive Director of the Joint Institute for the Study of the Atmosphere and Ocean at the University of Washington summarizes the position of the statement's authors as arguing that

> (1) recent and foreseeable climate change are largely natural in cause rather than the result of human activity, (2) climate change over this century will be moderate rather than catastrophic, (3) increased CO_2 will be good for plants and thereby help feed the world, (4) current plans such as Kyoto protocol would not produce significant mitigation, and (5) such efforts would seriously hurt the world's poor.[43]

In addition to concerns over the position taken by the Cornwall Declaration and many other Christian organizations,[44] there are concerns by other Christian groups that Christian environmental stewardship does not go far enough, given the serious crisis the advent of the Anthropocene represents. Many have argued that "stewardship," as used to describe Christian care of the environment, while useful, is not a strong enough term, and that indeed the

Cornwall Declaration is a statement on "environmental stewardship." Calvin University's David Warners, Michael Ryskamp, and Randall Van Dragt have argued that a better paradigm is "Reconciliation Ecology," because this term acknowledges the gravely serious environmental problems on an accelerating timescale related to our sinful nature as human beings struggling to care for the gift God gives us in his magnificent creation.[45] Should we not repent from what we have done to bring on the Anthropocene epoch, and does the hope of reconciliation not provide a powerful motivator for action to try to mitigate the dangerous consequences of a runaway Earth's system?

Holding It All Together: Reconciliation of All Things

Regardless of whether one is convinced that we ought to name a new epoch called the Anthropocene, the specter of the demise of God's good creation is profoundly disheartening. The creation is deeply wounded and so are we, who, as caretakers of the Lord's irreplaceable living art collection can but weep over the losses in many cases where there seems to be no hope of restoration to its former glory. If one believes Rembrandt to be a gifted creator of art, to see his works of art damaged or even stolen is a travesty for a follower of the great artist.[46] Likewise, this is what God's worshippers should be experiencing at this point when God's creation is being despoiled and plundered more than ever before.

Pick your favorite corner of creation and ponder the wasteful plunder of God's canvases. Whole paintings lost, left out in the rain so the colors run together and become an amorphous gray, stepped on, ripped, broken up with axes and chainsaws, and worse, until even the memory of what once was, is largely lost.

I think of the Hawaiian Islands, and in particular the portrait painted by *Islands in a Far Sea*, in which Culliney documents how the original "paradise" was broken down piece by piece, story by sad story.[47] So often the tragic irony of human brash arrogance is repeated in these stories, as what was intended for good, works evil against the provisions in creation. There was no attempt to try to understand the uniqueness of these island ecosystems or to ask the native Hawaiians about it in the headlong rush to transform the land—first for agriculture, later for urbanization, and finally for tourism. The Hawaiian Islands that tourists began flocking to in increasing numbers from the 1950s onward were already radically altered by a series of unfortunate events that had taken place since Captain Cook first "discovered" the Hawaiian Islands in 1779, particularly as a result of the introduction of invasive species.[48] Even before then, the Hawaiian Islands were drastically altered by the arrival of the Polynesians. These strikingly unique island ecosystems, the most isolated archipelago in the world, had thrived without human presence for millions of years prior to the relatively recent arrived of Polynesians, likely between 1000 and 1200 AD.[49] The Hawaiian story of habitat destruction, occurring over at least three separate waves, illustrates the general challenge of trying to focus in on 1950 as the definitive starting point for the Anthropocene. Island systems such as these represent only a tiny fraction of the earth's surface, but they contain a disproportionally large species complement, a myriad of voices singing of God's creativity. Many of these songs relatively few people have had the privilege of hearing before the voices were forever silenced by some version of human thoughtlessness and greed.

The somber story of loss in the Hawaiian Islands has been repeated the world over. The world in a very real sense is an island, a rare room within a gallery that one naturally enters, feeling a hush of awestruck wonder, perhaps projecting from the immanence of the Artist himself, because this is the exhibit where the precious miracle of life dwells on a miracle planet. And yet the lights that used to shine on the paintings have dimmed, or is it the paintings themselves that have been darkened and fallen into shadow? It is a dark canvas, regardless. This is hard. Still, it is against the backdrop of this dark canvas that our hope for a better future must shine as we strive to bear the weight and responsibility of the creator's image.

As we stand in the middle of this groaning creation, we pick up the text from Colossians and read a vision for reconciliation which is somehow more than a vision because it is actively taking place as narrated in these cosmic verses. It is not lamenting the losses or pining for what could have been. The text is not troubled by the dark storms that have passed over many places on the earth, such as the Hawaiian Islands, and that continue to batter creation, often literally battering the land and sea in the form of extreme storms. Yet the sovereign Lord who inspired

Colossians is aware of these dark storms. The Lord stands up in a boat in these raging storms and commands the wind and waves to be still (Matt. 8:23–27).

Who is this Jesus, the disciples ask, that even the wind and the waves obey him? In Colossians 1:15, Paul lays it out clearly: "The Son is the image of the invisible God, the firstborn over all creation." True, humans also were created in God's image (Gen. 1:27), but as the firstborn over all creation, there is more that Jesus represents, as we read in Colossians 1:16, "For in him all things were created: things in heaven and on earth, visible and invisible, whether thrones or powers or rulers or authorities; all things have been created through him and for him." Although we bemoan the losses of many Hawaiian bird species (among many other losses!), these ultimately were not created for us but for Jesus. So at least Jesus saw that these lost life forms were good, and he reveled in them. That is all well and good, but are we not pulling everything apart in our human rebellion, abusing the very framework of creation on Earth, discovering it to be more fragile than we might imagine?

Here it gets hopeful, in that the dark clouds are pulled aside to reveal that the sun yet shines. For in the next verse, we see Jesus holding together everything we are trying to pull apart in our avarice and ignorance. "He is before all things, and in him all things hold together" (Col. 1:17). If Jesus is holding everything together, where do we fit in? In the next verse, we are reminded that we are in fact his body, and if we acknowledge his headship, things look much better than if we ignore it. "And he is the head of the body, the church; he is the beginning and the firstborn from among the dead, so that in everything he might have the supremacy" (v. 18). Here the church is not a building, or a loose connection of affiliated people wandering in different directions, but image-bearers of the creator following the supreme image-bearer.

Reconciliation can happen. It does happen. It has happened. It will happen. There is power in the blood. "For God was pleased to have all his fullness dwell in him, and through him to reconcile to himself all things, whether things on earth or things in heaven, by making peace through his blood, shed on the cross" (Col. 1:19–20). It is clearly a 3-way reconciliation among God, humanity, and nature, and it is not just a tenuous reconciliation, it is a peace-making reconciliation through the cross, which brings peace to all for all time. In the meantime, of course, there is much to work out at a practical level, and we are not free from the cries of desperation from nearly all corners of creation. Still, this is a more solid hope than any of us could imagine from what we know of the science of environmental degradation. At the same time, it also represents a call to action, because reconciliation is at least a two-way street, and, in this case, a three-way street as we work out how to connect better to God and nature, and, in turn, God and nature are connecting with us, often in powerful and unexpected ways.

This three-way reconciliation does not have to be too complicated. As climate scientist Katharine Hayhoe has said,

> For Christians, doing something about climate change is about living out our faith—caring for those who need help, our neighbors here at home or on the other side of the world, and taking responsibility for this planet that God created and entrusted to us.[50]

As I previously referenced about a decade ago, Warners, Ryskamp, and Van Dragt argued that reconciliation ecology provided a "new paradigm for advancing creation care."[51] They carefully explained how this new paradigm was distinguished from Christian environmental stewardship. Their model of reconciliation ecology is characterized by the following five steps:

1. Recognize the wrong we have done,
2. Lament personal complicity,
3. Minimize further harm and work to fix the wrong that was done,
4. Accept forgiveness, and
5. Move forward in a new relationship marked by mutual flourishing.[52]

Just as reconciliation requires a reckoning with one's sinfulness and complicity in allowing bad things to happen, reconciliation ecology requires us to call our harm of the creation, sin. Pope Francis is clearly not hesitant to do so and calls upon all Christians to do the same.[53] By comparison to environmental stewardship, the power inherent in the reconciliation ecology paradigm lies in its requirement of a humble confession of wrongdoing against creation.

Warners and colleagues point out that reconciliation ecology does a much better job than Christian environmental stewardship of emphasizing the relational

aspects of caring for the earth. Furthermore, such an approach is consonant with Indigenous worldviews that emphasize strong and vibrant relationships among people, animals, and the rest of creation. As Robin Kimmerer writes in *Braiding Sweetgrass*:

> Joanna Macy [philosopher of ecology] writes that until we can grieve for our planet we cannot love it—grieving is a sign of spiritual health. But it is not enough to weep for our lost landscapes; we have to put our hands in the earth to make ourselves whole again. Even a wounded world is feeding us. Even a wounded world holds us, giving us moments of wonder and joy. I choose joy over despair.[54]

The Indigenous approach to creation care enforces and reinforces deep long-term connections between people and land. Kimmerer also writes:

> It was through her actions of reciprocity, the give and take with the land, that the original immigrant became indigenous. For all of us, becoming indigenous to a place means living as if your children's future mattered, to take care of the land as if our lives, both material and spiritual, depended on it.[55]

Such a relational viewpoint stands to provide helpful insights, coming alongside Western approaches to restoration ecology which often struggle in the pursuit to restore lands and oceans, locked within too rigid a scientific framework.

Restoration Ecology, Values, and Land Healing

A number of fields take the science of ecology and apply it in practical ways, including sustainable agriculture, forestry, range management, invasive species ecology, conservation biology, ecosystem health, and many others. For my purposes here, I will restrict my commentary to one such field, restoration ecology. However, many of the problems I will summarize apply to other disciplines within applied ecology.

The science of restoration ecology is ever fraught with the challenge of "restore to what?" Because ecosystems are complex, often without clear stable states, restoration ecologists are often challenged to come up with the ideal species composition. Value judgments are often necessary to decide what the restored ecosystem ought to look like.[56] Much of the debate among restoration ecologists is on how best to set goals.[57] If the goal is strictly to restore an ecosystem from the past, such a restoration may be difficult or impossible (e.g., because the species composition of the area and/or some aspect of functional ecology has changed). However, if efforts are directed at producing an ecosystem that is sustainable into the future, such restoration efforts are more likely to succeed.[58]

Because these goal-setting efforts acknowledge value judgments, there has been much discussion on how to incorporate them, and on the importance of acknowledging that even "impartial" scientists, developing restoration plans, come with their own biases, as do the human communities advocating for restoration. What about religious values? German conservation biologist Joern Fischer and colleagues point to the need for social-ecological systems thinking, acknowledging "the moral responsibility of taking care of the environment, advocating a stewardship ethic."[59] They acknowledge that such a view has been criticized because of its religious roots, but they maintain that stewardship should be placed in a "broader perspective" where stewardship consists of an "ethic of caring about all living things while recognizing their interconnectedness."[60]

Pope Francis in his *Laudato Si'—On Care for Our Common Home*, released June 18, 2015, similarly argued for an "integral ecology"—a holistic approach to earth stewardship.[61] *Laudato Si'* was widely endorsed by both scientific organizations such as the Ecological Society of America, and religious organizations such as the National Religious Partnership for the Environment in the U.S., as a promising response to the planetary environmental crisis we face.[62] The Pope warned against narrow or short-term technical approaches that ignore the larger underlying fundamental concepts, especially our God-given calling and motivation:

> Any technical solution which science claims to offer will be powerless to solve the serious problems of our world if humanity loses its compass, if we lose sight of the great motivations which make it possible for us to live in harmony, to make sacrifices and to treat others well.[63]

Osage Nation theologian George Tinker argues that we ignore Indigenous perspectives on the relationship between humans and creation at our peril:

> Like the varieties of species in the world, each culture has a contribution to make for the sustainability of the whole. Given the reality of eco-devastation threatening all of life today, the

> survival of American Indian cultures and cultural values may make the difference for the survival and sustainability for all the earth as we know it. What I have suggested implicitly is that American Indian peoples may have something of value—something corrective to Western values and the modern world system—to offer the world. The loss of these gifts, the loss of the particularity of these peoples, today threatens the survivability of us all.[64]

Another Native American theologian, Richard Twiss, identifies the critical difference between Western and native cultures that must be resolved about land:

> To the Native, the land is sacred, given by Wakan Tanka or the Creator, to be cared for and loved. They perceive a balanced relationship between humanity and the environment, a partnership of equality and respect. Native culture has an existential assumption that land is God-created, hence sacred, while Western culture views land like time, as a natural resource/commodity. Issues of identity, belonging, "place" relationships, providence, etc., are all issues of land. The West has commodified land as a natural resource, moving it out of the realm of the sacred to the "secular" world of matter. Incorporating a consideration of land into the redemption equation has never figured into the evangelistic Gospel endeavors of the West.[65]

As Kimmerer advocates in *Braiding Sweetgrass*:

> We need acts of restoration, not only for polluted waters and degraded lands, but also for our relationship to the world. We need to restore honor to the way we live, so that when we walk through the world we don't have to avert our eyes with shame, so that we can hold our heads up high and receive the respectful acknowledgment of the rest of the earth's beings.[66]

This focus on relationality points to some fundamental difficulties with the term "restoration" because the latter can be seen as technical progress toward some target ecosystem state, without expressly involving people. Indigenous scholar Jennifer Grenz advocates for "healing the land and the academy" through re-envisaging restoration ecology as healing.[67] Using healing to describe restoration efforts explicitly incorporates the values that restoration ecologists have been struggling to reckon with, and acknowledges that the area being restored almost always has an Indigenous history, whereby the landscape was shaped by the activities of Indigenous cultures over millennia.[68] Jennifer Grenz describes this kind of approach as a "medicine wheel for the planet" that integrates knowledge and wisdom of elders—seeing the world with fresh eyes, letting go of colonial narratives, and re-envisioning the role of western science in the process.[69] The medicine wheel illustrates the worldviews of many Indigenous Peoples, and is composed of a circle with four quadrants representing various important sets, such as the four directions (north, south, east west), the four seasons, and the four aspects of being (mental, physical, emotional, spiritual), in an interconnected way.[70]

It is clear that, unlike the narrowly technical approaches frequently taken within western science, values are integral to Indigenous ways of land healing, and spiritual elements are not merely add-ons. The need for more holistic approaches to setting goals for restoration is evident in a highly ambitious project now underway: the United Nations Decade on Ecosystem Restoration.

The United Nations Decade on Ecosystem Restoration

The United Nations Decade on Ecosystem Restoration strives to "prevent, halt and reverse the degradation of ecosystems on every continent and in every ocean."[71] Fischer and colleagues advocate that social-ecological systems thinking is needed to accomplish such lofty goals.[72] They acknowledge that the prospect of including human social and well-being considerations in the pictures has brought many new challenges to restorations. Ultimately, ecosystem restoration is seen to improve the state of the planet, both through social and environmental benefits, but there are many questions around what counts as a good result in every way. Furthermore, in the midst of rapid climate change, climate trajectories make it much more difficult for restoration planning.[73] Another key element requiring complex restoration decisions at an unprecedented scale is the continued rise of invasive species, which is, in fact, spurred on by climate change.[74] Thus, in restoring the planet's ecosystems, we need to decide when to accept that certain nonnative species are actually beneficial in restoration because, in many situations, there may be no other choice.[75]

As Fischer and colleagues assert, social and cultural factors are already becoming part of restoring ecosystems, so we should embrace the complex challenges; in tackling the United Nations initiative, we should welcome these opportunities to make restoration a

more truly multidisciplinary endeavor.[76] Since 2001, the Ecological Society of America has included a Traditional Ecological Knowledge section that has sought to foster such initiatives.[77] In speaking to this need for multiple perspectives, Jake Robinson and colleagues press for the need for Indigenous perspectives as integral to the United Nations 2021–2030 initiative.[78] In particular, they highlight the value of traditional ecological knowledge of Indigenous Peoples, and their right to "maintain, protect, and control their culture and ecological knowledge" according to Article 31 of the UN Declaration on the Rights of Indigenous Peoples.[79] If we can but think about the UN goal of planetary restoration more as healing, and work actively with those possessing working knowledge of the ecosystems, and see the ecosystems as cultural landscapes, both the landscapes and the peoples will benefit.

As *Laudato Si'* advocates, faith perspectives are important voices for planetary stewardship values on the international stage. The United Nations Faith for Earth program raises up such voices, as encapsulated as part of the vision statement of the Parliament of the World's Religions which states: "The Earth and all life are cherished, protected, healed, and restored. All people commit to living out their highest values and aspirations."[80] A world-wide awakening of faith groups advocating values-based approaches to caring for creation in the last several decades was highlighted by Gregory Hitzhusen and Mary Evelyn Tucker, who argued,

> Mobilizing religious believers to contribute to responsible stewardship of the Earth requires a critical appreciation of the complexity of religious traditions and the ways that religious communities view nature, as well as the cultural and spiritual resources that religious teachings provide in confronting change and human suffering.[81]

None of this is easy, and as other commentators have pointed out, "we have a long way to go if we want to realize the promise of the Decade on Ecosystem Restoration."[82] Still, others more optimistically have said, "The Decade on Ecosystem Restoration is an impetus to get it right."[83]

The Promise of Reconciliation Ecology

What does reconciliation ecology offer in the context of Christian faith? As I discussed previously, a decade ago, Warners and colleagues proposed that reconciliation ecology offered a far more robust model for creation care than stewardship. They argued that "the stewardship concept does not sufficiently emphasize our embedded, dependent relationship with the creation."[84] It is likewise clear from Indigenous perspectives that acknowledging the long-term relationship of peoples to place is pivotal to understanding how to heal a wounded planet. This kind of perspective does not see humans as separate from creation but as an integral part of it, as active agents working to make the world a better place. Could this mean future ecosystems configured in new ways, different from those in the past, and envisaged by those who see "novel ecosystems" as a way forward amid widespread ecosystem alteration by invasive species, climate change, urbanization, and other drivers?[85]

David Warners and Matthew Heun edited *Beyond Stewardship* in 2019 in which a number of authors took on the challenge of answering the question, if not stewardship, then what is the best way of expressing the biblical mandate for caring for the earth?[86] There are many creative ways in which Christians have expressed the deep-seated need to honor our creator by caring for his creation, often expressing beliefs in powerful and sacrificial actions. To me an organization that embodies reconciliation ecology through sacrificial actions is A Rocha, an international Christian creation care organization founded by Peter and Miranda Harris. In his book *Under the Bright Wings*, commemorating the early days of the first A Rocha project in Portugal in the 1980s, Peter Harris describes the holistic mission and vision A Rocha has taken on:

> Mission is the whole gospel because the gospel has never been just words about salvation. God did not send a voice from heaven or a letter, he sent Jesus. In his life was the message that we are cut off from God, and in his death and resurrection is the possibility of forgiveness, reconciliation and new life. In order for that message to have meaning or content to those who hear it, his disciples must live that life in the power of the Holy Spirit, and so mission will encompass the whole of human experience.[87]

Today A Rocha centers all over the world follow this overarching mission, and often focus on very particular places or organisms. For example, where I live in Langley, British Columbia, there are roads where migrations of baby Western toads reach epic proportions, numbering in the tens of thousands.

A Rocha Canada, led by Conservation Science Director Christy Juteau, argued that a local road should be closed temporarily to allow the toadlets to cross safely.[88] A Langley Township counselor suggested that putting signs up warning motorists of the migration should be good enough, to which Juteau emphatically responded "no!" Her actual response was: "Not really, because if you're in a car, and the toadlets are covering the road, you just wouldn't have a chance to miss them. So, they may be aware, but they'll just listen to them squishing underneath them." The toad situation is one of the many crossroads we are at in our current society where, if no one stands in the road to say "no!" nonhuman life forms will be run over by progress.

A Rocha is not the only expression of reconciliation ecology by any means, and there is need for a better assessment of the value of such an approach. Why is the reconciliation ecology approach unique? Why might it be an invaluable answer to the quandary of incorporating values into restoration? How might such an approach motivate a more sacrificial caring ethic in the Christian community than we have seen in recent creation care movements? As described in this essay, the needs of creation are more pressing than ever amid the ominous weight of a new age we now call the Anthropocene. Can we include in our collective wisdom and response, insights from Indigenous Peoples, as native theologian George Tinker admonishes us to?[89]

Merely understanding creation theology and ecological science is not enough to save the planet from our destructive human tendencies. Biblical wisdom requires redemptive action to heal the numerous rifts between God, humanity, and creation. Redemption and reconciliation are difficult by definition and we instinctively avoid these, just as we avoid hard conversations about potentially thorny issues such as climate change. Yet we have the strong voice of evangelical Christian and climate scientist Katharine Hayhoe admonishing us to "talk about it" as she declares:

> The bottom line is this. To care about climate change, you only need to be one thing, and that's a person living on planet Earth who wants a better future. Chances are, you're already that person—and so is everyone else you know.[90]

I look forward to seeing the collective wisdom that emerges through contributions to the upcoming special issue of *Perspectives on Science and Christian Faith* on Reconciliation Ecology in the Anthropocene.

Acknowledgments

I am grateful to Janel Curry for floating the idea and topic for this call for papers and encouraging me to take it on. I am also thankful to *PSCF* editor James Peterson and peer reviewers for shepherding me through the process to the point of accepting and publishing this call for papers. I gratefully acknowledge the inspiration I have received from numerous other mentors and colleagues in creation care.

Notes

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> But the proposal still needed an exemplar, a single geologic deposit that best captures the changes, just as a layer of iridium between two clays in a Moroccan cliffside left

by the dinosaur-killing asteroid strike marks the end of the Cretaceous period 66 million years ago." (Voosen, "Anthropocene's Emblem May Be Canadian Pond," *Science* 381, no. 6654 [2023]: 114, https://www.science.org/doi/epdf/10.1126/science.adj7016)

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History of Science

DOI: https://doi.org/10.56315/PSCF9-24DalPrete

ON THE EDGE OF ETERNITY: The Antiquity of the Earth in Medieval and Early Modern Europe by Ivano Dal Prete. Oxford, UK: Oxford University Press, 2022. 214 pages of text plus 82 pages of notes, a bibliography, an index, and sixteen pages of black-and-white halftones. Hardcover; $37.99. ISBN: 9780190678890. Kindle; $25.99. ISBN: 9780190678890.

Ivano Dal Prete is a senior lecturer in the History of Science and Medicine program at Yale University. After receiving his doctorate at the University of Verona, he served as a visiting professor at Columbia, Harvard, and Minnesota before coming to Yale. He has published two prior books in Italian on early modern science and its culture. He is also an amateur astronomer and is the co-discoverer of several asteroids.

On the Edge of Eternity is a helpful and also a disturbing book. Dal Prete's explicit purpose

> is to take the first steps toward a new paradigm for the history of deep time in Western culture. It aims to replace the view of a relatively recent discovery of the "abyss" of geological time with one that accounts for the complexity, diversity, and social and cultural significance of pre-modern Earth history. (p. 7)

In the process of his detailed narrative, he demonstrates how an originally multi-perspectival conversation could sadly devolve into polemics and escalating polarization, mimicking (or predicting?) what we have seen during the past century and a half.

Dal Prete carefully lays out the groundwork for his narrative in the first two chapters. Chapter 1, "Footprints in the Dust," concisely introduces classical sources such as Eusebius, Augustine, Avicenna, and Boethius, and their late medieval successors including Albertus Magnus and Thomas Aquinas. Of particular interest was the question of whether the world (today we might think of the material universe) was eternal or had a beginning in time (or with time). The question became highlighted following the translation of Aristotle's major works from Arabic into Latin during the twelfth century and played into the theses of the Fourth Lateran Council and later the controversies at the University of Paris during the thirteenth century. As Aquinas put it, reason could not assess whether the earth was eternal or not, but scripture settled the matter with an absolute beginning in time. However, many aspects of Earth history could be made to mesh with either viewpoint. This provided for a multiplicity of opinions and openings for merging empirical observations with philosophical perspective. For example, Noah's Flood could be a global catastrophe or a local catastrophe; further, it could be a singular event or one of many, repeatedly forced by hypothesized interchanges of land and water, hinted at in Aristotle's *Meteorologica*.

Chapter 2, "The Medieval Earth," summarizes multiple running debates, extending through the fourteenth century. A problematic issue was the origin of mountains. Erosion of highlands was easily observable, and without a mechanism to raise new highlands, the only result could be the washing of the entirety of the exposed earth into the sea. Thus, without such a mechanism, Earth's age would be constrained. But perhaps Aristotelian or Ptolemaic understandings of Earth's figure and the sea-land boundary could be used to support many cycles of erosion and sedimentation, resulting in new uplifts. Claims for astral influences were yet considered possible by many as well. Dal Prete examines the give-and-take between intellectuals such as Jean Buridan, Albert of Saxony, Pierre d'Ailly, and Dante Alighieri, among others.

Chapter 3, "Vernacular Earths, 1250–1500" broadens attention to the northern Italian Renaissance community of the mercantile class, including artisans and engineers, outside the university faculties. During this period, translations of the classical authors into vernacular dialects became widely available, as well as newer encyclopedic summaries of useful knowledge—for example, mathematics, astronomy/astrology, medicine. Coincidently, northern Italy developed as a major mining center, which literally opened up fertile material (rocks) for speculation. The nascent science of stratigraphy was developing, two centuries prior to Steno. Dal Prete convincingly argues that Leonardo da Vinci was not a lone predecessor of modern natural science, as is often depicted, but rather "just the most celebrated representative of an extremely rich and variegated tradition" (p. 77). Further, typifying his cultural milieu,

> Leonardo's writings do not provide the slightest hint that the idea of a young Earth ever crossed his mind. The Italian artist failed to bring up the problem not because it was too much an issue, but because it was not an issue at all. While his world was expanding horizontally toward other continents and vertically in the underground, the one dimension that did not need to be enlarged was time. (p. 90)

If this book were a novel, Dal Prete would have now laid the detailed foundation for ensuing confusion, conflict, and misrepresentation. Unfortunately, this is not a novel. Things begin to unwind in chapter 4, "A 'Pious' History of the Earth? 1500–1650." Here, Dal Prete

explicates the creative attempts to formulate a physico-theology for Earth's historical development during the period of the Reformation. Within Reformation-era Protestantism, the principle of *Sola scriptura* settled the question of Earth's possible eternity. Earth had a definite beginning in (linear) time. But *Sola scriptura* could be employed to argue for a face-value interpretation of the genealogies of Genesis, plus a 24-hour-day view of the Creation week, to yield a very compressed Creation account. Reflexively, Counter-Reformation scholars, in their efforts to outdo their Protestant counterparts, often employed the same tactics and principles to take back the "high ground." Their efforts were also responses to the great voyages of discovery, which revealed whole segments of humanity previously unknown to the Christian world. What was the relationship of the inhabitants of the New World to the biblical genealogies? A strict appeal to the Flood of Noah as a singular Earth agent provided an anchor for a lineal descent of the American aboriginal population from Noah and therefore from Adam; they were thus inheritors of the Divine image.

Chapter 5, "The Rise of Diluvialism, 1650–1720," expeditiously covers a lot of territory that will be familiar to many of our readers. During this period, early Earth scientists, including Kircher, de Maillet, Aldrovandi, Scilla, Hooke, Burnet, Woodward, Vallisneri, and others grappled with observations of marine fossils in layered rocks exposed in mountains. They pondered a possible relationship to the Noachian Flood, but derived disparate histories. Some retained a modified Aristotelian Earth, with a protracted history of alterations of land and sea. Some natural historians attempted to meld the rock record with a Noachian Flood in a Newtonian gravity-driven world. Others argued for the strictly miraculous nature of the Flood of Noah, that could not be expected to yield a record in the rocks. But overall, "the idea of a 'Mosaic' natural philosophy met with considerable success, and its influence was profound" (p. 127).

In chapter 6, "The Invention of the History of Deep Time, 1700–1770," Dal Prete examines a diversity of Enlightenment-era historians and philosophers. These vary from Christians (e.g., Leibniz, Calmet) to deists (Voltaire, Buffon) to atheists (de Maillet, Diderot, Boulanger, d'Holbach). Their proposed schemes for cosmic and human prehistory demonstrate varying familiarity with real Earth phenomena, as well as an expansive willingness to speculate beyond the evidence at hand. However, they realized correctly that Earth must be quite old. Unfortunately, the increasingly strident, even vicious, polemics that some of these thinkers offered against the Christian faith engendered a wide range of popular respondents. And unfortunately, many of these respondents easily seized on diluvialist versions of Earth histories to rebut anti-Creation philosophies. Thus, a century and a half before European and American rationalists invented the "warfare" thesis, a popular perception began to emerge that materialist philosophies often went hand-in-glove with the study of nature.

At this point, Dal Prete returns to Venice and northeastern mainland Italy, in chapter 7, "Political Fossils, 1740–1800." Italian translations of works of the French materialists began to appear in northern Italy in 1740. Up until this time, there had existed a strong community involvement in natural history pursuits. These included clergy: the priest Giovanni Giacomo Spada is reported to have put together a collection of fossil fishes (from the nearby site of Monte Bolca, famed among modern paleontologists) that was far superior to that of John Woodward. But after 1740, numerous books appeared arguing the diluvialist cause. Fossils were co-opted as evidences for the Flood and a young age of Earth. Dal Prete carefully chronicles how the political and economic elites of the region "elaborated a diluvialist orthodoxy allegedly supported by 'true philosophy' and 'sane science,' which appeared very different from the Earth history many enlightened Catholics conceived only a few decades earlier" (p. 183).

I found this book useful (but disturbing) for three reasons: (1) Dal Prete demonstrates that prior to AD 1700, many serious Christian scholars realized Earth was an old object and saw no theological problem; (2) the classic fairytale of some age-long conflict between Christianity and natural science began to be manufactured during the eighteenth century, long before Draper, White, and others in the later nineteenth century; and (3) Dal Prete demonstrates that the oversimplistic claims and harsh rhetoric of the diluvialists of the seventeenth and eighteenth centuries, provoked by and responding to erudite but self-important atheists, eerily presage the writings of twentieth-century diluvialists. And thus, the magnificence of God's creative activity in deep time is clouded by verbiage. Ouch.

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DOI: https://doi.org/10.56315/PSCF9-24Topham

READING THE BOOK OF NATURE: How Eight Best Sellers Reconnected Christianity and the Sciences on the Eve of the Victorian Age by Jonathan R. Topham. Chicago, IL: University of Chicago Press, 2022. 544 pages. Hardcover; $47.50. ISBN: 9780226815763.

Jonathan R. Topham's *Reading the Book of Nature* examines the interplay between science and religion in nineteenth-century Britain, focusing on the *Bridgewater Treatises*—an influential collection of eight scientific works commissioned to explore the "Power, Wisdom, and Goodness of God, as manifested in the Creation." Armed with a rich array of primary sources, Topham is particularly interested in setting this interplay against the backdrop of the evolving print culture. Topham's is not just a treatise on treatises, nor simply a history of ideas, but an exploration grounded in the lens of book history, which involves investigating the production, distribution, and reception of printed materials, including books, periodicals, and pamphlets. Topham thus wants to understand the entire "network of communication" in which the *Bridgewaters* were enmeshed, including publishers, reviewers, libraries, and readers.

Topham divides the book into three parts. The first examines the authorship of the *Bridgewaters* themselves, revealing the complicated (and often contested) process of "writing God into Nature" (p. 107). Chapter 1 navigates the intricacies of establishing oneself as a scientific author, which posed multifaceted challenges. Topham shows that many practical matters consumed the time of the authors, and sometimes delayed their work a great deal (p. 105). Moreover, the task of writing was rarely solitary. Topham highlights the collaborative nature of writing, emphasizing the contributions of the authors' wives and female relatives (pp. 91–105).

What is most interesting in this part, however, and which Topham emphasizes again and again throughout his book, is that the *Bridgewaters* should not be seen as mere works of "natural theology." Though the authors relate their work to William Paley's *Natural Theology* (1802), the *Bridgewaters* were not simply new arguments from design. They adopted a more comprehensive approach, examining various scientific disciplines to showcase the harmony between science and theology (p. 80). Topham introduces the concept of an emerging "theistic science," suggesting the series aimed to reassure readers that science and religion were not adversarial but rather mutually reinforcing (p. 14). It was, in short, an effort to present a tamed science tailored to align with Christian sensibilities.

In chapter 2, Topham examines the intended purpose of the treatises, such as the need to respond to popular science treatises and their alleged association with radical thought, particularly to the utilitarian approach to science advocated by such thinkers as John Stuart Mill or the materialism of French scientists such as Baron D'Holbach and Pierre-Simon Laplace. Indeed, according to Topham, it was mainly "French speculators" who motivated the *Bridgewaters* (p. 166).

In part two, Topham explores the significance of selecting a reputable publisher for the *Bridgewaters*. Chapter 3 gives insight into the decision to publish with William Pickering rather than John Murray. Murray was known for both its literary and scientific focus, publishing works by Jane Austen, Lord Byron, Charles Lyell, and Charles Darwin. This made the John Murray Publishing House a hub for nineteenth-century intellectual and literary circles. Conversely, Pickering was mostly known for classical literature, including works by John Milton and William Wordsworth. Because the *Bridgewaters* needed to be seen as "dignified" (p. 189), the authors were more philosophically (and socially) aligned with Pickering, with its focus on high-quality printing, crucial for the series' numerous iconic illustrations (p. 205). The authors settled nicely with a "publisher who was used to producing beautiful works for gentlemanly connoisseurs" (p. 224).

Chapter 4 offers a comprehensive overview of how the *Bridgewaters* were "serialized"—that is, how they were critically reviewed in scientific and religious periodicals. In general, the *Bridgewaters* were well received within academic and intellectual circles. Many scholars appreciated the efforts to reconcile scientific discoveries with religious beliefs. The series also had a notable influence on later Victorian thought, contributing to a broader conception of natural theology and the accessible popularization of science. Many religiously conservative periodicals were ambivalent if not "hostile" to natural theology (p. 246), albeit not natural theology in the traditional sense. If used properly, the "*Bridgewaters* could evoke suitable feelings toward God while developing an enlarged but theologically orthodox understanding of the creation" (p. 330). Periodicals less conservative than High Church and evangelical journals still found them "useful vehicles of scientific enlightenment" (p. 263). Medical and scientific journals, including the then radical *Lancet*, also found the *Bridgewaters* "trustworthy" (p. 273).

In the final section of his book, Topham focuses on case studies of "reading." Chapter 5, for instance, looks at how the *Bridgewaters* were used, remarkably, in the daily devotional reading practices of several individuals. Some readers even promoted *Bridgewaters* as courtship reading material (p. 311)!

Chapter 6 explores how Christian preachers utilized the *Bridgewaters* to reinforce theological and moral lessons and offer "a positive vision of the sciences" (p. 331). This

affirmation of the "religious tendency of the sciences" was all the more important in an era marked by a growing separation of science from theology.

Chapter 7 provides an interesting examination of how the authors of the *Bridgewaters* constructed an image of the Christian "man of science" in an era when many scientific practitioners wanted to establish a new identity of the man of science, in direct opposition to the clerical gentlemen of science that the authors represented. As Steven Shapin has pointed out, in early modern culture the "man of science" was heterogeneous in that it attached to preexisting roles. A number of key figures spent their whole lives working within religious institutions or sustained by clerical positions, such as Nicholaus Copernicus, Marin Mersenne, and Pierre Gassendi. The argument that God had written two books by which his existence, attributes, and intentions might be known was foundational for "natural theology" to such English clerics such as John Ray, Stephen Hales, Gilbert White, and William Paley. The naturalist-parson, Shapin contended, belonged to the century's inventory of recognized characters, and the scientific portion of his activities was understood to flow from some version of what it was to be a minister.

But this "priestly" role is seen almost concurrently in other key figures who spent much of their careers as amanuenses, clerks, tutors, or domestic servants to the gentry and aristocracy. With the advent of the eighteenth century, we witness a vast expansion in the numbers of scientifically trained people employed as civic experts in commerce, the military, and government. The man of science as godly naturalist and moral philosopher buckled under the emerging identity of the valued civic expert. While professorial and medical roles included the "pious naturalist" and, more specifically, parson-naturalist, especially among Protestants, there was a growing perception by the beginning of the nineteenth century that men of science were objects of "religious suspicion" (p. 375). Thus the authors of the *Bridgewaters* strategically reemphasized "the vision of the man of science as pious, patient, and humble" (p. 390), "embedded within Christian orthodoxy and as inculcating Christian habits of mind" (p. 429).

Chapter 8 examines how the *Bridgewaters* influenced the scientific practices of notable readers such as Charles Babbage, Charles Darwin, Robert Chambers, Richard Owens, and William Carpenter. Topham illustrates how the *Bridgewaters* functioned as a foil, enabling them to negotiate between arguments advocating for intelligent design and those rooted in empirical scientific observation. The irascible Babbage, for instance, who published his own unauthorized *Ninth Bridgewater Treatise*, appreciated the design arguments presented in the series, but offered a radically different "vision of God's agency" (p. 436) which amounted to little more than deism. Darwin, moreover, included an epigraph from Whewell's *Bridgewater* at the start of his *Origins of Species*, but the two ultimately disagreed on the mechanism of evolution.

In his conclusion, Topham returns to the *Bridgewaters* as promoting a "theistic science" serving "to assure a generation that the rapidly changing disciplinary sciences … would feed rather than undermine Christian faith" (p. 471). They were a "godsend to the sciences," he writes, convincing the public that the progress of science was not inimical to Christianity (p. 473). At the same time, the theological meaning of the *Bridgewaters* was "somewhat ill defined," in part since most authors came from strikingly different theological orientations (p. 474). Topham concludes, as I did in my research on the liberal Christians John W. Draper and Andrew D. White, who are often labeled "co-founders" of the "conflict thesis," that science and religion are fundamentally at war. While Draper and White believed that their liberal theologies offered a reconciliation of science and faith, secularists, free-thinkers, and atheists used their narratives as weapons against all religious traditions.

Similarly, Topham notes how the *Bridgewaters* led many radical thinkers, such as George Holyoake, to see theistic science as "hopelessly outmoded" (p. 477), hollow, and ultimately constraining science (p. 478). There seems to be a lesson here that, for whatever reason, today's theologians and Christian men and women of science keep ignoring.

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Neuroscience

DOI: https://doi.org/10.56315/PSCF9-24May

NEUROETHICS: Agency in the Age of Brain Science by Joshua May. New York: Oxford University Press, 2023. 340 pages. Hardcover; $110.00. ISBN: 9780197648087. Paperback; $29.95. ISBN: 9780197648094.

Neuroethics, "the study of moral issues that are either raised or answered by neuroscience" (p. 4), is a relatively young field, whose origins are generally traced to the early 2000s. Despite its rapid growth since then, it remains unfamiliar to many, and over the years, numerous introductions and overviews have been written to make it more familiar. Joshua May's new book, the latest in this line, is described as an "opinionated introduction" (p. 9). It has grown out of the author's undergraduate course in neuroethics and is written partly

with students in mind. However, he aims to "[challenge] the distinction between a research monograph and a textbook" (p. xvi), not only introducing a representative range of neuroethical topics, but also contributing to the debates.

May follows Adina Roskies, one of the field's founders, in distinguishing two main branches of neuroethics: the more practically focused "ethics of neuroscience" and the more theoretical "neuroscience of ethics." He emphasizes, though, how "intertwined" (p. 6) these branches are. The design of the book reflects this: each of the four main parts consists of a pair of chapters on related topics, one more theoretical and one more practical in focus.

Before we reach these, a single introductory chapter is designated as Part I. This does a good job of defining and introducing the field, as well as summarizing the book and announcing May's overall approach and conclusions. In addition, the chapter offers appendices with overviews of philosophy and neuroscience for readers unfamiliar with these disciplines. To put it mildly, this is an ambitious thing to attempt in a few pages of an opening chapter, but May succeeds in offering lucid and accessible accounts.

In the first main part, "Autonomy" (Part II), the more theoretically focused chapter (chap. 2) is on free will, while the more practically focused (chap. 3) is entitled "Manipulating Brains." The former examines three threats that neuroscience might pose to the idea that humans have free will: determinism, physicalism, and epiphenomenalism (the last implying that our experience of conscious will is illusory). May argues that none of these rules out free will, but they do suggest that we are less free than we often think. Chapter 3 then explores ethical concerns about manipulating brain activity for therapeutic purposes, concluding that such interventions are legitimate, but a cautious approach to balancing risks and benefits is needed.

Part III is entitled "Care" (perhaps an odd title for a pair of chapters largely concerned with agency and responsibility). Chapter 4 focuses on mental disorders, asking "whether having a mental illness … categorically exculpate[s] one for inappropriate behavior" (p. 116). May's answer is that a "nuanced" view is required, in which we cannot generalize about the effects of mental disorder on agency and responsibility but must judge on a case-by-case basis. To my mind, while I generally agree with the conclusion, this chapter is less satisfying than much of the book. It is built on a contrast between "naïve" and "nuanced" views of the implications of psychopathology for responsibility, but the former seems something of a straw man, as May himself comes close to acknowledging in the conclusion. One section of the argument, claiming that some psychopathologies enhance agency, I find rather unconvincing. And there are a few instances of careless expression, as when physical injury is categorized as a non-pathological effect on agency (p. 115, table 4.2). Chapter 5 continues in similar vein with a discussion of addiction, critically examining the "brain disease model" and arguing that conceptualizing addiction as a disorder (as distinct from a disease) does not imply complete loss of agency, responsibility, or accountability.

Part IV turns to the neuroscience of morality, with one chapter examining the neuroscience of moral judgment and another assessing the legitimacy of moral enhancement. The first is focused on the relationship and balance between reason and emotion in the making of moral judgments. It includes a well-judged critical account of Joshua Greene's high-profile but controversial brain-imaging studies of moral cognition. This is followed in chapter 7 by an ethical evaluation of moral bioenhancement: the project to improve ourselves morally by the use of neurotechnologies such as psychoactive drugs or electrical brain stimulation. May develops a "presumptive case" (p. 175) in favor of this project and rejects a series of objections to it.

The final main part is entitled "Justice." Chapter 8, "Motivated Reasoning," begins with neuroscientific perspectives on self-deception, cognitive bias, and the like, then moves into a discussion of bias, questionable practice, and misconduct in science. While acknowledging the challenges—including those facing neuroscience, in particular—May takes an optimistic view of the capacity of scientific communities to produce genuine knowledge. This optimism feeds into the next chapter on brain reading, the use of functional neuroimaging to gain information about subjects' mental activity, in which it takes two almost opposite forms. In criminal justice, May concludes that for all its limitations, brain reading can be useful in the courts. By contrast, he believes that it is unlikely to be effective enough in neuromarketing to seriously threaten consumers' privacy or autonomy; other technologies such as big data pose greater threats. While May takes concerns about brain reading seriously, I can't help wondering if his general aversion to alarmism tends in this chapter toward overoptimism. But it would take a longer discussion to settle that question.

May's overall argument, spelled out in the concluding chapter, is for a "nuanced neuroethics" that avoids alarmism, takes evidence and complexity seriously, recognizes the alikeness of neurotypical and neurodiverse

people, and engages both neuroscience and philosophy carefully. The book is beautifully written, communicating complex content and ideas with admirable clarity. In general, I find it persuasively argued, with a few caveats of the sort indicated earlier. The structure of the book is effective in integrating the "neuroscience of ethics" with the "ethics of neuroscience." Another valuable design feature is that each chapter begins and ends with a real-life case study, effectively keeping the book's complex discussions grounded in concrete realities. However, most of the case studies are drawn from the world of criminal justice, which could give a rather skewed impression of the areas of human life on which neuroethics has a bearing.

I would certainly recommend May's book to readers of this journal. While some of the content is complex and challenging, the clarity of presentation should make it accessible to advanced students. It would be a valuable text for an upper-level undergraduate or graduate class in neuroethics, as well as an excellent introduction for anyone prepared to work through some complex ideas and arguments. If I use it for my own classes, though, I shall need to supplement it, because one thing it does not address at all is religious and theological perspectives. This is not to fault May for not having written a different book: as a philosopher also trained in neuroscience, he brings these two disciplines together very adeptly. In this respect, the book also faithfully reflects neuroethics as a field, often a highly secular one in which religious and theological voices are not much in evidence. To my mind, there is work to be done to challenge that secularity and explore what difference a theological engagement with this field might make. But that is my agenda, not May's.

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Psychology

DOI: https://doi.org/10.56315/PSCF9-24LindnerGunnoe

THE PERSON IN PSYCHOLOGY AND CHRISTIANITY: A Faith-Based Critique of Five Theories of Social Development by Marjorie Lindner Gunnoe. Downers Grove, IL: IVP Academic, 2022. 244 pages. Paperback; $30.00. ISBN: 9780830828722.

As a teacher of counseling psychology in a faith-based (Christian) tertiary institution, Marjorie Lindner Gunnoe responds to the challenge facing her students to engage theologically with contemporary psychological science. Her goal is to facilitate a bridge between the (largely secular) theories that dominate the field of counseling practice and the Christian faith of psychology practitioners and educators. To this end, Lindner Gunnoe develops what she sees as a trans-confessional (broad, not framed within a particular Christian theological tradition—though still largely Protestant) theological position about human ontology, motivation, and behavior, applying it to five key theories in contemporary psychology.

Linder Gunnoe's "faith-based working model" (p. 2) presents a Christian stance along four dimensions: the essence of human life; human purpose; moral-ethical tendency; and agency and accountability. Lindner Gunnoe does acknowledge her own location in the Reformed tradition but references widely while eschewing any attempt to anchor her theology in that tradition. Most of the book is devoted to comparing the four dimensions of this faith lens to the theories and work of five twentieth-century shapers of contemporary psychology: Erik Erikson and his lifespan stages; John Bowlby and Mary Ainsworth's attachment theory; B.F. Skinner's radical behaviorism; Albert Bandura's social learning theory; and evolutionary psychology broadly. For each theory, she identifies the way in which the questions posed by the four dimensions are answered (or not), asking how and if they are compatible with the faith-based position articulated at the beginning.

While the book is academic, written by an academic for academic teaching contexts, it is academic 'light' in reference density, using more accessible language suitable for practical theology and knowledge mobilization in the field. Lindner Gunnoe's attempt to thoroughly understand and represent nuances in the writings of the psychology founders is appreciated. With each theory, she tries to present a balanced view, moving past the reductionist (and atheist) emphasis of the theories that is commonly presented in (secular) textbooks, by digging into a variety of primary and secondary sources. The book is thought-provoking, insightful, and interesting both from the standpoint of faith in practice, and from the field of psychology.

Making no claims to be a theologian, Linder Gunnoe offers reflections on the "temporal characteristics of personhood … physical and psychological features manifest in our relationships with other humans and the rest of creation" (p. 5). Rather than approach her reflection from the traditional theological categories (e.g., ontology, teleology), she identifies the four key aspects of humanity that are addressed by biblical reference, and which pertain most directly to the field of psychological intervention (essence, purpose, morality/ethics, and agency/accountability).

Essence is the central intrinsic quality of humans (vs. other species) ascribed in Genesis 1: the image of God. She argues that this central feature continues to be important after the Fall, since it is later referenced in Genesis 9. It has substantive qualities (e.g., reason, embodiment, inherently gendered "different but equal"), relational qualities (inherent relationality, i.e., between genders, between humans and God), and functional qualities. The functional qualities relate to the task of "dominion" over the creation, which she describes in caring stewardship terms (i.e., careful management for the health of creation vs. "right to abuse" historically blamed on Christianity). It is the relationality and functionality of human essence that shape the purpose of humanity: love and "dominion work."

Purpose in theological traditions may be emphasized differently, depending on the relative importance placed on relationality versus functionality. Lindner Gunnoe grounds the purpose to love in Genesis 2 (that humans should not be alone), as supported in the New Testament by Jesus's statement that the greatest command is to love (Matt. 22) and by the many injunctions to love one another (Matt. 5, Rom. 12, 1 Cor. 12). That we are also created (in the context of love) to engage in creative work on the earth is seen first in Genesis 2. Later biblical references such as Ephesians 2 remind us that God has ordained creative work. There is an overarching telos which is the goal to become more conformed to the image of God (due to the Fall we are created in it, but some of our work involves spiritual work to return to a better reflection of it). Although there is an end goal spiritually, Lindner Gunnoe skirts the spiritual-eschatological debates (e.g., free will vs. chosen regarding salvation), to focus on "temporal" aspects (what we are meant to be doing in the here-and-now life).

Moral-ethical tendencies in the faith framework of this book refer to "propensities toward good and evil in our daily dealings" (p. 20), rather than to questions of eternal life. Rather than position the drives or motivations toward good or bad action as part of human essence, Lindner Gunnoe uses the term "tendency" to refer to a latent capacity that could go either way. Once again based on the opening chapters of Genesis, Gunnoe argues that humans are structurally good in an embodied way that allows us to be capable of God-like abilities (i.e., the choice of right, reason). They are additionally (since the Fall) also now inherently inclined (but not structurally, i.e., in nature) toward evil. After a brief review of different theological debates about the acquired versus inherent nature of evil, she describes the tendency to wrong as more of an emergent property. It is something that we are capable of, but only as a warping of the core power that was initially created good (the image of God).

The issue of moral-ethical tendency gives rise to the issue of humanity's degree of agency. Agency is framed as the degree and power of choice, whereas accountability is the degree of liability for agency. While finding widespread support in the Bible for God's expectation of both human agency and accountability, this chapter also addresses concepts which create degrees of these, such as Old Testament laws differentiating between a sinful act conducted under force versus conducted willfully (Num. 14), and New Testament references to different expectations based on the age of the person (child vs. adult) (Luke 12, Romans 2).

These four elements of the faith-framework are then applied in each chapter to exploring the five psychological traditions with which she is engaging. The central question for Gunnoe is not whether the psychologist(s) who created the theory adhered to Christianity (or any other faith), but whether there are compatibilities (or opposition) to the four elements of her faith framework.

The discussion of each of the five theories is prefaced with an engaging and fresh biographical story about the relevant theorist, that provides insight into the life questions they sought to answer through their work. This approach reminds the reader that theory (and theology) are inherently grounded in personal perspective, and that all "argument" with others is first an exercise in understanding and respecting the Other and their story. This is, of course, the central task of any counseling encounter. It is also grounded on the biblical tenet that (all) humans are created in the image of God.

It is difficult to draw definitive conclusions about the secular streams of thought presented, since she does not present them as right/wrong, or for/against Christianity, in a neat way that absolves the reader of doing the thinking for themselves. Some may be uncomfortable and find it difficult to have the edges of binary in-group/out-group thinking challenged. The underpinning theological arguments may be unsatisfactorily light for some. However, she achieves her goal of unmooring the reader from entrenched denominational thinking, and from stereotyped and categorical representations of the psychological ideas and their founders.

The book leaves the reader with a new appreciation for the value of the theories in clinical practice, as well as the challenge to continue to wrestle theologically with the tools of the counseling trade rather than abandon them, or compartmentalize professional practice and faith life. The responsibility remains with the reader to

think through their own position. Even if holding an uncomfortable relationship with an approach, the point is to be more aware of one's own convictions and their impact on practice integrity. Such spiritual and existential thinking is a critical form of awareness training for anyone in a counseling role in ministry or in mental health, especially in a multi-religious and post-Christian society. Overall, I found this book fresh, enjoyable, and relevant to anyone in pastoral care, counseling, or psychology.

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DOI: https://doi.org/10.56315/PSCF9-24Edelman

THE CONSCIOUSNESS REVOLUTIONS: From Amoeba Awareness to Human Emancipation by Shimon Edelman. New York: Springer, 2023 (1st ed.). 226 pages. Hardcover; $44.99. ISBN: 9783031240119.

In *The Consciousness Revolutions: From Amoeba Awareness to Human Emancipation*, Shimon Edelman takes on the onerous task of defining consciousness at multiple levels of complexity, from the most basic of life forms such as amoebas and microbes, to some of the most complex interactions between individual humans and their communities and political systems. In the Prelude, Edelman's characterization of essential consciousness in single-celled organisms is at first surprising and appears to stand in direct opposition to the prevailing view that consciousness is what separates humankind from other living organisms. However, in chapter 1, he quickly qualifies this by turning the reader's attention toward "the experience, of being a fully conscious, alert, and focused human" (p. 7), thereby setting the stage for ascent to complexity of consciousness through seven revolutions, concluding with a discussion on the inevitable emergence of capitalism with proponents protected by armed forces and the formation of social class structure which limits accessibility of privileged consciousness to those with the right status (e.g., via skin tone, financial means, and educational opportunities).

The book is organized into Edelman's introduction, two sections, an interlude, and an epilogue. Section I, "The Human Condition," comprises the first five chapters. Chapter 1 defines essential consciousness as the ability to differentiate self from other and move away from potentially threatening objects in order to survive, an operational definition met by even simple organisms. The foundation is then laid for the rest of the text to describe how the mind is necessarily, indirectly, supported by the brain whose processes are calculated by algorithms, like comparing the risk of getting spiked by thorny berry bushes against the need to eat. Chapter 2 details a slightly higher level of consciousness where cause and effect become understood, both in the present and when analyzing the past, leading to learning and blame. In chapter 3, self-monitoring, agency, and free will are tied to one's ability to make accurate predictions and to the emotional response of the system (of self) when errors are made. Chapter 4 characterizes the development of language as a tool for consciousness that works almost like "magic"—extending influence and power over (even distant) others. Chapter 5 covers the self in relation to society, formation of morals, and how privilege allows for consciousness.

Section II, "The Roads to Freedom," moves us into higher levels of consciousness where social constructs are now an integral part of the conscious experience. Chapter 6 describes the balance of self and others and some options on getting help. Finally, chapter 7 is a rather depressing narrative on the inevitable ascent of capitalism, a societal system marred by oppression and injustice, concluding with a message of cautious hope.

Most chapters are densely written and probably best understood by those with expertise from microbiology, neuroscience, and cognitive psychology in the early chapters and philosophy, political science, and economics in the later chapters. Lack of knowledge in one or more areas may leave a reader confused (especially in chap. 3) and disrupt one's climb to the Epilogue. However, aids to the reader include quotes from Buddhist monks, Catholic saints, current philosophers, and storytellers, with additional notes in the columns to define or summarize content. Moreover, each chapter is followed by extensive endnotes with references.

Edelman's writing reminds one of a mix between Vonnegut and a science fiction novel with a strong dash of political perspective/economic theory and a spoonful of cognitive psychology and neuroscience. His writing is entertaining and interesting. He uses numerous cognitive constructs woven together to describe the building blocks of consciousness, from essential consciousness in an amoeba up to the privileged consciousness of capitalist societies. If one reads with this in mind, they might appreciate the novel take on consciousness, the comprehensive tie-in of relevant (and tangential) literature, and witty humor.

Two overarching themes bear mentioning. One involves an organism being a system that makes predictions where the feedback should hold no surprises if it is "inherently good." The organism's dilemma is in trying to plan its actions based upon how the world will respond to it, a logical impasse, dealt with by feeling that the self is in control.

> Unfortunately, this also makes the self automatically the bearer of all responsibility for everything that comes out of its host's actions—a side effect of being self-aware that really helps learning, at the cost of condemning a conscious being to anxiety and suffering. (p. 4)

This comment is made in the book's introduction and carried through to the end as the inevitable demise of society—a system run by the richest and most privileged who are seemingly imperious to the plight of those with less privilege.

A second theme is one of consciousness revolutions in an ascent toward the complexity and perils of being human in community. Each revolution has its own chapter. This is evident in the description of book sections and chapters (above), beginning with the amoeba's essential consciousness and ending in the highly complex consciousness of humans in community.

One main point of the book is that true consciousness is defined by being at a level where one does not have to worry about freedom, politics, or the economy. Thus, a person needs to have enough resources (e.g., financial means) to just focus on self, family, and science. "Being, or at least being well-off, does after all determine consciousness" (p. 128). This indicates, then, that one must be of privilege to experience consciousness, in its current iteration. Thus, the inevitable evolution of societies into a capitalist structure, with overlooked and underprivileged classes of individuals, means an unequal ability for multitudes of people to experience "consciousness"—at least, until another consciousness revolution occurs. Edelman declines to elaborate on the next revolution but implies, with careful optimism, a transformation of the freedom that arises from privilege into true freedom for all humans, with a decline in materialism/capitalism.

Edelman's proposal for evidence of consciousness detours away from how it is defined in the cognitive domain by being both too simplistic and broad. In the cognitive literature, processes linked to consciousness must reveal knowledge of a person, place, and time specific to an event. It would certainly be difficult to find evidence of this in the behavior of amoebas, but humans are generally able to show it, regardless of social class (with the latter point contradicting Edelman's later revolutions). Language is another defining feature of conscious cognitive process, a requirement met in chapter 4, but not met in earlier chapters and not enough to meet the requirement for consciousness in later chapters. Since Edelman defines consciousness in many different layers of complexity, it ends up feeling like a moving target and many definitions. This complicates empirical evaluation and comparison with existing cognitive theories of consciousness.

In relating Edelman's ideas to those of Christian theology, some Christian theologians assume that conscious cognitive processes are what set us apart from animals and are part of being made "in His image." For some theorists this includes not being so reactive to emotions. Arguably, though, the incorporation of those emotions into the decision-making processes may lead to poor decision making. Yet, the current focus on mindfulness encourages us to dig into our emotions and become aware of them. Moving into a state of flow, a state considered to be quite positive and an optimal experience, requires unhooking from the planning and coordinating and relying on our bodies to do what they know how to do; this would seem to be a more animalistic, unconscious state.

Edelman describes the inevitable fall of society into a money-prioritized capitalistic structure where only the elite are able to experience consciousness. This implies a lack of choice in this fate, and certainly a lack of a loving God providing oversight. It contradicts that reliance upon God might be easier for those of less means as their needs prevent them from falling into the fallacy that they do not need a God. In fact, it could be argued that it is harder for the elite to rely on God, just as it is hard for a camel to travel through the eye of a needle, as they may assume a false sense of control and, therefore, fail to recognize that they need God. If the marginalized classes have an easier time relying upon God and, therefore, experiencing him more fully, aren't they the ones more likely to experience heightened consciousness?

The book is reasonably priced and enjoyable. I often found myself smiling while I read, highlighting insightful passages for later reference, including those in the interlude. Thus, I recommend this book. Just make sure you have had your coffee first.

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Social Studies of Science

DOI: https://doi.org/10.56315/PSCF9-24Sugimoto

EQUITY FOR WOMEN IN SCIENCE: Dismantling Systemic Barriers to Advancement by Cassidy R. Sugimoto and Vincent Larivière. Cambridge, MA: Harvard University Press, 2023. 256 pages. Hardcover; $35.00. ISBN: 9780674919297.

In *Equity for Women in Science: Dismantling Systemic Barriers to Advancement*, Cassidy Sugimoto and Vincent Larivière take a social science approach to characterizing and assessing the role of gender in the successful pursuit of science. Using seven metrics—production of scientific results, collaboration, contributorship, funding levels, ability to move and travel, scientific impact, and a scientist's role within social institutions—the authors find that despite country of origin, male scientists continue to outpace female scientists across these areas.

Each chapter of *Equity for Women in Science* focuses on one of the seven metrics, beginning with stories from the history of science. In this way, the authors highlight the achievements of early women, as well as the barriers they faced and the sacrifices that were required. While these sections will be familiar to those who have studied the history of women in science, the examples are excellent and represent many of the strongest exemplars of early women in the sciences. Even for those who may already know the stories, these sections are a strength of the book and provide needed context for the subsequent analysis and discussion of the modern situation.

The chapters then transition through time, presenting meta-analysis of existing data followed subsequently by new, largely bibliographic, data produced by the authors. In most cases, the authors utilize publication authorship, the gender of the authors, placement within the author list, and subsequent publication citations, as indicators of the relative contributions of men and women. While the authors do acknowledge the limitations of their analysis (e.g., considering gender as a binary, assigning gender based on an author's name, etc.), these restrictions remain significant caveats to the reported results. In an effort to overcome these limitations, the authors supplement their bibliographic data with that from other sources, including the National Science Foundation (NSF) and Academic Analytics. However, while these datasets provide further evidence that disparities in productivity, funding, and mobility exist between male and female scientists, they too are plagued by limitations (e.g., NSF is a single US funding agency). Regardless, *Equity for Women in Science* provides a useful framework for the assessment and subsequent discussion of the persistent gender gaps in science.

The authors' engagement with the idea of contributorship was new to this reviewer and is a helpful metric for determining gendered roles in the production of scientific results. Since authors contribute in distinct ways to published work, it is helpful to know the role that each author has played (e.g., conceiving of the work, doing the experiments or the analysis, writing or editing a manuscript, etc.) and whether that distribution deviates by gender. Within the biomedical sciences, many top journals have begun requiring authors to attribute coauthor contributions within publications; however, many other fields have yet to move in this direction. Regardless, in journals that attribute contribution, the authors find that women are more likely than their male counterparts to conduct experiments, rather than raise funds or conceive of the ideas. This suggests that women are disproportionately serving in technical roles, rather than leading teams. Yet, the authors show that when women do lead teams, as indicated by their presence as last author on publications, more women are included within those teams. Moving forward, the lens of contributorship may provide a useful means for gauging gender parity in science.

The global nature of the data provides a broader context than one usually sees in these types of analyses; unfortunately, the limitations of bibliographic analysis render the findings more approximate than quantitative. For example, the authors measure the mobility of scientists based on joint publications with international coauthors. While these examples indicate the ability of one or both collaborators to travel, they significantly undercount collaborations within a single country that may also require travel, such as those between colleagues at US institutions that are on opposite coasts, and assume that both collaborators, rather than only one, are engaged in such travel. By using only published international collaboration to measure a scientist's mobility, the reported gender disparity is unlikely to accurately represent the actual mobility of male versus female scientists.

The book finishes with a chapter of recommendations and conclusions, which nicely summarizes many best practices for increasing inclusion of historically underrepresented groups in science. While none of the suggestions are groundbreaking, this section serves as a "quick start guide" for those who are just beginning to think about how to make science more inclusive for women and other underrepresented groups. This chapter would be an excellent resource for those who are introducing these ideas to advanced undergraduate or graduate students.

I believe that the strength of *Equity for Women in Science* rests in its ability to provide a succinct summary of key historical examples of women in science, its characterization of seven individual, but interrelated, measures for gauging gender parity, including the previously underappreciated area of contributorship, and its final summary of best practices for increasing inclusion across disciplines. While the observed trends suggest that more needs to be done to support women

in science, the limitations of the authors' bibliographic methodology hinder the specificity of their findings.

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Theology

DOI: https://doi.org/10.56315/PSCF9-24Wilkinson

CIRCLES AND THE CROSS: Cosmos, Consciousness, Christ, and the Human Place in Creation by Loren Wilkinson. Eugene, OR: Cascade Books, 2023. xvii + 354 pages. Paperback; $36.00. ISBN: 9781666746341.

This book invites the reader to share a great-hearted and generous journey through some profoundly important territory. I take its aim to be to show both how humanity has arrived at the distorted and potentially disastrous relationship we have with the non-human creation, and that Christian thought, framed through an emphasis on creation, incarnation, kenosis, and resurrection can form the basis for a just form of earthkeeping which is also a sharing in the new creation.

In Part I Wilkinson identifies consciousness as the great mystery to be puzzled over, together with the fact of the existence of the cosmos. Part II reviews different aspects of the practice of science—its pleasures, paradoxes, and pains. Part III traces tensions and ambiguities in how science has evolved through the Enlightenment and its interaction with Romanticism, then how that interaction gave rise to the environmental movement, paving the way for various forms of new religion, especially variants of pantheism. Part IV then takes up the theological task, emphasizing incarnation and kenosis. In a concluding Part V, Wilkinson stresses the importance of resurrection and new creation in shaping the Christian story and understanding the human vocation.

The book, then, makes a huge journey. It is the fruit of painstaking research and long reflection. But it is written in such an engaging style that the reader's attention need never flag. The journey is, moreover, leavened with personal reminiscences which show how grounded the author is in his own place (the Pacific Northwest), and how passionately involved he has been in the journey, taking with him many generations of students and conversation partners. It was, for instance, a delight to read that he had held dialogue with E.O. Wilson, whose reductionist views differed so radically from the author's own.

Wilkinson begins from reflections on circles, with their association with cyclic time and rhythms of being, from which there is no escape, and the Cross as a decisive interruption of time. He writes fascinatingly about the design of the Celtic cross, and notes how recent religious longings have wanted to recapture a sense of the rhythms of the earth. Arguably, the linearity of the Christian narrative, and its eschatological drive, make this recapture harder. I would like to have seen this circle-cross motif developed further, but it seemed to get rather lost as the book evolved.

The author's two great allies make a fascinating pair. The first is Iain McGilchrist, whose book *The Master and His Emissary* provides an increasingly influential model of how the two hemispheres of the brain operate differently, the left toward reductive problem-solving, the right toward wonder, imagination, and empathy. The second is the poet Gerard Manley Hopkins (with Wilkinson's knowledge of Romantic poets adding significantly to his analysis).

The author's conclusion will be congenial to most readers of this journal. Some of his history of science will be very familiar ground. I found the tracing of the voluntarism that catalyzed scientific enquiry back to Scotus and William of Ockham fascinating, though it must be of concern that neither of those premier historians of the rise of science, John Hedley Brooke and Peter Harrison, feature in the bibliography. And I felt that there was significant sleight-of-hand in simply associating the Enlightenment with reductive understandings of human beings and the world.

Theologically, Wilkinson's dominant motif is kenosis, which he maps back from Philippians 2 all the way into the heart of the Trinity (following von Balthasar), and forward into the necessary costs to some creatures that enable other creatures to flourish (following Holmes Rolston). I have criticized Rolston for invoking kenosis in the latter respect, since it seems to me to confuse voluntary self-giving with creatures' instinctive survival at the expense of others. Perhaps one of Wilkinson's examples, the Pacific salmon returning upriver to spawn, will make me start to think again. But neither Rolston nor Wilkinson clarify why it is that creation must be so costly to creatures and to God—it seems this is just the pattern that triune creation has to follow.

Wilkinson is very much influenced by the collection of essays *The Work of Love: Creation as Kenosis* edited by John Polkinghorne; I too love that book, but it is important to take note of the criticisms of kenosis, both from classical systematics and from feminism, offered by Sarah Coakley in the concluding essay. Karen Kilby's recent work is a significant sequel to this critique; however, a more comprehensive treatment is needed to address this.

The innovative theology of the book is developed in a fascinating section at the end of Part IV. Wilkinson moves us up a gear with his invocation of Heidegger's *Gelassenheit*, "releasement," or "letting be." It was a disappointment that Loren did not interact with Ruth Page's use of that term in *God and the Web of Creation*, but what he goes on to do is very striking. He uses Hopkins's terminology of "selving" from the sonnet "As Kingfishers Catch Fire" to develop the idea of transitive and intransitive selving. Creatures in general "selve" intransitively—to return to the poem, they "fling out" that "What I do is me, for that I came." But God, through what Hopkins called "the great sacrifice," selves transitively in a ceaseless and costly letting be. So far, so good, but then there is a yet bolder step, in suggesting that humans too are called to transitive selving. When our "gifts of reason, creativity, and imagination are directed to other creatures—not in order to use them, but to know, name and enhance *their* true selves … human selving can echo God's selving" (p. 299). This is (using the sestet of the same poem) the selving activity of "the just man" who "justices," using humans' unique gifts to nourish the selves of other creatures, and becomes "in God's eye … Christ," as Hopkins has it. (This extraordinary theological claim could be justified by appeal to the idea that the human being perfectly "justicing" is acting as the authentic image of God in the world. The Pauline letters identify Christ as this image [Col. 1:15, 2 Cor. 4:4]. So, the process by which humans can be "conformed to the image of [God's] Son" [Rom. 8:29] and be "transformed into the same image" [2 Cor. 3:18] is seen as complete in the justicing human. But Wilkinson does not offer this groundwork—he is content to work from the poem itself.)

Here I would suggest that Heidegger's term *Gelassenheit* is very helpful, because it addresses the vital question of what it is that humans can do for the non-human creation. We can let it be, in ways that draw on all our gifts, very much including the scientific, and all our virtues—vitally those of wonder, love and hope. This hope is underpinned by resurrection, as Wilkinson goes on to conclude. I found this formulation both original and compelling. It begs many questions, but I hope it will stimulate much thought, as such a rich offering deserves to do.

There were occasional errors—for instance, Laplace should be "Pierre-Simon" not "Simon"—but the book is attractively presented and well indexed. It will introduce the general Christian reader to an intriguing vein of reflection on our place in creation and new creation, and students to important aspects of the science-religion debate. The ecotheologian will find plenty to chew on in Part IV. Above all, I am left with the sense of a profound gift generously given, by which we are all left in Loren Wilkinson's debt.

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Letter

On Makous and Biblical Longevities

In the most recent past issue of *PSCF*, Walter Makous ("Exponential Decay of Biblical Longevities," *PSCF* 76, no. 1 [2024]: 30–34) presented an intriguing theory that attempts to explain the decay in the lengths of patriarchal longevities from Shem to Moses reported in the genealogy of Genesis chapter 11.[1] Makous previously argued that the lifetimes of these patriarchs were not fabricated or "manufactured" numbers, based on an analysis of the first digit in each longevity figure.[2] In a dialogue with Walter Huebner that followed publication of the earlier paper, Makous argued that his analysis did not say that the numbers were accurately transmitted, but "simply provides evidence against fabrication as one particular source of inaccuracy."[3] However, in his new analysis, Makous has gone considerably further, by attempting to validate the patriarchal lifetimes as real numbers, with the conclusion that this "somewhat strengthens one's confidence in the truth of the biblical longevities."[4]

However, other evidence suggests that the ages in the patriarchal genealogies are not *meant* to be taken literally. If that is the case, a belief in the "truth of the biblical longevities" reported in the genealogies of Genesis may lead to the erroneous dating of historical events described in the Bible, and therefore may actually undermine the historicity of the biblical record.

Some of these issues were raised in an earlier paper by Carol Hill, which Makous did not properly take account of in either of his own papers. For example, Hill analyzed both of the major genealogies in Genesis (Adam to Noah and Shem to Abram), which list the age of each patriarch at the birth of their first son, their remaining years and their total lifespan, comprising a total of sixty age values.[5] Within these sixty values, the final digit in each age never ends in 1 or 6. If these final digits were randomly distributed, as would be expected for true age information, Hill calculated a one in half-a-million chance that these values would result.

In contrast, Makous analyzed the first digit in each of these ages, with the suggestion that the first, second,

third, or any other digit is essentially equivalent. However, this is not the case at all. For example, no-one would expect the first digit of modern longevities to be random, since the "standard" human lifetime is 70 years. On the other hand, we might well expect the final digit of a modern longevity to be random, because it falls within the realm of what we would call "noise." So, the argument in Makous's original paper was not entirely valid, but on the other hand it made very limited claims. In contrast, the new paper makes a much more ambitious proposal.

The essence of the new argument is that the fall in longevities from Shem to Abraham was caused by intermittent unions with the short-lived "daughters of Cain." The assumption is that offspring from a union of two people with vastly different longevities will be a simple average of the two parents. However, the scientific basis for suggesting that the offspring of a marriage will have a longevity almost exactly half-way between a miraculously long-lived father and a mother with normal longevity is extremely weak. There is no known mechanism for consistently averaging two extremely different longevities in the offspring.

An even larger mechanistic shortcoming of the model is that the wives of the offspring of mixed-age unions are required to vary in lockstep with their husbands. This could realistically be satisfied (within the parameters of the model) only if the wives were all half-sisters of their husbands. Otherwise, such a coincidence is extremely unlikely. Hence, I suggest that this model is really a numerical contrivance rather than one based in biological reality. But beyond that, I suggest that it is necessary for our understanding of how Genesis fits into ancient history that the genealogy of Shem *not* be regarded as chronologically accurate.[6]

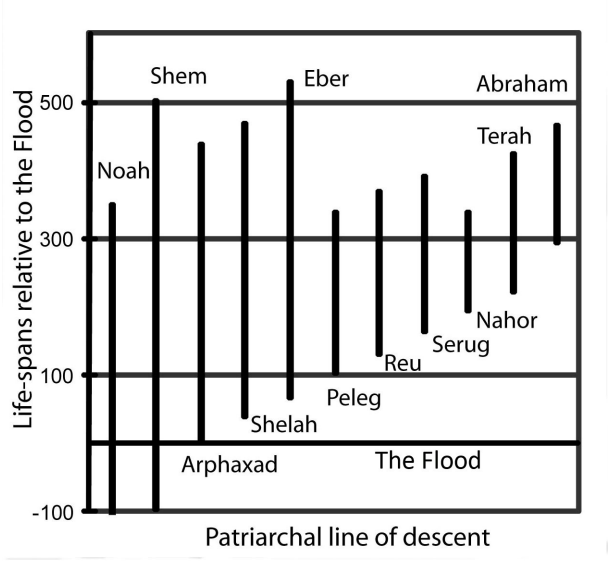

Figure 1. Graphical illustration of the lifetimes of the post-diluvian patriarchs relative to Noah's Flood, according to the Masoretic Text.

Patriarchal lifetimes are not the only component in the genealogy of Genesis chapter 11. The other component is the age of each patriarch at the birth of his first son. Together, these two values allow the individual lifespans to be linked together into an apparent chronology (fig. 1). This is the chronology that was used by Bishop Ussher to date the creation to 4004 BC, and also Noah's Flood to 2350 BC.[7] However, the date of 2350 BC is very late in Middle Eastern civilization, and there is no evidence whatever for a great flood at this time, even of a regional extent. In addition, the genealogy in figure 1 leads to the claim that Noah was still alive when Abraham was born, and Shem actually outlived Abraham, which seems at least unlikely.

These observations are based on the genealogical information in the Hebrew Masoretic text, whereas the Greek Septuagint version of the Old Testament adds 100 years to the date when most of these patriarchs fathered their first son. This has the effect of stretching out the genealogy so that Shem dies before Abraham is born. It also increases the date of Noah's Flood to around 3300 BC. However, this date is at the height of Sumerian civilization in Mesopotamia, when monumental temple architecture was being built at the city of Uruk on a scale similar to the Greek Parthenon nearly 3,000 years later.[8] Since the temple at Uruk was built beside the River Euphrates near the center of the plain of Mesopotamia, it is unbelievable that there could be no archaeological evidence for Noah's Flood if it happened at that time.

New Testament quotes from the Old Testament are based on both the Hebrew and the Greek texts, with a majority from the Greek text.[9] This shows that both versions were regarded as the inspired Word of God, despite there being two different versions of the genealogy of Shem with these differences in the ages of the patriarchs when their sons were born. This suggests that such genealogies are not intended to provide chronological information.

In fact, scientific evidence gives a most likely date for Noah's Flood in the Neolithic period, around 5600 BC. This date is supported by several distinct lines of evidence. Firstly, it is before the Ubaid period, when trade networks spanning the Middle East were clearly established.[10] Only before this period could flooding of the plain of Mesopotamia realistically have been identified as a flood that covered the entire earth. Secondly, a flood in the Neolithic period is required for the biblical belief (Genesis chapter 10) that all Middle Eastern peoples and languages originated from Noah's sons after the Flood.[11]

A flood in the historical period could not reasonably have occurred before the origins of all of these peoples and languages. Thirdly, the sixth millennium BC is the last period when very wet climatic conditions occurred in the Fertile Crescent, when massive flooding of the plain of Mesopotamia would have been most likely.[12]

If Noah's Flood occurred around 5600 BC, this would be about 3,500 years before the time of Abraham, which implies more than 100 generations between them, rather than the ten generations in the genealogy of Shem. This supports the idea that this genealogy is meant to be schematic, and not to be taken literally as a record of real ages. Instead, this genealogy has quite a different function. Notwithstanding the claim of Joshua 24:2 that Abraham's ancestors were idolaters, it asserts that Abraham was a spiritual descendant of Noah, and therefore that the faith of Noah was passed down to Abraham within Mesopotamian culture, however much this may have been obscured.

This continuity of faith by the patriarchs was what the Reformers Luther and Calvin took from Genesis 11.[13] They believed these verses literally, but they also lived in a pre-scientific world where the sun was believed to orbit the earth, and the moon was believed to be literally on fire.[14] In the twenty-first century, our challenge is to accept the theological implications of the "golden thread" of divine revelation to humankind, while at the same time using scientific evidence to accurately chart ancient history. Paradoxically, a belief in the real historicity of Genesis requires that the genealogies of Genesis not be taken literally.

Notes

[1]Walter Makous, "Exponential Decay of Biblical Longevities," *Perspectives on Science & Christian Faith* 76, no. 1 (2024): 30–34.

[2]Walter Makous, "Biblical Longevities: Empirical Data or Fabricated Numbers?," *Perspectives on Science and Christian Faith* 63, no. 2 (2011): 117–30, https://www.asa3.org/ASA/PSCF/2011/PSCF6-11Makous.pdf.

[3]Walter Makous, "Biblical Longevities: Reply to Huebner," *Perspectives on Science and Christian Faith* 64, no. 2 (2012): 143, https://www.asa3.org/ASA/PSCF/2012/PSCF6-12Makous.pdf.

[4]Makous, "Exponential Decay of Biblical Longevities," 33.

[5]Carol A. Hill, "Making Sense of the Numbers of Genesis," *Perspectives on Science and Christian Faith* 55, no. 4 (2003): 239–51, https://www.asa3.org/ASA/PSCF/2003/PSCF12-03Hill.pdf.

[6]Ronald L. Numbers, "'The Most Important Biblical Discovery of Our Time': William Henry Green and the Demise of Ussher's Chronology," *Church History* 69, no. 2 (2000): 257–76, https://doi.org/10.2307/3169579.

[7]James Barr, "Why the World Was Created in 4004 BC: Archbishop Ussher and Biblical Chronology," *Bulletin of the John Rylands Library* 67, no. 2 (1985): 575–608, https://www.escholar.manchester.ac.uk/api/datastream?publicationPid=uk-ac-man-scw:1m1647&datastreamId=POST-PEER-REVIEW-PUBLISHERS-DOCUMENT.PDF.

[8]Charles A. Burney, *From Village to Empire: An Introduction to Near Eastern Archaeology* (New York: Phaidon Press, 1977), 59.

[9]Crawford H. Toy, *Quotations in the New Testament* (New York: Charles Scribner's Sons, 1884), ix.

[10]Robert A. Carter, "Globalising Interactions in the Arabian Neolithic and the 'Ubaid,'" in *Globalization in Prehistory*, ed. Nicole Boivin and Michael D. Frachetti (New York: Cambridge University Press, 2018), 43–79.

[11]Andrew Kitchen et al., "Bayesian Phylogenetic Analysis of Semitic Languages Identifies an Early Bronze Age Origin of Semitic in the Near East," *Proceedings of the Royal Society B: Biological Sciences* 276, no. 1668 (2009): 2703–10, https://doi.org/10.1098/rspb.2009.0408.

[12]Miryam Bar-Matthews et al., "The Eastern Mediterranean Paleoclimate as a Reflection of Regional Events: Soreq Cave, Israel," *Earth and Planetary Science Letters* 166, no. 1-2 (1999): 85–95, https://doi.org/10.1016/S0012-821X(98)00275-1.

[13]John Calvin, *Commentaries on the First Book of Moses* (1554), *Calvin's Commentaries*, vol 1, trans. John King (Calvin Translation Society, 1847; reprint, Grand Rapids, MI: Baker Book House, 1984), 334.

[14]Calvin, *Commentaries on the First Book of Moses,* 46.

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DOI: https://doi.org/10.56315/PSCF9-24Complete

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