Stephen M. Contakes

Call for Papers

Chemistry to the Glory of God?

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Readers are encouraged to take up one of the insights or questions in the following invitation essay and its extensive 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. These can be sent as an attachment to scontakes@westmont.edu. An abstract should be included in the text of the email. The best essays will go on to peer review and the potential for publication in a chemistry theme issue of *Perspectives on Science and Christian Faith,* or independently in a variety issue of *PSCF.*

The lead editorial in the December 2021 issue of *PSCF* outlines what the journal looks for in the articles we publish. For best consideration for inclusion in the theme issue, manuscripts should be received electronically before February 28, 2023.

Looking forward to learning from your contributions,

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

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Chemistry is sometimes defined as the study of matter and its changes, which, in a certain sense, means the study of everything material since all physical objects and materials, including ourselves, are made of chemicals. More precisely, chemistry is the study of matter and its changes at the level of atoms, molecules, and ions, composed of their next-lower-level components, protons, neutrons, and electrons. In this sense, chemistry is both reductionist and antireductionist; it seeks to reduce things to the atomic and molecular level but no more. This way of thinking about matter allows chemists to reason both "bottom up"—that is, starting from atoms and molecules—and "top-down"—that is, figure out things about atoms and molecules starting from what a larger system is like. To do this well, chemists translate the insights of physics into models of atoms and molecules that are useful for solving chemical problems, of which there are many in the biosciences, geosciences, and numerous branches of engineering. Because it links so many sciences together in this way, chemistry is called the central science.[1] Chemistry is also sometimes called an impure science, since chemists do not only seek to understand matter but also to manipulate it for useful ends.[2] In this, it has been remarkably successful. Because of its impact on agriculture, industry, medicine, and many other aspects of human culture, chemistry is also the workhorse science of what has sometimes been called the chemical age.[3]

Given chemistry's outsized impact, it would be reasonable to expect chemistry to loom large in discussions about science and Christianity. Nevertheless, with the exception of conversations involving origin of life and evolutionary biochemistry, the chemical sciences have played only a peripheral role. That such a societally influential and theologically relevant discipline has received so little attention is a topic worthy of careful consideration.

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What might the vast gap between chemistry's importance to society and Christian thinking indicate? Does it reflect sober judgment or inadequate views of science, Christianity, and the relationship between the two? Has the science-Christianity dialogue been well served by focusing on fundamental physics, biology, and neuroscience to the exclusion of chemistry? Or, putting things more positively, might anything be gained by bringing more chemistry into the conversation?

This essay is a call to explore how the chemical sciences might contribute to the science-Christianity conversation. Specifically, it solicits papers for a theme issue addressing the chemical enterprise and Christianity. To encourage an appropriately broad set of perspectives, the chemical sciences envisioned in this call for papers encompasses biochemistry, chemical engineering, chemistry, geochemistry, materials science, molecular pharmacology, polymer science, engineering, and other disciplines which employ atomic-molecular views of matter to comprehend and transform the material world. Similarly, since the relationship between chemistry and faith does not occur only at the level of conscious thought, the Christian faith envisioned in this call for papers includes background assumptions and clearly stated tenets of faith; it is intellectual, affective, and effective; and it is present-focused and resurrection-looking. So, contributions may address how any aspect of the chemical enterprise relates to Christian thought, practices, affections, spirituality, or any other aspect of Christianity, broadly defined.

As a help to potential respondents, the remainder of this essay will seek to sketch a selection of opportunities and challenges raised by chemistry.[4] Some of these are related to chemistry's understanding of matter and technologically promising avenues of chemical research such as solar energy conversion, green chemistry and engineering, gene editing, or efforts to develop new materials, therapies, diagnostic tools, and other products. Equally important, though, are issues associated with what chemists do and humankind's use of chemicals, things such as risk, responsibility, and chemistry's role in shaping both society and Earth's environment.

To get the conversation started I will point out a few reasons why Christians should care about the chemical sciences. Here I will try to explain what chemistry is, what chemists do, and how Christians have thought about the chemical sciences in the past, as well as to outline some of the theological and moral terrain that Christians might have to navigate. The idea is to raise questions and suggest perspectives that respondents might develop or challenge. Periodically, I will also note thorny issues or contributions that might be helpful. Other types of contributions would also be welcome.

God Values the Matter That Chemistry Studies

There is a need for theologies of chemistry that are robust enough to address the opportunities and challenges associated with chemicals.[5] In the interim, I suggest that the theological context of chemistry involves what matter is, what humans are, and what humans are called to do. Of these, Christianity teaches that God made, values, and has a purpose for matter. The preeminent example of this is the Incarnation, although throughout the scriptures matter is presented as a sovereign creation of the triune God, subject to God's care, a theater for God's encounter with humankind, a locus of right worship and malformed worship (including in our bodies), good (rather than something we are called to escape from), and something for which God intends fruitfulness. In the Genesis creation account alone, God is portrayed as ordering an originally formless and void creation, which, at times, responds by bringing forth new structures in the form of things such as plants and various creatures. This suggests a creation under God's care and control, developing its God-endowed potentialities and experiencing fruitfulness as it responds to the call of its maker, bringing forth a good, well-functioning creation.[6]

Christianity also values how we live out our embodied existence in a material world. Again, in the Genesis account, God's final creative act is presented as involving special intimacy (the breath of God) to give God's own "image" and "likeness" (*imago Dei*). Although a number of implications of this *imago Dei* have been proposed, the passage's immediate context suggests that humans are created co-creators[7]—that is, they are to reflect and represent a creative God who lovingly works with creation to order it, in part by bringing out matter's potentialities in ways that help make creation fruitful and function properly.[8]

Christians Are Called to Use Matter for God's Glory

The created co-creator concept would seem to validate the legitimacy of chemistry; chemists reflect something of God as they work with creation's potentialities to order matter in new ways.[9] The so-called culture,[10] stewardship,[11] and labor mandates[12] of the Genesis creation and Fall accounts (along with other passages) further develop what humans are generally called to do, how they are called to do it, and why. Humans are called to reflect God's care for creation as they fill up and lovingly govern the earth. Nevertheless, theirs is a delegated government. Humans are not to rule over creation recklessly or exploitatively as free agents. Rather, they are stewards called to govern in ways that recognize creation as God's and for God's glory.

The primeval history of Genesis 1–11 indicates that both our government of creation and the potentialities we are called to develop involve technology-infused culture building—with agriculture, animal husbandry, city building, metallurgy, and music mentioned directly.[13] Nevertheless, this does not mean that technology is presented as wholly salutary or unproblematic. It is alternatively associated with sin (for example, Adam and Eve's fig leaves, Noah's wine) and God's gracious provision for humankind (God's coat of animal skins, Noah's ark). That arts such as metallurgy are presented as derived from the ungodly Cainite line problematizes the possibility of achieving shalom through technology alone. This point is forcefully brought home in the development of novel brickmaking materials as an occasion for the rebellious building of the tower of Babel.[14] Outside of the primeval history, the biblical narrative repeats this pattern of matter as a potential locus of idolatry, worship, and God's provision for humanity through accounts such as the de-bittering of the water at Marah,[15] and the making of the golden calf, the tabernacle, and the bronze serpent until God's ultimate verdict is reached. In the Incarnation, Christ embodies, works with, and transforms matter in ways that demonstrate God's intention for human stewardship of the material world.

Thus, a distinctly Christian approach to chemistry will recognize the church's role in demonstrating the self-emptying and reconciling love of Christ to all creation as embodied materially in Christ's earthly ministry, death, and bodily resurrection and proclaimed by believers both verbally and through such activities as water baptism, the breaking of bread, and material acts of love. Within this context, distinctly Christian approaches to chemistry involve pursuing Christlike relationships of reconciliation, flourishing, and shalom throughout creation.[16] To do this well, it can be helpful to understand how creation works at the atomic and molecular level. This is a powerful reason for Christians to pursue the study and practice of chemistry.

In this respect, Christians should care about chemistry for the insights it brings into the nature of the material cosmos. Through modern chemical theories and a host of spectroscopic, crystallographic, microscopic, and wet chemical methods, chemists have gained a remarkably detailed understanding of what matter is like at the molecular level. This is true about molecules individually and about how molecules work in concert with one another as part of larger systems. These larger systems do not involve only things such as rocks, minerals, liquids, and gases, or even a chemical reaction taking place in a single flask. Chemistry works in concert with disciplines such as astronomy, engineering, and the geological, biological, and materials sciences to explain how everything from individual bacterial cells to entire planets work. Therefore, chemistry can provide insight into God's wisdom and power in creation at multiple levels.[17]

Further, chemistry remains a vibrant field of work, pregnant with possibilities for us to grow in our understanding of atoms, molecules, and how they work together.[18] With chemistry's success has come a growing awareness that only a small portion of the possible structures and reactions available to molecules has been explored. There is also a need to apply chemical theories and tools to ever-larger and more-complex living, environmental, supramolecular, nanoscale, and bulk materials and other systems, as well as to problems in molecular biology, biotechnology, and medicine, including rational drug design.

Chemistry Discloses God's Wisdom and Power in Creation

Chemistry does not seek to answer theological questions. Nevertheless, chemistry's insights into the atomic- and molecular-level workings of nature contribute to natural revelation, that is, what can be known about God through nature. In addition,

chemistry's picture of atoms and molecules, working in accordance with the principles of electromagnetism, quantum mechanics, and thermodynamics, is part of the cultural toolkit contemporary people use to think theologically. Chemistry influences how Christians think about God creating and acting through creation, how we encounter God in creation, what humans are, and how to live in accordance with what Christians are called to do. In this respect, chemistry helps inform conversations about issues such as origins, divine action, miracles, natural evil, free will, and similar topics, even when it is not a conscious lens through which these concerns are viewed. Equally, if not more importantly, chemistry helps shape how we think about things such as Jesus's Incarnation, death, and resurrection; the mission, calling, and worship of the church; our own hoped for bodily resurrection; and the life of the world to come.

The question of exactly how chemical knowledge currently affects Christian thinking has not been rigorously explored. Nevertheless, there are several clear indications of science's influence in this area. Unlike ancient and medieval believers, Christians today find the idea that matter is made of atoms theologically uncontroversial[19] and use various hermeneutical moves to interpret scriptural passages that employ classical matter concepts. Examples include passages that speak of the world being formed of water, and of resurrection in terms of "earthly" and "heavenly" bodies. It is also clear that contemporary physics has had some influence on Protestant views of baptism and other bodily aspects of Christian living and worship.[20]

Nevertheless, the best-documented cases of natural philosophy influencing the articulation of Christian doctrine do not involve modern chemistry but the role of Aristotelian, stoic, and other classical ideas about matter in late-Medieval Europe. During this period, classical matter theories were used to explain seemingly miraculous events, distinguish between legitimate miracles and diabolical activity, and explain the then-recently ratified doctrine of transubstantiation.[21] Particularly notable was Thomas Aquinas's effort to use Aristotelian matter theory to reconcile the Roman Catholic doctrine of Eucharistic real presence. For Aquinas, the Eucharistic bread and wine could transform into the body and blood of Christ while remaining materially indistinct from ordinary bread and wine because the change occurred at the level of Aristotelian substance, distinguishing what something is, from what it appears to be.[22] The medieval and early modern periods also witnessed the development of what have been called prophetic or visionary alchemical traditions in which alchemical transformations came to be viewed as parallel to Christian truths.[23] Eventually, early-modern alchemists such as Jan Baptist van Helmont[24] would seek divine illumination through the practice of chemistry, a quest echoed weakly in Robert Boyle's understanding of chemistry as priestly service in the temple of nature.[25]

The most prominent influence of chemistry on recent Christian thinking involves natural theology arguments intended to address materialist conceptions of reality.[26] The use of chemistry in this fashion can be traced to one of modern chemistry's principal founders, Robert Boyle.[27] Boyle not only looked to chemistry as a source of natural revelation, but he and contemporaries such as John Ray also advanced the idea that nature demonstrates God's existence and power.[28] Partly through the influence of annual lectures, financed by Boyle himself, Christian thinkers began to construct increasingly powerful and sophisticated arguments advocating for this "physico-theology." At first, these mainly employed examples from physics and biology, although since the nineteenth century, they began to include examples from chemistry, biochemistry, and geochemistry, too.[29] Then as now, they were nominally aimed at convincing unbelievers, but they also served to encourage the faithful.[30]

The flexibility of Boyle's natural theology program meant that it could be used to support a variety of orthodox and heterodox theological views, including deism among those who were willing to reject or reinterpret revealed theology. Interestingly, Darwin's problematizing of the biological design-based natural theology arguments that had become common by the early nineteenth century, contributed somewhat to a resurgence in chemistry-based design arguments. These often focused on various aspects of biogeochemistry (often with a special focus on water) and are somewhat akin to modern arguments that point to anthropic coincidences, although at least one also relied on methodological parallels between theology and science.[31] From the nineteenth century until today, they have been used to support a variety

of theistic antievolutionary, theistic evolutionary, and naturalistic positions.[32]

The late-twentieth century also saw the rise of various "creation science" and intelligent design movement arguments that broke from the tradition of offering well-attested science as evidence for God's wisdom. The most notable of these involved the efforts of the young earth creationist biochemist Duane Gish and the intelligent design movement biochemist Michael Behe, who argued that chemistry challenged accepted evolutionary and origin-of-life science.[33] Among these, Gish's use of chemistry was somewhat limited by his tendency to "gallop" through a range of arguments, most of which had little to do with chemistry.[34] Behe[35] (and to a lesser extent, other intelligent design movement biochemists such as Michael Denton[36]), however, offered elaborate arguments purporting to demonstrate that structural biochemistry contra-indicated naturalistic evolutionary accounts of life's development. So far their proposals have yet to find acceptance among the scientific community, even after extensive criticism and debate.

Papers addressing chemistry-based natural theology arguments could contribute productively to a theme issue devoted to chemistry and faith in several ways. New chemistry-based natural theology proposals would be welcome, as would critical analyses of existing proposals: for example, those in the recent intelligent design movement and old earth creationist literature;[37] Alister McGrath's argument that origin-of-life chemistry aligns with Augustinian ideas of creation as containing potential for development (logical seeds);[38] and arguments that the properties of atoms and molecules are echoes of the Trinity in nature.[39] Two approaches, in particular, have received surprisingly little attention. The first involves alignment between the chemistry's picture of probabilistically moving[40] atoms, molecules, and ions reacting and self-assembling to give larger structures and biblical themes of creation involving the ordering of chaos.[41] This theme (sans its probabilistic aspect) was prominent among the followers of Paracelsus, who even interpreted Genesis in terms of God acting as a synthetic chemist to order matter in creation.[42] The second approach involves natural theologies based on the existence of beauty in nature, which could align with contemporary chemists' propensity to talk about beautiful molecules, elegant syntheses, and otherwise to use aesthetic language. Some of the necessary groundwork for a chemical natural theology of beauty has been done by Timothy Weatherstone,[43] although little has been done to follow up on his proposal, even by way of critical analysis. Finally, there is also a need for reviews of the relevant background literature at a level suitable for a general science and faith audience. Tutorial reviews[44] that present the state of the origin of life, evolutionary biochemistry, geochemistry, supramolecular chemistry, and similar fields relevant to these natural theologies might be particularly valuable, as would reviews which summarize historical and social science analyses of chemistry-based natural theologies.

Chemistry Is an Opportunity to Live and Love Christianly

It is difficult to overestimate chemistry's impact on human welfare. Chemical technologies contribute to human health and welfare in so many ways[45] that a recent *Bloomberg Businessweek* editorial declared "we are well past the Stone Age, the Bronze Age, and the Iron Age, and into the Everything Age, because almost every entry on the periodic table is being put to some kind of use in today's economy."[46] According to the American Chemistry Council (a chemical manufacturers' association), over 96% of manufactured products are "directly touched by the business of chemistry."[47] Without Fritz Haber and Carl Bosch's development of industrial nitrogen fixation, it would be impossible to feed everyone alive today.[48] The US chemical industry alone[49] employs approximately 529,000 workers, and almost half of US chemists and materials scientists (49%) are involved in either manufacturing (33%), testing (11%), or administrative services such as waste management (4%), a total over three times larger than the number involved in basic research (14%).[50] Worldwide, the chemical industry consumes approximately 6.6% of the world's energy[51] while its direct products and precursors—that is, chemicals, minerals, and petroleum—together account for 21.4% of world trade.[52]

Historically, the largest uses of chemicals have been associated with agriculture (sulfuric acid, nitrogen, ammonia, nitrates, urea, and phosphoric acid), steel manufacture (through the oxygen used in smelting), polymers, detergents, dyestuffs, construction (cements), and chemicals used to make other chemicals (hydrogen, chlor-alkali products, etc.).[53] In

addition, chemical know-how is important for the production of pharmaceuticals, structural materials such as cement and concrete, protective coatings such as paint, cosmetic chemicals and disinfectants, pesticides and herbicides, fuels such as coal and petroleum, plastics,[54] and many other things, including virtually every part of the electronic devices which characterize contemporary life. Chemistry also contributes to human and environmental welfare by means of the application of electrochemical sensors, instruments, and wet chemical analysis to medicine, agriculture, industry, public health, and safety. Chemical scientists have revolutionized how we monitor human and animal health, track pollutants, ensure the safety and efficacy of numerous products, solve crimes, and detect medical and environmental problems wherever they occur.

That such an influential enterprise presents numerous opportunities for Christian service has long been recognized, despite Tertullian's early objection to synthetic dyes and recurring fears that (al)chemists were inappropriately altering nature.[55] Alchemy was a recognized pursuit in Byzantine and Latin Christendom, the latter especially after the recovery of Greco-Roman learning in the high Middle Ages. Many monks pursued alchemy,[56] and it proved a fit object of discussion for such luminaries as Albert the Great,[57] Robert Grosseteste,[58] and Roger Bacon.[59] Bacon even advocated alchemy as a promising source of wealth and human longevity both of which he considered important for the welfare of Christian Europe.[60] Later, the protestant reformer Martin Luther, who saw ordinary work as a Christian calling,[61] expressed appreciation for alchemy in part "for the profits it brings in melting metals, in decocting, preparing, extracting, and distilling herbs, roots."[62] For the early industrial chemist Johan Glauber, chemistry was a way to fulfil the golden rule, specifically by seeking others' welfare and prosperity.[63] Recently, the Roman Catholic Pontiff listed the chemical industry among the technological advances produced by "God-Given human creativity" about which "it is right to rejoice" and "be excited by the immense possibilities which they continue to open up."[64]

Today, chemists have a wealth of opportunities to follow Glauber as virtually every aspect of the chemical enterprise can be used to promote human welfare in some fashion. Nevertheless, as this issue has received little attention in the recent literature,[65] there is a pressing need for articles that explore how Christians might promote human welfare through chemistry, both in terms of providing general frameworks and an analysis of particular opportunities.

Early Christian medicinal chemists such as Paracelsus and Jan Baptiste van Helmont viewed their work as a holy calling; Paracelsus even considered Christlike love the "bedrock of medicine."[66] So, articles that explore chemists' efforts to promote human health through new pharmaceuticals and other therapies (including the recently developed mRNA vaccines), clinical analyses, and investigations into biochemical pathways of disease, would be welcomed, as would contributions addressing the role of chemistry in advancing public health through the monitoring of air, water, food, and consumer products.[67] Here there is precedent in Michael Faraday's efforts to improve water quality in the Thames, which seem congruent with his theology. For Faraday, since humanity was important in God's plan, science should be used for human betterment.[68] A more complicated example involves the chemist-physician Harvey Washington Wiley's efforts to curtail the use of toxic additives in the food and drug industry, although the fruits of his efforts are more controversial and the relationship between his mature religious beliefs and chemical work is less well explored.[69]

Chemistry is an important science for environmental stewardship. In addition to the traditional environmental monitoring and modelling work, chemists are addressing the need for a more sustainable and environmentally friendly chemical industry[70] through research and development work in green chemistry, renewable energy, carbon capture and storage, and similar fields. The 2015 Papal Encyclical *Laudato Si'*[71] addresses specific problems associated with chemical pollution and the use of fossil fuels, while the Greek Orthodox Church called on both researchers and governments to develop technologies aimed at alleviating environmental and agricultural problems.[72] There has also been considerable theological reflection on geoengineering (which includes carbon capture and storage) as an effort to deliberately alter climate (as opposed to incidentally affecting climate through pollution).[73] There has been much platitudinizing about green chemistry as an opportunity for Christians in chemistry to live out their faith, along with a few substantive articles arguing that the twelve principles of green chemistry and

engineering[74] are broadly congruent with Judeo-Christian productivity stewardship approaches to the environment.[75] Otherwise little effort has been made to explore how Christians might care for creation through green chemistry, despite long-standing Christian approaches to creation care[76] and development.[77]

Chemists also have opportunities to promote societal justice, either indirectly through caring for the environment or directly by seeking to advance human economic wellbeing.[78] There is a need for contributions that examine some of the recently identified opportunities[79] in the context of Christian teachings.[80] There is also a need to address the disproportionate harms that low-income communities and people of color experience[81] through fossil fuel burning,[82] chemical manufacture,[83] pesticide exposure,[84] and personal care product endocrine system disruptor exposure.[85] As the value of technological know-how[86] and Christian engagement in addressing chemistry-related issues of social justice are both well documented,[87] there is a particular need for contributions that suggest concrete ways in which Christians might leverage chemistry's ability to help address these issues.

Christians should also care about how chemical technologies advance or impede justice globally. Chemistry provides enormous opportunities for Christians in the sciences to improve human flourishing on a global scale. Through the development of chemical fertilizers, essential medicines, refined fuels, hygienic plastic objects, inexpensive fabrics, colorful dyes, and other medical, dental, energy, and commercial technologies, chemistry has done much to bring wealth and wellness to communities worldwide. Christians in chemistry can contribute to these efforts as well as address some of the ways chemistry's benefits and harms have been distributed unequally and unfairly. These include how chemical products have not always been made available to the communities that most need them[88] and how the harms of chemistry sometimes fall unevenly on the poor.[89]

Even when there is an effort to meet the needs of developing or marginalized communities, injustices can occur when the actual needs and contexts of the recipients are not thoroughly considered. In the 1986 Bhopal disaster, several thousand poor squatters were killed by the unimpeded release of toxic methyl isocyanate gas from a pesticide precursor plant that was built by Union Carbide to support Indian agriculture. Although both the cause and impacts of the disaster have been disputed, a failure to consider how North American plant design and operations principles might apply in an Indian context appears a contributing factor.[90] A more mundane but insidious example involves the increased toxin exposure that results when chemical technologies are transferred to developing nations without adequately addressing issues of pollution control and environmental monitoring.[91]

It is also likely that there are disparities in chemical research and development funding similar to the 10/90 gap, whereby only 10% of disease research funding is directed toward the diseases that most affect 90% of the world.[92] To my knowledge, none of these issues has been addressed in the science and faith literature. Perhaps the recent application of Roman Catholic social teachings to the 10/90 gap might provide a model for respondents to consider.[93]

Chemistry contributes to corrective justice through forensic chemists' everyday analysis of crime lab samples and analytical methods, such as DNA sequencing methods that allow for the high-fidelity identification and exoneration of suspects. Through these, chemists help keep people safe, and they advance or impede the conceptions of retributive and restorative justice embodied in legal systems. This work is extremely morally demanding, with bachelor degree-level forensic chemists placed in an "adversarial, crime-fighting culture" in which they "are tempted, many times in their career," to data fudging and fabrication.[94] Contributors might address how the church can support those engaged in forensic work. However, given the role played by reckless analytical practices and lax oversight in the Patricia Stallings and Annie Dookhan scandals,[95] contributors could also consider how Christians might promote more rigorous, truth-oriented, and humane standards in the forensic chemistry field.

Christians can also contribute to cultures which promote justice and equity within the chemical enterprise itself. This is particularly true with respect to longstanding issues associated with chemistry's self-image as the "marines of the sciences," which has been used to justify "weed-out" introductory

chemistry courses and academic research cultures that are so grueling, exclusive, exploitative, and otherwise psychologically and personally costly as to drive people from the profession.[96]

Any assessment of chemistry's potential to promote shalom should account for the reality of human fallibility and sin. The twentieth century presents clear cases of chemists and the chemical industry acting to advance parochial self-interest as even the best-intentioned efforts can go awry through chemists' inability to foresee unintended consequences or control how their work is used. Between excitement over the potential utility of new discoveries and the need for funding,[97] there can be a tendency to make overinflated claims. For instance, after nanotechnology was touted as a way to alleviate poverty and injustice, more sober analysts pointed out that it would be more readily available to the wealthy than to the medically, economically, and militarily vulnerable.[98]

Chemistry Is an Opportunity to Develop Appropriate Theologies of Risk

The realization of the intellectual and practical benefits of chemistry requires the stewardship of massive human, financial, and other resources as well as the management of risks. To do this well requires a great deal of discernment among the individual chemists, research teams, corporations, and governmental agencies involved in the discovery, development, manufacture, transport, storage, use, regulation, and monitoring of chemical technologies. So while contributors might address publication ethics and other professional norms,[99] it is perhaps even more vital to address the social responsibility of chemists and the consequences of public policy involving the risks of chemistry.[100] Although these present opportunities for Christian prophetic witness, many otherwise insightful writers have either avoided chemical use entirely, misrepresented the chemistry involved, or offered the sort of ill-informed blanket condemnation that is likely to alienate those who would most benefit from their message.[101] Consequently there is a need for both original chemically and theologically informed analyses of the social and ethical dimensions of chemistry and critical analyses that correct or strengthen existing analyses. A recent survey of the climate impacts of human energy use might serve as a useful model in this regard.[102]

The effective stewardship of chemistry requires the management of risks. That chemistry involves risk is powerfully illustrated by the chemical disasters of the twentieth century, which featured several instances in which a miracle chemical was later found to be an environmental disaster. Of these DDT is the best known. Originally lauded for its role in the eradication of disease, it was used carelessly for nearly 20 years and banned only after Rachel Carson highlighted its deleterious environmental impacts.[103] Chlorofluorocarbon refrigerants experienced a similar fate: until they were found to be responsible for the Antarctic ozone hole, they were hailed as safe replacements for earlier toxic refrigerants.

There is also a need for theologies of risk that address the range of concerns and cases articulated in the recent ethics of chemistry[104] and chemical risk-management fields.[105] One way forward might be to develop Gregerson's argument that Jesus's two parables of the talents and grain of wheat support an ethics of risk-taking.[106] However, the simple application of this principle to chemical technology would seem to be at odds with the broader ethic implied by passages such as the Levitical law of the goring ox,[107] the book of Proverbs' commending of risk avoidance,[108] Jesus's enjoinder toward spiritual quality assurance in calling us to "watch and pray" lest we "fall into temptation."[109] So, Gregerson's account might be supplemented with theological assessments of risk similar to those made in the context of debates over biotechnology.[110] More-ambitious contributors might also seek to address issues associated with the disproportionate distribution of chemical risks onto the poor and vulnerable,[111] or theologically evaluate the perspectives that underlie chemical risk management regimes.[112] Possible starting points include Mullins's and Sani's efforts to Christianize secular risk management principles as congruent with Christian understandings of how God acts in creation[113] and the efforts of Susan Bratton[114] and the Presbyterian Church USA (PCUSA)[115] to address deficiencies in Christian approaches to agricultural and marine chemicals. However, much more chemically informed work is needed to help Christians adequately navigate between the benefits and riskiness[116] of chemical use even in these limited spheres.

The "risk discourses" that are put in place to manage risk should also be considered.[117] Some of the issues involved can be nicely illustrated by considering the

dual-use dilemmas that can arise over technologies such as protein engineering,[118] directed evolution studies,[119] combinatorial chemistry,[120] microreactors,[121] drug discovery AI,[122] and published chemical syntheses[123] that can be repurposed for illicit ends. At issue is whether to help a potential recipient by providing them with a beneficial technology or to prevent a foreseeable harm by withholding it. In most cases, the decision involves questions of security and is typically made by individual researchers, businesses, and governments (who help decide whether to develop technologies) or corporations and governments (who control access and export). Typically, the decision makers are wealthier more-powerful entities whose interests differ somewhat from the poorer less-powerful prospective recipients. Ethical issues can arise in the decision itself, how the decision-making process is constructed (Should chemists have a say? What about the prospective recipient?), and in the actions of the decision makers themselves (Do they honestly communicate likely risks and benefits? Disclose conflicts of interest? Consider other stakeholders' perspectives?). The importance of a carefully constructed risk discourse was recently illustrated by recent bans on plastic straws, resulting in a decision that was environmentally responsible but disregarded the needs of disabled people.[124] There are also questions about how the wealthy and powerful might justly withhold from the poor. Can they do so for their own security? If they do so, do they have an obligation to provide for the poor in other ways, such as through safer technologies?

Christians Are Called to Be Salt and Light[125] in a Chemical World

Christians should also care about chemistry because the church is called to equip its members to live out the gospel in a world that is profoundly shaped by chemistry. While some Christians may be engaged directly in chemical work,[126] all use synthetic chemicals in one way or another, even if only indirectly through goods such as concrete cityscapes, asphalt roadways, clean water, food, and other products made with chemicals. The environmental and social impacts of these are simultaneously the responsibility of everyone and no one in particular. This situation is sometimes referred to as organized irresponsibility,[127] but ideally the different actors all have some responsibility to see to it that chemicals are used responsibly. For example, governments regulate who has access to chemicals; R&D scientists investigate safety and provide instructions as to proper use; manufacturers perform quality control checks to make sure chemical products function properly and do not contain harmful impurities; the products are marketed honestly to appropriate users; end-users use the chemicals responsibly; appropriate health and environmental monitoring is undertaken; and harms are detected and remedied as soon as they occur.

In practice, these steps can be costly, sometimes prohibitively, so tradeoffs are made; breakdowns can occur due to malfeasance or ignorance, and it can be difficult to know where and how Christians might be called to act differently or exert a prophetic voice. Further, ethical issues that have nothing to do with professional norms can be even harder to recognize. It is one thing to conscientiously object to military research that violates international treaties, another for a cosmetic chemist to know what to do when the demand for their work is manufactured by making 400 million Chinese women feel self-conscious about their body hair.[128]

Even when a potential problem is identified, chemists need wise guidance. During controversies over Dow's role in supplying napalm to US forces in Vietnam, Dow President Ted Doan complained about a book on Christian ethics that he had consulted, noting its focus on "personal responsibility" to the exclusion of "corporate responsibility."[129] In this regard, there is a need for ethical resources suitable for use by Christians in chemistry, whether in the form of general approaches, analyses of various chemical codes of conduct,[130] or case studies similar to those given in the recent *Ethics of Chemistry* volume.[131]

Although it is hoped that contributors will explore a range of chemical enterprises, a possible starting point might be chemists' involvement in military work. Christian just war and pacifist traditions might serve as ready-made analytical frameworks. The moral arguments involved might be more accessible since chemists involved in military work are sometimes called upon to explain the moral rationale for their work publicly. The issues involved are likely to be usefully complex. Chemical products can be used for offensive, defensive, and medical purposes,[132] and chemists engage in military work for a variety

of reasons. Some do it opportunistically or out of nationalism. Others see military work as a way to seek the security of the place God placed them, either as a way to help deter potential aggressors or mitigate war's adverse impacts.[133] Some conscientiously refuse to do any military work[134]—or they seek out projects that promote peace and security. Examples include the ion mobility mass spectrometry systems that monitor for chemical and biological threats in airports, and methods for spectroscopically "fingerprinting" conflict minerals that make it harder for violent groups to profit from their extraction.[135]

The cases which have been examined so far seem to illustrate several features of moral dialogue in chemistry. The first is the need for cultural and self-awareness and to guard against moral slippage. Although poison gas research engenders considerable moral horror today, many World War I era chemists enthusiastically pursued it.[136] Nominally, they employed a mix of just war and realist arguments that map nicely onto those used by political and military leaders[137]—in this case, supported by a mix of nationalism and Pollyannaish reasoning about the effects of the gas. Known cases of possible moral slippage by degrees include Louis Fieser's work on napalm[138] and the "devil's chemists" of the holocaust. Few deliberately set out to run the holocaust's only privately run concentration camp or knowingly sell the Zyklon B for murderous purposes; most seem to have more or less unwittingly become involved and only later became willingly complicit.[139] Apart from the complicated case of the confessing church member and disinfectant specialist Kurt Gerstein,[140] the role Christianity played in chemists' sustained and deliberate involvement in these crimes has yet to be studied,[141] although "Christian" nationalism is known to have played a role in other Third Reich atrocities.[142]

Contributors might explore how chemists could use their professional influence to promote human flourishing. Examples include the Quaker crystallographer Kathleen Lonsdale's personal efforts to promote peace through relationship building, or the much more public and professionally costly activism of the secular humanist quantum chemistry pioneer Linus Pauling. The Methodist quantum chemist Charles Coulson promoted flourishing in multiple arenas. He succored refugees and sought after peace, equitable global development, church unity, and the end of poverty, unemployment, and racism.[143]

The relationship between chemistry and idolatry is a particularly thorny one. Chemists' many contributions to medicine, commerce, culture, and many other aspects of everyday life should be rightly celebrated.[144] However, as with all powerful technologies, there is always a danger of technological messianism. Sometimes the messianism is explicit. Margaret Sanger, anticipating chemists' successful development of oral contraceptives, proclaimed "science, the only possible savior of humankind, must put it in the power of woman to decide for herself whether she will or will not become a mother."[145] Other times, it is implied, as with the quasi-religious depictions of chemists and chemical plants in Abraham Cressy Morrison's *Man in a Chemical World*.[146] More often it involves shaping practices and affections. As a number of commentators have noted, chemical fertilizers, antibiotics, and contraceptives have alleviated people's sense of dependence on God and made it easier for them to live as if God did not exist.[147] However, here chemistry does not replace the God of Christianity but a "god in the gaps of our technological powers."[148] More serious, then, are things such as Du Pont's "better living through chemistry" ad campaign, which did not offer chemistry as a messiah directly so much as to help encourage a culture of consumerism.[149]

Although chemists, among other humans, are subject to hubris and other vices common to humanity, the connection between idolatry and what chemists do is far from simple. Chemists, chemicals, and chemical institutions should not be stereotyped as particularly idolatrous or vice-filled, for such caricatures will seem foreign to most practicing chemists, and hazard not showing due regard for the image of God in every human. The need to be careful in this regard is illustrated by the Nobel prize winner Fritz Haber. In 1909, Haber solved one of the defining scientific challenges of his time by developing an effective ammonia production process. Without his work, it would be impossible to feed the world. Yet, less than a decade after his discovery, Haber would become known as the "father" of modern chemical warfare. By all accounts his was an amazing life, in some respects worthy of being called a "morality tale for those who hope to see technology used to improve civilization, not destroy it."[150] Yet as his godson the

historian Fritz Stern reminds us, the story of Haber has often been told flatly and uncharitably, without due regard for Haber, the legendry scientific mentor, diplomat, friend of the pacifist Einstein, resister against Nazi demands to fire his Jewish subordinates, and, like many scientists, someone eager to use his talents to help meet the needs of his time.[151]

It is similarly difficult to draw a straight line between particular advances in chemistry and right worship or idolatry. Polymers and plastics may have contributed to cultures of consumerism, waste, and wastefulness in which "throwaway living" is celebrated.[152] However, they also contribute much to human health, wealth, and cleanliness. Polymers are also fundamentally expressions of scientific knowledge and know-how, and consequently, of both the wisdom of God and the God-imaging creativity of humanity. So, the real issue is not chemistry but the human heart. Issues of idolatry are not about chemistry per se but about how we think, live, and organize society, the church, and our individual lives.[153] As Carl Djerassi noted, synthetic oral contraceptives' role in transforming culture was "partly causative, though mostly facultative, by the simple fact that at precisely the right time in Western social history, a convenient oral contraceptive became available that completely divorced contraception from sex."[154] In other words, it is not only about chemistry's benefits and harms but also about whether we are shaping and using chemistry in ways that reflect robustly Christian "notions of the good, or the right, or the fitting."[155] In this regard, there is a need for contributions that address the theological outlooks we express through movements such as green chemistry, the risk discourses surrounding chemistry, and technologies such as plastics, adhesives, pesticides, food additives, fuels, solar energy technologies, and CRISPR/Cas9.[156]

Chemistry Enriches Our Understanding of Science and How It Relates to Religion

Chemistry's multifaceted approach to the study of matter not only reveals the richness of creation, but it also helps illuminate the richness of the human quest for understanding through science. Chemists engage in a variety of activities. In terms of basic research alone, some chemists use analytical instruments such as spectrometers and chromatographs to probe the composition of matter, while others use experiments or computational models to figure out how atoms and molecules behave or work together as part of larger systems. Nevertheless, overall, relatively few chemists seek to probe the fundamental structure of matter like some physicists do. Rather, to the extent chemists seek to explain how matter works, they do so at the level of atoms and molecules. Further, even then, chemists do not always use the most sophisticated scientific tools and models that are available. Some chemists make measurements with exacting accuracy and precision or employ highly sophisticated models in their efforts to understand chemical structure. However, even when reasonably reliable computational models are available, many chemists find simple models of chemical structure and reactivity more useful as everyday reasoning tools.[157] The general rule is that chemists seek to use whatever tool or model is most helpful in a given situation.

So, chemistry is at once exacting and flexible, objective and personal, a search for truth and a search for utility. It recognizes that humanity's search for understanding, whether in science or theology, engages a multifaceted reality that is no less true when described at different levels of detail or by using analogies or approximations. In this respect, it pushes back against simplistic notions of science as either a monolithic search for truth or a disinterested enterprise. Nevertheless, it does not do so in ways that would permit ideologues to legitimately challenge chemistry's established conclusions.[158] Rather, it does so in ways that suggest it may be fruitful to explore parallels between chemical reasoning and various forms of theological thinking, including areas such as practical theology that are not normally considered dialogue partners for the sciences.[159]

The long tradition of Christian thinking about matter may be fruitfully explored.[160] The ancient, medieval, and early modern church all engaged Aristotelian, Platonic, Epicurean, and Stoic philosophies of matter[161] as well as theory-driven experimental work in the form of craft and alchemical-chemical traditions.[162] Examples of the use of classical element theory in the New Testament include the description of bodies in 1 Corinthians 15:35–58 as "earthly" and "heavenly" and possibly the mention of the world being formed out of the classical element water in 2 Peter 3:5. The story of atomic ideas (atomism) is particularly notable.[163] Classical and early medieval

thinkers were wary of atomism since it was associated with the major ateleological system of the ancient world, Epicureanism,[164] and since atomists were unable to explain why anything orderly happened in nature (until the twentieth century, atomic theory could not explain how and why atoms associated in the way they did). Thus, although some of the church fathers employed atomic ideas to explain things such as God's creation of the cosmos or how the resurrection might have taken place, atomism was not seriously considered until the modern period. Until the work of Robert Boyle, Antoine Lavoisier, John Dalton, and many others from the seventeenth century onwards, various Stoic and Aristotelian ideas seemed more promising, both theologically and as a guide for chemical experimentation. Nevertheless, the church's commitment to these ideas was kept tenuous by the ecclesiastical denial of Aristotelian dogmatism amidst political and philosophical strife at the University of Paris (which also encouraged Christians to consider that the void of atomism might exist[165]) and alchemists' failure to produce either gold or immortality. This made it considerably easier for the French priest Pierre Gassendi to recast atoms as created by God as part of his efforts to rehabilitate Epicureanism.[166] Ultimately, however, the tradition of quantitative experimentation initiated by Boyle undergirded the Quaker schoolmaster John Dalton's proposal of the first chemically significant atomic theory.[167] So, the story of atomic theory *might* be taken as an example of science and faith interacting in constructive ways, even though it has sometimes been inaccurately portrayed as an example of conflict by advocates of the warfare model.[168]

Chemistry Is Also an Opportunity for the Church to Learn from Chemists

The book of Hebrews presents us with a cloud of witnesses of those who have gone before and then later enjoins us to remember our teachers, consider their way of life, and imitate their faith.[169] To that end, contributions outlining the lives of Christians in chemistry could also be worthwhile. Those from the modern period onward that have been documented include Paracelsus,[170] Oswald Croll,[171] Jan Baptist van Helmont,[172] Johan Glauber,[173] Robert Boyle,[174] John Dalton,[175] Benjamin Silliman Sr., Michael Faraday,[176] Josiah Parsons Cooke,[177] John Draper,[178] Hermann Kolbe,[179] George Washington Carver,[180] Charles Stine,[181] José María Albareda,[182] Edward Francis Caldin,[183] Percy Lavon Julian,[184] Michael Polanyi,[185] Kathleen Lonsdale,[186] Charles Coulson,[187] Arthur Peacocke,[188] Rustem Roy, Colin Russell,[189] Alister McGrath,[190] John Goodenough,[191] James Tour,[192] Fritz Schaeffer,[193] Edgar Andrews, Duane Gish,[194] Michael Behe,[195] Fazale Rana,[196] Marcos Eberlin,[197] Robert Fay,[198] Gary Patterson, Daniel Romo, Troy Van Voorhis,[199] David Vosburg,[200] Sy Garte,[201] Jorge Mario Bergoglio,[202] and others of whom I am only dimly aware.

Even though the relationship between science and Christianity in actual human lives is always somewhat messy, it may be enlightening to consider how chemists might express their beliefs through the sort of problems they choose to work on or the way they talk about their work.[203] One chemist whose life seems inadequately explored in this regard is the steroid chemist Percy Lavon Julian, who was widely respected as a humanist for the practical benefits of his work. Yet Julian did not talk directly about his faith in public or scientific arenas, even though its importance was evident to those of his colleagues who talked about and remembered him. It might similarly be instructive to evaluate these chemists' efforts to relate their faith and work with respect to contemporary views about how the church should engage with culture,[204] the meaning and value of work,[205] and whether and how the church should engage politically charged issues.[206] One incompletely explored example in which differences about these issues seems to be in play is the Dow napalm controversy, which involved a clash between the Clergy and Laity against Vietnam organization and devout Episcopalian and Presbyterian managers on Dow's board over the latter's supplying of napalm to the American military.[207] Historical context should also be considered.[208] For example, although the Franciscan friar Roger Bacon's advocacy of lethal alchemical warfare might be regarded as cringeworthy today, it made sense in the context of the apocalyptic speculations circulating in thirteenth-century Latin Christendom.[209]

Atheist and agnostic chemists provide opportunities for chemists to help the church understand and respond to materialist pictures of reality. Although the most prominent examples of scientism are usually associated with biology, neuroscience, and

physics, there is also a notable tradition of skepticism and agnosticism in chemistry. The crystallographer John Desmond Bernal,[210] textbook writer Peter Atkins,[211] spectroscopist Harold Kroto,[212] theoretical chemist Roald Hoffmann[213] and historian of chemistry William Jensen[214] have all explained their thinking in enough detail to be thoughtfully engaged. Other historical examples include Marcelin Berthelot,[215] Svante Arrhenius,[216] and Wilhelm Ostwald.[217] Arrhenius and Ostwald are also interesting on account of their association with the Monist League and, in Ostwald's case, the German church withdrawal movement. Joseph Priestley, Humphrey Davy, and Edward Frankland had more-complicated relationships with orthodox Christian belief that may be worth pondering.[218] In this regard, it might be valuable for Christians in the chemical sciences to expand on some of the existing analyses of scientific materialism in chemistry in ways that graciously and thoughtfully engage the arguments of these and similar thinkers. [219]

Final Reflections

As a partially reductionist culture-shaping central science, chemistry offers to enrich our understanding of how science and faith interact. From the standpoint of chemistry, the science-Christianity relationship cannot and should not be conceived in exclusively cognitive terms.[220] Chemistry is too important a locus for what one astute observer has called "the meeting of science and religion in real life."[221] How churches and individuals think about chemistry and use chemicals can reflect either defective or sound thinking about God, creation, and the gospel.[222] It is hoped that contributions to this call for papers will, in however small a measure, contribute to sound thinking. ▼

Notes

[1]In this connection chemistry has also been called the keystone science. Ivor Griffith, "Chemistry as a Source of New Wealth," *The Annals of the American Academy of Political and Social Science* 115 (1924): 38, https://www.jstor.org/stable/1015788.

[2]The characterization of chemistry as an "impure science" also refers to how chemistry has altered the environment through waste and pollution. See Bernadette Bensaude-Vincent and Jonathan Simon, *Chemistry: The Impure Science* (London, UK: Imperial College Press, 2008). For those who dislike the word "impure," another term that chemistry has been called (but does not give exactly the same idea) is the "cardinal creative science" (Griffith, "Chemistry as a Source of New Wealth").

[3]Roughly from the late nineteenth century onward, Hugh D. Crone, *Chemicals and Society: A Guide to the New Chemical Age* (Cambridge, UK: Cambridge University Press, 1988); and Frank A. von Hippel, *The Chemical Age: How Chemists Fought Famine and Disease, Killed Millions, and Changed Our Relationship with the Earth* (Chicago, IL: University of Chicago Press, 2020).

[4]For other general Christian reflections on issues and approaches in chemistry, see Jonathan Foster and Bob Slade, "Studying Chemistry as a Christian," Christians in Science, 2013, https://www.bethinking.org/your-studies/studying-chemistry; Michael Newton and Andrew Halestrap, "Studying Biochemistry as a Christian," Christians in Science, n.d., https://www.cis.org.uk/upload/Resources/Students/Biochemistry_text_only.pdf; Walter R. Hearn, "Chemistry," *Journal of the American Scientific Affiliation* 11, no. 2 (1959): 10–12, https://www.asa3.org/ASA/PSCF/1959/JASA6-59Hearn.html; Russell Maatman, "Chemistry," *Journal of the American Scientific Affiliation: Science in Christian Perspective* 17, no. 1 (1965): 27–28, https://www.asa3.org/ASA/PSCF/1965/JASA3-65Maatman.html; ___, "Chemistry: A Gift of God," *Perspectives on Science and Christian Faith* 38, no. 4 (1986): 232–36, https://www.asa3.org/ASA/PSCF/1986/PSCF12-86Maatman.html; ___, "Suggestion: Use a World-and-Life View in the Teaching of Chemistry," *Journal of Chemical Education* 65, no. 10 (1988): 885–86, https://doi.org/10.1021/ed065p885; Peter K. Walhout, "How Does Chemistry Impact Human Society?," in *Not Just Science: Questions Where Christian Faith and Natural Science Intersect,* ed. Dorothy F. Chappell and E. David Cook (Grand Rapids, MI: Zondervan, 2005): 223–28; Arie Leegwater, "Loving the Kingdom and Responsible Technology," *Perspectives on Science and Christian Faith* 62, no. 4 (2010): 233–34, https://www.asa3.org/ASA/PSCF/2010/PSCF12-10Leegwater.pdf; ___, "A Brief Excursion in Chemistry: 'God-Talk' in Chemistry?," *Perspectives on Science and Christian Faith* 63, no. 3 (2011): 145, https://www.asa3.org/ASA/PSCF/2011/PSCF9-11Leegwater.pdf; and Stephen Contakes, "Wisdom in and for Chemistry," in *Where Wisdom May Be Found,* ed. Edward P. Meadors (Eugene, OR: Wipf & Stock, 2019): 187–201.

[5]For an inspiring reflection on matter, see Dallas Willard, "The Material World and the Rule of God: Matter or Physical Substance as Understood Today," 1982 Staley Lecture Series for Bethel College, Kansas, September 20, 1982, https://conversatio.org/the-material-world-and-the-rule-of-god-matter-or-physical-substance-as-understood-today/. It is noteworthy that popular-level theologies of making have been developed for the arts and business, such as Makoto Fujimura, *Art and Faith: A Theology of Making* (New Haven, CT: Yale University Press., 2020); and Jordan Raynor, *Called to Create: A Biblical Invitation to Create, Innovate, and Risk* (Grand Rapids, MI: Baker Books, 2017). Some starting points for a theology of chemistry might be found in general introductory perspectives on technology such as John Dyer, *From the Garden to the City: The Redeeming and Corrupting Power of Technology* (Grand Rapids, MI: Kregel Publications, 2011); Noreen L. Herzfeld, *Technology and Religion: Remaining Human in a Co-Created World* (West Conshohocken, PA: Templeton Press, 2009); John H. Thomas, "A New Voice Arising: A Pastoral Letter on Faith Engaging Science and Technology" (Cleveland, OH: United Church of Christ, 2008), https://www.ucc.org/wp-content/uploads/2021/01/pastoral-letter-on-faith

-and-science.pdf; and Egbert Schuurman, *The Technological World Picture and an Ethics of Responsibility: Struggles in the Ethics of Technology* (Sioux Center, IA: Dordt College Press, 2005). More specific proposals and issues are developed in Stephen V. Monsma, ed., *Responsible Technology: A Christian Perspective* (Grand Rapids, MI: Eerdmans, 1986); Jack Clayton Swearengen, *Beyond Paradise: Technology and the Kingdom of God* (Eugene, OR: Wipf & Stock, 2007); Willem Drees, "Introduction: Technological and Moral Creatures or Creators?," in *Creative Creatures: Values and Ethical Issues in Theology, Science, and Technology,* ed. Ulf Görman, Willem B. Drees, and Hubert Meisinger (London, UK: T & T Clark International, 2005): 1–12. Helpful article-length perspectives are found in Leegwater, "Loving the Kingdom"; Michael J. Clifford, "Appropriate Technology: The Poetry of Science," *Science and Christian Belief* 17, no. 1 (2005): 71–82; Denis Alexander, "Worshipping God with Technology," *Cambridge Papers* (December 2003); and Tom McLeish, "Medieval Lessons for the Modern Science/Religion Debate," chap. 15 in *Robert Grosseteste and the Pursuit of Religious and Scientific Learning in the Middle Ages*, ed. Jack P. Cunningham and Mark Hocknull (Switzerland: Springer, 2016): 281–300. For an interesting exploration of historical Christian attitudes toward technology, see John Hedley Brooke, "Detracting from Divine Power? Religious Belief and the Appraisal of New Technologies," in *Re-Ordering Nature: Theology, Society, and the New Genetics*, ed. Celia Deane-Drummond, Bronislaw Szerszynski, and Robin Grove-White (London, UK: T&T Clark, 2003), 43–64.

[6]For more on the idea of creation's goodness as involving proper functioning, see Robert C. Bishop, "Recovering the Doctrine of Creation: A Theological View of Science," BioLogos Foundation, January 31, 2011, https://biologos.org/articles/recovering-the-doctrine-of-creation-a-theological-view-of-science.

[7]Some resources that develop this point, albeit more in light of the biological and social sciences than chemistry, include Philip J. Hefner, *The Human Factor: Evolution, Culture, and Religion* (Minneapolis, MN: Fortress Press, 1993); and ___, *Technology and Human Becoming* (Minneapolis, MN: Fortress Press, 2003). Subsequent to Hefner's work the created co-creator concept has also been applied to work in the arts, business, and other fields. For thoughts on its application to chemistry, see Willem B. Drees, "'Playing God? Yes.' Religion in the Light of Technology," *Zygon*® 37, no. 3 (2002): 643–54, https://doi.org/10.1111/1467-9744.00442.

[8]Note that I am not claiming that humans should be understood as "created co-Creators" in the sense of independent free agents. Rather, I am claiming they are "creative creatures" with God-given creativity which they are called to exercise under God. For more on this point, see James C. Peterson, *Changing Human Nature: Ecology, Ethics, Genes, and God* (Grand Rapids, MI: Eerdmans, 2010), 46; and Willem B. Drees, *Religion and Science in Context: A Guide to the Debates* (New York: Routledge, 2010): 122–24. For the theological implications of different views of human calling on a technological issue, see Forrest Clingerman, "Geoengineering, Theology, and the Meaning of Being Human," *Zygon*® 49, no. 1 (2014): 6–21, https://doi.org/10.1111/zygo.12072.

[9]For an example of a chemist who understands their work in this way, see David Vosburg, "What Does Christ Have to Do with Chemistry?," The Faraday Institute for Science and Religion, February 27, 2014. http://scienceandbelief.org/2014/02/27/what-does-christ-have-to-do-with-chemistry/

[10]For a brief treatment of the culture mandate as a call to bring out creation's potentialities, see Naomi Noguchi Reese, "Culture Mandate," in *Dictionary of Christianity and Science,* ed. Paul Copan et al. (Grand Rapids, MI: Zondervan, 2017), 149. Useful popular treatments of the culture mandate include Andy Crouch, *Culture Making: Recovering Our Creative Calling* (Downers Grove, IL: InterVarsity Press, 2008); and ___, *Playing God: Redeeming the Gift of Power* (Downers Grove, IL: Intervarsity Press, 2013).

[11]For an exploration of the stewardship mandate, see Sandra L. Richter, *Stewards of Eden: What Scripture Says about the Environment and Why It Matters* (Downers Grove, IL: InterVarsity Press, 2020), especially pp. 5–14.

[12]Genesis 1:28; 2:15; cf. Psalm 8.

[13]Genesis 1:28; 4:17–22 (cf. 3:17–23, 4:11–12; 5:29).

[14]For a readable account of these bricks as a materials science achievement, see Stephen L. Sass, *The Substance of Civilization: Materials and Human History from the Stone Age to the Age of Silicon* (New York: Arcade, 1998), 125–27.

[15]For an interesting chemistry-laden discussion of the debittering of the waters of Marah, see Roald Hoffmann and Shira Leibowitz Schmidt, *Old Wine, New Flasks: Reflections on Science and Jewish Tradition* (New York: W. H. Freeman, 1997), 123–57.

[16]For examples of Christians in science who view their work as promoting shalom, see Elaine Howard Ecklund, *Why Science and Faith Need Each Other: Eight Shared Values That Move Us Beyond Fear* (Grand Rapids, MI: Brazos, 2020), 133–44.

[17]For a magisterial treatment on science as a source of wisdom, see Tom McLeish, *Faith and Wisdom in Science* (Oxford, UK: Oxford University Press, 2015). For more on chemistry as a source of wisdom, see Contakes, "Wisdom in and for Chemistry." For an exploration of one area of chemistry, see Gary Patterson, "Theology and Thermodynamics: In Praise of Entropy," *Perspectives on Science and Christian Faith* 64, no. 4 (2012): 242–49, https://www.asa3.org/ASA/PSCF/2012/PSCF12-12Patterson.pdf.

[18]For a slightly dated but still very useful summary of the challenges and research needs facing chemistry, see National Research Council, *Beyond the Molecular Frontier: Challenges for Chemistry and Chemical Engineering* (Washington, DC: National Academies Press, 2003).

[19]Atoms differ markedly from the indivisible classical particles envisioned by Epicurus, Leucippus, and Democritus. A failure to understand this basic distinction has led to significant misunderstandings about early Christian objections to atomism. In fact, their objections were right to the point. Because the Epicureans lacked a coherent theory of chemical structure and bonding, their atomic ideas did not actually explain why matter forms the structures that it does.

[20]For an interesting article from a Lutheran perspective, see George Murphy, "The Impact of Science on Christian Worship," *Seminary Ridge Review* 1, no. 2 (1999): 63–74. For Roman Catholicism, see Rev. Michael J. Ahern, S.J., "Liturgical Chemistry," *Bulletin of the American Association of Jesuit Scientists*, Eastern Section 11, no. 4 (1934): 218–21, https://jesuitonlinelibrary.bc.edu/?a=d&d=aajses19340501-01.2.14&e=-------en-20--1--txt-txIN-------. For private examples of chemistry informing a worshipful attitude toward scripture and nature, see Therese Southgate, "A

Chemist's Prayer," *Journal of Chemical Education* 23, no. 10 (1946): 507, https://doi.org/10.1021/ed023p507; Roy Berkenbosch, "Good Chemistry in a Fallen World: A Service Planned and Led by Chemists," *Reformed Worship* 83 (March 2007), https://www.reformedworship.org/article/march-2007/good-chemistry-fallen-world; Kaylee Hill, "Synthesis," *God & Nature* (Summer 2018), https://godandnature.asa3.org/hill-poem-synthesis.html; Stacy A. Trasancos, "Atoms, Elements, and the Grandeur of God," *U.S. Catholic*, November 1, 2016, https://uscatholic.org/articles/201611/atoms-elements-and-the-grandeur-of-god/; and Allison Dick, "A Prayer for Chemists," *InterVarsity Emerging Scholars Network Blog*, November 9, 2020, https://blog.emergingscholars.org/2020/11/a-prayer-for-chemists/. In addition, chemistry textbooks written for a Christian homeschool audience often incorporate chemistry-based devotional elements.

[21]For examples, see Caroline Walker Bynum, *Christian Materiality: An Essay on Religion in Late Medieval Europe* (Cambridge, MA: MIT Press, 2011), 217–65; and William R. Newman, "Alchemy and the Art-Nature Debate," in *Promethean Ambitions: Alchemy and the Quest to Perfect Nature* (Chicago, IL: University of Chicago Press, 2004), 34–114. For the continuation of these trends in the early modern period, see John Henry, "Theology and the Meaning of Matter in the Early Modern Period: A Response to Peter Harrison," in *Matter and Meaning: Is Matter Sacred or Profane?,* ed. Michael Fuller (Newcastle upon Tyne, UK: Cambridge Scholars, 2010), 57–66.

[22]On scholastic efforts to reconcile late medieval matter theory with the then-recently ratified doctrine of transubstantiation, see Marilyn McCord Adams, *Some Later Medieval Theories of the Eucharist: Thomas Aquinas, Gilles of Rome, Duns Scotus, and William Ockham* (Oxford, UK: Oxford University Press, 2010). For aspects of the debate in modern Roman Catholicism, see Stephen M. Barr, "Does Quantum Physics Render Transubstantiation Meaningless?," *First Things* (May 25, 2010), https://www.firstthings.com/blogs/firstthoughts/2010/05/does-quantum-physics-render-transubstantiation-meaningless; Richard G. Cipolla, "Selvaggi Revisited: Transubstantiation and Contemporary Science," *Theological Studies* 35, no. 4 (1974): 667–91, https://doi.org/10.1177%2F004056397403500403; Joseph T. Clark, "Physics, Philosophy, Transubstantiation, Theology," *Theological Studies* 12, no. 1 (1951): 24–51, https://doi.org/10.1177%2F004056395101200102; and Cyril Vollert, "The Eucharist: Controversy on Transubstantiation," *Theological Studies* 22, no. 3 (1961): 391–425, https://doi.org/10.1177%2F004056396102200302.

[23]Chiara Crisciani, "Opus and Sermo: The Relationship between Alchemy and Prophecy (12th–14th Centuries)," *Early Science and Medicine* 13, no. 1 (2008): 4–24, http://dx.doi.org/10.1163/157338207X242447; Tara Nummedal, "Alchemy and Religion in Christian Europe," *Ambix* 60, no. 4 (2013): 311–12, and references therein, https://doi.org/10.1179/0002698013Z.00000000036; and Lawrence Principe, *The Secrets of Alchemy* (Chicago, IL: University of Chicago Press, 2013), 190–206.

[24]Following 2 Peter 3:5, van Helmont's famous tree experiment was an attempt to uncover how things could be formed of water.

[25]See Edward Davis, "A Priest Serving in Nature's Temple: Robert Boyle's Career Blended Faith, Doubt, and the Use of Science to Heal Disease and Fight Atheism," *Christian History* (November 2002): 28–31, https://www.christianitytoday.com/history/issues/issue-76/priest-serving-in-natures-temple.html; and Robert Boyle, "Some Considerations Touching the Usefulness of Experimental Natural Philosophy," in *The Works of the Honourable Robert Boyle*, 6 vols., ed. Thomas Birch (Hildesheim, Germany: Georg Olms, 1966), 2.31. For an account of Boyle's notion of the priest-scientist, see Harold Fisch, "The Scientist as Priest: A Note on Robert Boyle's Natural Theology," *Isis* 44, no. 3 (1953): 252–65, https://doi.org/10.1086/348227; and Peter Harrison, "Sentiments of Devotion and Experimental Philosophy in Seventeenth-Century England," *Journal of Medieval and Early Modern Studies* 44, no. 1 (2014): 113–33, https://doi.org/10.1215/10829636-2389515.

[26]For more on these arguments, see John Hedley Brooke, "Chemistry," in *The History of Science and Religion in the Western Tradition: An Encyclopedia*, ed. Gary B. Ferngren, Edward J. Larson, and Daniel W. Amundsen (New York: Garland, 2000), 378–83; David M. Knight, "Chemical Sciences and Natural Theology," in *The Oxford Handbook of Natural Theology*, ed. Russell Re Manning (Oxford, UK: Oxford University Press, 2013), 434–48.

[27]Known among chemists as the discoverer of Boyle's law.

[28]Notably, Boyle did not believe nature offered knockdown arguments for God's existence. For an accessible introduction to Boyle, see William Eaton, "Boyle, Robert (1627–1691)," *The Internet Encyclopedia of Philosophy*, https://iep.utm.edu/robert-boyle/. For a book-length study, see Michael Hunter, *Boyle: Between God and Science* (New Haven, CT: Yale University Press, 2010). For a study of the relationship between Boyle's theology and its role in the development of chemistry through de-spiritualized views of matter, see Eugene M. Klaaren, *Religious Origins of Modern Science: Belief in Creation in Seventeenth-Century Thought* (Grand Rapids, MI: Eerdmans, 1977).

[29]Some that address chemistry are William Prout, *Chemistry, Meteorology, and the Function of Digestion, Considered with Reference to Natural Theology* (London, UK: W. Pickering, 1834); George Fownes, *Chemistry, As Exemplifying the Wisdom and Beneficence of God* (New York: Wiley and Putnam, 1844); Josiah Parsons Cooke, *Religion and Chemistry; or, Proofs of God's Plan in the Atmosphere and its Elements* (New York: Scribner, 1864)—this was revised in 1880 as *Religion and Chemistry; a Re-Statement of an Old Argument*, with a third edition following in 1891; John Phin, *Chemical History of the Six Days of Creation* (New York: Handicraft Publication Co, 1872); Josiah Parsons Cooke, *The Credentials of Science, the Warrant of Faith,* 2nd edition (New York: Appleton, 1893); Simon Conway Morris, *Life's Solution: Inevitable Humans in a Lonely Universe* (Cambridge, UK: Cambridge University Press, 2003); Ruth M. Lynden-Bell et al., eds., *Water and Life: The Unique Properties of H_2O* (Boca Raton, FL: CRC Press, 2010); Alister E. McGrath, *A Fine-Tuned Universe: The Quest for God in Science and Theology* (Louisville, KY: Westminster John Knox Press, 2009); and Fazale Rana, *Fit for a Purpose: Does the Anthropic Principle Include Biochemistry?* (Covina, CA: Reasons to Believe Press, 2021). For an interesting fine-tuning argument that focuses on fine-tuning through quantum mechanics as necessary for a life-supporting chemistry, see also Stephen M. Barr, "Anthropic Coincidences and the Multiverse Idea," https://washtheocon.org/wp-content/uploads/2013/12/Universe-Designed-for-Life.pdf.

[30]Then as now, this was sometimes made more or less explicit. Among modern examples, for a theologically

sophisticated and historically aware program that merges homiletic, apologetic, and contemplative approaches by a polymer physicist, is McLeish, *Faith and Wisdom in Science*; and ___, "The Re-Discovery of Contemplation through Science," *Zygon*® 56, no. 3 (2021): 758–76, https://doi.org/10.1111/zygo.12719. Homiletic popular-level examples of varying credibility include George Wilson and Jessie A. Wilson, *Religio Chemici Essays* (London: Macmillan and Co., 1862); M. R. DeHaan, *The Chemistry of the Blood and Other Stirring Messages* (Grand Rapids, MI: Zondervan, 1943); A. Cressy Morrison, *Man Does Not Stand Alone* (New York: Fleming H. Revell Company, 1944) [This work was later republished as *Seven Reasons Why a Scientist Believes in God* (Westwood, NJ: Revell, 1962)]; Charles M. A. Stine, *A Chemist and His Bible,* 3rd edition (Philadelphia, PA: Sunday School Times, 1947); Sylvia Slaughter, *Messages from Matter: Finding God's Word in the Fundamentals of Chemistry* (Bloomington, IN: Westbow Press, 2015); and George B. Hill, *Discovering Jesus in a Chemistry Lab* (Self-published through LULU, 2017). For a respectable work of popular apologetics that touches on chemistry, see Henry F. Schaefer, *Science and Christianity: Conflict or Coherence?* (Athens, GA: University of Georgia, 2010). In addition to these, many chemistry textbooks written for Christian homeschooling audiences present an implicit natural theology. For an early example, see J. Carrington Sellars, *Chemistianity* (Birkenhead: Self-Published, 1873), https://elements.vanderkrogt.net/chemistianity.php.

[31]Cooke, *Religion & Chemistry*; and ___, *Credentials of Science*. For my analysis, see Stephen M. Contakes and Christopher Willard Kyle, "Josiah Parsons Cooke Jr.: Epistemology in the Service of Science, Pedagogy, and Natural Theology," *Hyle—International Journal for the Philosophy of Chemistry* 17, no. 1 (2011): 1–23, PhilArchive copy v1: https://philarchive.org/archive/CONJPCv1. For another chemistry-inspired example, see Daniel Luzon Morris, *Possibilities Unlimited: A Scientist's Approach to Christianity* (New York: Harper, 1952).

[32]A section on chemistry was included in Barrow and Tipler's classic work on the anthropic principle: John D. Barrow and Frank J. Tipler, *The Anthropic Cosmological Principle* (Oxford, UK: Oxford University Press, 1986), 510–75, although it had earlier been offered as an example of the anthropic principle in Cooke, *Religion and Chemistry*; and in Lawrence Joseph Henderson, *The Fitness of the Environment; an Inquiry into the Biological Significance of the Properties of Matter* (New York: The Macmillan Company, 1913). For a theistic evolutionary approach based on Augustine's seed principle, see Alister E. McGrath, *A Fine-Tuned Universe: The Quest for God in Science and Theology* (Louisville, KY: Westminster John Knox Press, 2009). For a chemistry-based natural theology based on beauty in chemistry, see Timothy Weatherstone, *Reconstructing Wonder: Chemistry Informing a Natural Theology* (Frankfurt am Main, Germany: Peter Lang, 2017). For a recent old earth perspective, see Rana, *Fit for a Purpose*. For intelligent design movement perspectives, see Marcos Eberlin, *Foresight: How the Chemistry of Life Reveals Planning and Purpose* (Seattle, WA: Discovery Institute Press, 2019); also Ryan Huxley and Casey Luskin, "Evidence of the Design of the Universe through the Anthropic Principle," Intelligent Design and Evolution Awareness Center, http://www.ideacenter.org/contentmgr/showdetails.php/id/837. For examples of past and present natural theology approaches based on the unique properties of water, see the essays in Lynden-Bell et al., *Water & Life*.

[33]In the UK, the chemist A. E. Wilders-Smith and materials scientist Edgar Andrews performed similar roles.

[34]While a comprehensive review of creationist (and other antievolutionist) uses of chemistry is beyond the scope of this article, for examples see Richard B. Bliss, *In Search of the … Origin of Life: Evolution, Creation* (San Diego, CA: Creation-Life Publishers, 1979); Duane Gish, "Thermodynamics and the Origin of Life (Part II)," *Acts & Facts* 7, no. 4 (1978), https://www.icr.org/article/thermodynamics-origin-life-part-ii/; and Duane T. Gish, *Speculations and Experiments Related to Theories on the Origin of Life: A Critique* (San Diego, CA: Institute for Creation Research, 1972).

[35]Michael J. Behe, *Darwin's Black Box: The Biochemical Challenge to Evolution* (New York: Free Press, 1996); ___, *The Edge of Evolution: The Search for the Limits of Darwinism* (New York: Free Press, 2008); and ___, *Darwin Devolves: The New Science about DNA That Challenges Evolution* (New York: HarperOne, 2020).

[36]Michael Denton, *Evolution: A Theory in Crisis* (Bethesda, MD: Adler & Adler, 1986).

[37]Fazale Rana and Hugh Ross, *Origins of Life: Biblical and Evolutionary Models Face Off* (Colorado Springs, CO: NavPress, 2004); Fazale Rana, *The Cell's Design: How Chemistry Reveals the Creator's Artistry* (Grand Rapids, MI: Baker Books, 2008); Eberlin, *Foresight*; and Rana, *Fit for a Purpose* and Change Laura Tan and Rob Stadler, *The Stairway of Life: An Origin-of-Life Reality Check* (Self-Published, 2020).

[38]McGrath, *A Fine-Tuned Universe.*

[39]W. Ross Hastings, *Echoes of Coinherence: Trinitarian Theology and Science Together* (Eugene, OR: Cascade Books, 2017), 128–35; and José M. Romero-Baró, "God's Mark on Nature. A Trinitarian Approach," Metanexus Institute. Science and Religion: Global Perspectives Conference, June 4–8, 2005, Philadelphia, PA, https://www.newdualism.org/papers/J.Romero-Baro/gods-mark.htm.

[40]Random in the sense of probabilistic.

[41]For my own nonrigorous efforts to suggest such correspondence, see Contakes, "Wisdom in and for Chemistry."

[42]For examples of God as a chemist in creation, see Allen G. Debus, *The Chemical Philosophy: Paracelsian Science and Medicine in the Sixteenth and Seventeenth Centuries* (New York: Science History Publications, 1977); and Michael Thomson Walton, *Genesis and the Chemical Philosophy: True Christian Science in the Sixteenth and Seventeenth Centuries* (Brooklyn, NY: AMS Press, 2011).

[43]Weatherstone, *Reconstructing Wonder*. For another important analysis, see Peter K. Walhout, "The Beautiful and the Sublime in Natural Science," *Zygon*® 44, no. 4 (2009): 757–76, https://doi.org/10.1111/j.1467-9744.2009.01032.x. The theologian Ross Hastings also mentions chemistry in connection with theologies of beauty, albeit in connection with his experience as an organometallic chemist. See Hastings, *Echoes of Coinherence*, 182–84, 220.

[44]Tutorial reviews are introductory reviews specifically intended for use as educational tools. For more on tutorial reviews, see the tutorial review guidelines for *Chemical Society Reviews* at https://www.rsc.org/journals-books-databases/about-journals/chem-soc-rev/. A suitable review may exist for origin of life chemistry: H. James Cleaves, *The Origins of Life: A Review of Scientific Inquiry* (West Conshohocken, PA: John Templeton Foundation, 2020), https://www.templeton.org/wp-content/uploads/2021/07/JTF_Origins_of_Life_Final.pdf.

[45]Although it is not written from a Christian or even a social justice perspective, various ways in which chemistry

impacts human wellbeing are described in John Emsley, *A Healthy, Wealthy, Sustainable World* (Cambridge, UK: RSC Publishing, 2010). For an interesting, if dated, account of chemistry's societal benefits written by a sometime Christian apologist, see A. Cressy Morrison, *Man in a Chemical World: The Service of Chemical Industry* (New York: C. Scribner's Sons, 1937).

[46]Peter Coy, "Why the Periodic Table of Elements Is More Important than Ever," *Bloomberg Businessweek*, August 28, 2019, https://www.bloomberg.com/news/features/2019-08-28/the-modern-triumph-of-the-periodic-table-of-elements. This article is part of a special issue on *The Elements* that describes many economic uses of the elements, https://www.bloomberg.com/features/2019-periodic-table-elements-issue/.

[47]American Chemistry Council, *2021 Guide to the Business of Chemistry*, https://www.americanchemistry.com/chemistry-in-america/data-industry-statistics.

[48]For more on the Haber-Bosch process, see Vaclav Smil, *Enriching the Earth: Fritz Haber, Carl Bosch, and the Transformation of World Food Production* (Cambridge, MA: MIT Press, 2001); Dietrich Stoltzenberg, *Fritz Haber: Chemist, Nobel Laureate, German, Jew* (Philadelphia, PA: Chemical Heritage Press, 2004); Daniel Charles, *Master Mind: The Rise and Fall of Fritz Haber, the Nobel Laureate Who Launched the Age of Chemical Warfare* (New York: Ecco, 2005); and Henry Harris, "To Serve Mankind in Peace and the Fatherland in War. The Case of Fritz Haber," *German History* 10, no. 1 (1992): 24–38, https://doi.org/10.1093/gh/10.1.24. For Christian perspectives, see Daniel Charles, "The Idol of Progress," *Sojourners Magazine* (2006): 24–27, and Darren Brouwer, "Better Living through Chemistry? Why Chemists Need to Be Humanists," *Comment* [Online], June 23, 2016, https://comment.org/better-living-through-chemistry/.

[49]That is, not counting petroleum, pharmaceuticals, and the biotech industry.

[50]The proportion of chemical engineers engaged in research and development is perhaps even lower (10% according to the US Bureau of Labor Statistics). See Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook*, Chemical Engineers, https://www.bls.gov/ooh/architecture-and-engineering/chemical-engineers.htm (visited March 28, 2022). Note that these numbers do not include those for petroleum engineers, chemical technicians, or for chemists involved in nonchemistry jobs, such as management and technical sales.

[51]Elizabeth Sendich, "Energy Products Are Key Inputs to Global Chemicals Industry," US Energy Information Administration, June 21, 2019, https://www.eia.gov/todayinenergy/detail.php?id=39952#.

[52]From the observatory of economic complexity data based on Alexander James Gaspar Simoes and Cesar A. Hidalgo, "The Economic Complexity Observatory: An Analytical Tool for Understanding the Dynamics of Economic Development," Paper from a workshop at the Twenty-Fifth AAAI Conference on Artificial Intelligence: Scalable Integration of Analytics and Visualization, San Francisco, California, August 7, 2011, https://www.researchgate.net/profile/Cesar-Hidalgo-2/publication/221605462_The_Economic_Complexity_Observatory_An_Analytical_Tool_for_Understanding_the_Dynamics_of_Economic_Development/links/54f472430cf24eb8794e8a6d/The-Economic-Complexity-Observatory-An-Analytical-Tool-for-Understanding-the-Dynamics-of-Economic-Development.pdf.

[53]For more on the chemical industry, see James Albert Kent, ed., *Handbook of Industrial Chemistry and Biotechnology,* 12th edition (New York: Springer, 2012); Mark Anthony Benvenuto, *Industrial Chemistry: For Advanced Students* (Boston, MA: De Gruyter, 2015); and Alan Heaton, *The Chemical Industry,* 2nd edition (London, UK: Blackie Academic & Professional, 1994). Readable accounts that are not accurate in every detail but which might be more accessible to nonchemist respondents include Ben Selinger and Russell Barrow, *Chemistry in the Marketplace,* 6th edition (Clayton South, VIC, Australia: CSIRO Publishing, 2017); and Donald L. Burdick and William L. Leffler, *Petrochemicals in Nontechnical Language,* 4th edition (Tulsa, OK: PennWell Corp, 2012).

[54]The impact of plastics has yet to be systematically explored in science and religion discourse. For some of the issues, see Jeffrey L. Meikle, *American Plastic: A Cultural History* (New Brunswick, NJ: Rutgers University Press, 1995); Susan Freinkel, *Plastic: A Toxic Love Story* (Boston, MA: Houghton Mifflin Harcourt, 2011); and Wiebe E. Bijker, *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change* (Cambridge, MA: MIT Press, 1995). For a survey of some of the issues from someone with "catholic scientific interests" along with ways forward, see Christopher J. Rhodes, "Solving the Plastic Problem: From Cradle to Grave, to Reincarnation," *Science Progress* 102, no. 3 (2019): 218–48, https://doi.org/10.1177/0036850419867204.

[55]Joachim Schummer, "'Are You Playing God?': Synthetic Biology and the Chemical Ambition to Create Artificial Life," *HYLE – International Journal for the Philosophy of Chemistry* 22, no. 1 (2016): 149–72, http://www.hyle.org/journal/issues/22-1/schummer.htm. See also Peter Dabrock, "Playing God? Synthetic Biology as a Theological and Ethical Challenge," *Systems and Synthetic Biology* 3 (1–4) (2009): 47–54, https://doi.org/10.1007%2Fs11693-009-9028-5; Ted Peters, *Playing God?: Genetic Determinism and Human Freedom,* 2nd edition (London, UK: Routledge, 2014); and Alexander Massmann and Keith R. Fox, *Modifying Our Genes: Theology, Science and "Playing God"* (La Vergne, UK: Hymns Ancient & Modern, 2014). A summary of the influence of theology on these discussions is given in Henk van den Belt, "Playing God in Frankenstein's Footsteps: Synthetic Biology and the Meaning of Life," *Nanoethics* 3, no. 3 (2009): 257–68, https://doi.org/10.1007%2Fs11569-009-0079-6.

[56]Wilfred Theisen, "The Attraction of Alchemy for Monks and Friars in the 13th–14th Centuries," *The American Benedictine Review* 46, no. 3 (1995): 239–53, https://www.scribd.com/document/364620582/THEISEN-Wilfrid-The-attraction-of-alchemy-for-monks-and-friars-in-the-13th-14th-centuries-pdf. For a cleric-alchemist who thought of his work in terms of the created co-creator concept, see Wilfred Theisen, "John Dastin: The Alchemist as Co-Creator," *Ambix* 38, no. 2 (1991): 73–78, https://doi.org/10.1179/amb.1991.38.2.73.

[57]For details of Albert's thought, see Albertus Magnus, *Book of Minerals,* trans. Dorothy Wyckoff (Oxford, UK: Clarendon Press, 1967); and Albert The Great, *On the Causes of the Properties of the Elements* [Liber de Causis Proprietatium Elementorum], Mediaeval Philosophical Texts in Translation, trans. Irven Michael Resnick (Milwaukee, WI: Marquette University Press, 2010). Important secondary sources include Adam Takahashi, "Nature, Formative Power and Intellect in the Natural Philosophy of Albert the Great," *Early Science and Medicine* 13, no. 5 (2008),

https://www.jstor.org/stable/20617751; the essays in Francis Joseph Kovach and Robert W. Shahan, *Albert the Great: Commemorative Essays* (Norman, OK: University of Oklahoma Press, 1980); and Irven Michael Resnick, ed., *A Companion to Albert the Great: Theology, Philosophy, and the Sciences* (Leiden, The Netherlands: Brill, 2013). Also Albert The Great's eight-volume discussion of Aristotle's physics; *On the Causes and the Procession of the Universe from the Prime Cause* and account of creation (*De IV coaequaevis*) are important for understanding his approach to matter but unfortunately not available in English translation. They may be accessed via the Alberti Magni e-corpus at http://albertusmagnus.uwaterloo.ca/.

[58]For Grosseteste's view of matter, see Nicola Polloni, "Early Robert Grosseteste on Matter," *Notes and Record: The Royal Society Journal of the History of Science* 75, no. 3 (2021): 397–414, https://doi.org/10.1098/rsnr.2020.0017; Giles E. M. Gasper et al., "The Use of the Stars: Alchemy, Plants, and Medicine," in *The Scientific Works of Robert Grosseteste. Vol. 1, Knowing and Speaking: Robert Grosseteste's 'De artibus liberalibus'* [on the Liberal Arts] *and 'De generatione sonorum'* [on the Generation of Sounds], ed. Giles E. M. Gasper et al. (Oxford, UK: Oxford University Press, 2019), 166–95.

[59]For Bacon's advocacy of alchemy and similar pursuits, see Roger Bacon, *The Opus Majus of R. Bacon*, trans. John Henry Bridges (London, UK: Williams & Norgate, 1900). For a summary of Bacon's thought in context, see Amanda Power, *Roger Bacon and the Defence of Christendom* (Cambridge, UK: Cambridge University Press, 2013), 96; Athanasios Rinotas, "The Interplay among Alchemy, Theology and Philosophy in the Late Middle Ages: The Cases of Roger Bacon and John of Rupescissa," *Vegueta. Anuario de la Facultad de Geografía e Historia* 17 (2017): 161–73, https://www.academia.edu/34085595/; Zachary Matus, "Reconsidering Roger Bacon's Apocalypticism in Light of His Alchemical and Scientific Thought," *The Harvard Theological Review* 105, no. 2 (2012): 189–222, https://www.jstor.org/stable/41474572; and ___, "Resurrected Bodies and Roger Bacon's Elixir," *Ambix* 60, no. 4 (2013): 323–40, https://doi.org/10.1179/0002698013Z.00000000037.

[60]Bacon's argument can be seen in the dedicatory preface to Bacon, *The Opus Majus of R. Bacon*, trans. Bridges. For other examples of prophecy-influenced alchemical programs, see Leah DeVun, *Prophecy, Alchemy, and the End of Time: John of Rupescissa in the Late Middle Ages* (New York: Columbia University Press, 2009); and Walter W. Woodward, *Prospero's America: John Winthrop Jr., Alchemy, and the Creation of New England Culture, 1606–1676* (Chapel Hill, NC: University of North Carolina Press, 2010).

[61]Martin Luther and Scott H. Hendrix, *Treatise on Good Works* (Minneapolis, MN: Fortress Press, 2012). See also Ian Hart, "The Teaching of Luther and Calvin about Ordinary Work: 1. Martin Luther (1483–1546)," *The Evangelical Quarterly* 67, no. 1 (1995): 35–52, https://vdocuments.net/the-teaching-of-luther-and-calvin-about-ordinary-work-1-martin-luther-2013-7.html?page=1. Luther and many of his contemporaries also linked alchemical and Christian thought, as explained in Nummedal, "Alchemy & Religion in Christian Europe."

[62]Luther also recognized resonances between alchemical and Christian imagery—for example, how chemical transformations could act as allegories of death and resurrection, an idea that survives in the form of terms such as crucible. On Luther's thought, see Martin Luther, *Table Talk,* trans. William Hazlitt (London: G. Bell, 1902), 326. See also Hart, "The Teaching of Luther and Calvin about Ordinary Work: 1. Martin Luther (1483–1546)." In addition, Luther appreciated alchemy for the way alchemical transformations could be seen as allegories of Christian truths. For more on this and related themes, see Nummedal, "Alchemy & Religion in Christian Europe" and references therein. For more on alchemical signification, see Crisciani, "Opus and Sermo."

[63]For an accessible account of Glauber's thinking, see Walton, *Genesis and the Chemical Philosophy*, 97–100.

[64]Pope Francis, *Laudato Si': On Care for Our Common Home* (Vatican City, Italy: Libreria Editrice Vaticana, 2015), 102.

[65]Contributions that do address this issue include Foster and Slade, "Studying Chemistry as a Christian"; Walhout, "How Does Chemistry Impact Human Society?"; Leegwater, "Loving the Kingdom"; Contakes, "Wisdom in and for Chemistry"; and Darren Brouwer, "Better Living through Chemistry? Why Chemists Need to Be Humanists," *Comment* (2016), published electronically June 23, 2016, https://comment.org/better-living-through-chemistry/.

[66]Bruce T. Moran, *Paracelsus: An Alchemical Life* (London, UK: Reaktion Books, 2019); and Walton, "Genesis and the Chemical Philosophy."

[67]The latter might be especially timely, given the increased recognition of the importance of water analysis in the wake of the Flint water crisis. Michael Torrice, "How Lead Ended Up in Flint's Tap Water," *Chemical & Engineering News* 94, no. 7 (2015), https://cen.acs.org/articles/94/i7/Lead-Ended-Flints-Tap-Water.html. A popular account is Anna Clark, *The Poisoned City: Flint's Water and the American Urban Tragedy* (New York: Picador, 2019).

[68]For connections between Faraday's faith and applied science, see G. N. Cantor, *Michael Faraday: Sandemanian and Scientist: A Study of Science and Religion in the Nineteenth Century* (London, UK: Macmillan, 1993): 193–95.

[69]Wiley had a Stone-Campbell restorationist and abolitionist upbringing. Some starting points for an exploration of Wiley's thought and work include Philip J. Hilts, *Protecting America's Health: The FDA, Business, and One Hundred Years of Regulation* (New York: Alfred A. Knopf, 2003); Deborah Blum, *The Poison Squad: One Chemist's Single-Minded Crusade for Food Safety at the Turn of the Twentieth Century* (London, UK: Penguin Press, 2018); Harvey Washington Wiley, *An Autobiography* (Emmaus, PA: Rodale Books, 1957); and for a critical appraisal of the value of Wiley's efforts, see Jonathan Rees, *The Chemistry of Fear: Harvey Wiley's Fight for Pure Food* (Baltimore, MD: Johns Hopkins University Press, 2021).

[70]For an assessment of the needs, see National Research Council (U.S.) Committee on Grand Challenges for Sustainability in the Chemical Industry, *Sustainability in the Chemical Industry—Grand Challenges and Research Needs: A Workshop Report* (Washington, DC: The National Academies Press, 2006). For an interesting survey of the state of the chemical industry's sustainability efforts through 2012, see Eric Johnson, *Sustainability in the Chemical Industry* (Dordrecht, The Netherlands: Springer, 2012).

[71]Francis, *Laudato Si'*.

[72]The Greek Orthodox Archdiocese of America, *For the Life of the World: Toward a Social Ethos of the Orthodox Church*, https://www.goarch.org/social-ethos?fbclid=IwAR2RSPrgYRhPfAgT9p2iIQkd9wqtOYJ74Gtjnpmyq9xYdxshwqr6U1FJFiY, §71 and §76.

[73]For an introduction, see the essays in Forrest Clingerman and Kevin J. O'Brien, eds., *Theological and Ethical Perspectives on Climate Engineering: Calming the Storm. Religious Ethics and Environmental Challenges* (Lanham, MD: Lexington Books, 2016); Christopher J. Preston, ed., *Engineering the Climate: The Ethics of Solar Radiation Management* (New York: Lexington Books, 2012); Clingerman, "Geoengineering, Theology, and the Meaning of Being Human"; Forrest Clingerman and Gary Gardner, eds., *Playing God? Multi-faith Responses to the Prospect of Climate Engineering* (Highland Park, NJ: GreenFaith, 2018); Celia Deane-Drummond, Sigurd Bergmann and Bronislaw Szerszynski, eds., *Technofutures, Nature and the Sacred: Transdisciplinary Perspectives* (Surrey, UK: Ashgate Publishing, 2015); and Meric A. Srokosz, "Geoengineering or Planet Hacking?," *Perspectives on Science and Christian Faith* 66, no. 4 (2014): 213–20, https://www.asa3.org/ASA/PSCF/2014/PSCF12-14Srokosz.pdf.

[74]The American Chemical Society maintains many excellent resources on green chemistry at https://www.acs.org/content/acs/en/greenchemistry.html. In addition, see the classic text, Paul T. Anastas and John Charles Warner, *Green Chemistry: Theory and Practice* (Oxford, UK: Oxford University Press, 1998); and M. Lancaster, *Green Chemistry: An Introductory Text,* 2nd edition (Cambridge, UK: Royal Society of Chemistry, 2010).

[75]George D. Bennett, "A Comparison of Green Chemistry to the Environmental Ethics of the Abrahamic Religions," *Perspectives on Science and Christian Faith* 60, no. 1 (2008): 16–25, https://www.asa3.org/ASA/PSCF/2008/PSCF3-08Bennett.pdf; George D. Bennett, "Green Chemistry as an Expression of Environmental Ethics," in *Green Chemistry for Environmental Sustainability,* ed. Sanjay Kumar Sharma and Ackmez Mudhoo (New York: CRC Press, 2010): 105–25.

[76]Some of the issues were helpfully outlined by Ian Barbour half a century ago: Ian G. Barbour, *Technology, Environment, and Human Values* (New York: Praeger, 1980); and ___, *Ethics in an Age of Technology* (San Francisco, CA: HarperSanFrancisco, 1993).

[77]For a well-referenced summary of the main issues from a pro-development perspective, see Edd S. Noell and Stephen L. S. Smith, "Economics, Theology, and a Case for Economic Growth: An Assessment of Recent Critiques," *Christian Scholar's Review* 50, no. 1 (2020): 5–23, https://christianscholars.com/economics-theology-and-a-case-for-economic-growth-an-assessment-of-recent-critiques/. Additional considerations from Christians involved in land management and energy development may be found in Ian Hore-Lacy, *Responsible Dominion: A Christian Approach to Sustainable Development* (Vancouver, BC: Regent College Publishing, 2006); and Richard W. Gijsbers, "Christian Voices in the Environment Debate," *Christian Perspectives on Science and Technology (ISCAST Online Journal)*, no. 11 (2016), https://iscast.org/uncategorized/christian-voices-in-the-environment-debate/. For a survey of different visions that influence how people address environmental issues, see Jennifer Clapp and Peter Dauvergne, *Paths to a Green World: The Political Economy of the Global Environment*, 2nd edition (Cambridge, MA: The MIT Press, 2011), 227–49.

[78]In most cases, caring for the environment and economic wellbeing are interconnected. This can be seen in Francis, *Laudato Si'*.

[79]For examples, see Grace A. Lasker and Edward J. Brush, "Integrating Social and Environmental Justice into the Chemistry Classroom: A Chemist's Toolbox," *Green Chemistry Letters and Reviews* 12, no. 2 (2019): 168–177, https://doi.org/10.1080/17518253.2019.1609602; Grace A. Lasker et al., "Social and Environmental Justice in the Chemistry Classroom," *Journal of Chemical Education* 94, no. 8 (2017): 983–87, https://doi.org/10.1021/acs.jchemed.6b00968; Aren E. Gerdon, "Connecting Chemistry to Social Justice in a Seminar Course for Chemistry Majors," *Journal of Chemical Education* 97, no. 12 (2020): 4316–20, https://doi.org/10.1021/acs.jchemed.0c01043; and Fiona Case, "Chemists on a Mission," *Chemistry World* (February 20, 2014), https://www.chemistryworld.com/features/chemists-on-a-mission/7105.article.

[80]For an extremely short overview of biblical teachings on justice from an Anabaptist perspective, see Christopher D. Marshall, *The Little Book of Biblical Justice: A Fresh Approach to the Bible's Teachings on Justice* (Intercourse, PA: Good Books, 2005). For a popular-level Presbyterian one, see Timothy Keller, *Generous Justice: How God's Grace Makes Us Just* (New York: Dutton, 2010). Others include Walter Brueggemann, *The Prophetic Imagination* (Minneapolis, MN: Fortress Press, 2018); and Cynthia L. Westfall and Bryan R. Dyer, eds., *The Bible and Social Justice: Old Testament and New Testament Foundations for the Church's Urgent Call* (Hamilton, ON: McMaster Divinity College Press, 2015). For issues of economic justice that can be applied to chemistry, see Stephen Mott and Ronald J. Sider, "Economic Justice: A Biblical Paradigm," *Transformation* 17, no. 2 (2000): 50–63, https://www.jstor.org/stable/43070241; and Richard A. Horsley, *Covenant Economics: A Biblical Vision of Justice for All* (Louisville, KY: Westminster John Knox Press, 2009).

[81]For a historical overview, see Francois Jarrige, *Contamination of the Earth: A History of Pollutions in the Industrial Age* (Cambridge, MA: MIT Press, 2021), 280–86.

[82]Christopher W. Tessum et al., "Inequity in Consumption of Goods and Services Adds to Racial & Ethnic Disparities in Air Pollution Exposure," *Proceedings of the National Academy of Sciences* 116, no. 13 (2019): 6001–6, https://www.pnas.org/doi/full/10.1073/pnas.1818859116.

[83]Jill Johnston and Lara Cushing, "Chemical Exposures, Health, and Environmental Justice in Communities Living on the Fenceline of Industry," *Current Environmental Health Reports* 7, no. 1 (2020): 48–57, https://doi.org/10.1007/s40572-020-00263-8.

[84]Nathan Donley et al., "Pesticides and Environmental Injustice in the USA: Root Causes, Current Regulatory Reinforcement and a Path Forward," *BMC Public Health* 22, no. 1 (2022): article number 708, https://doi.org/10.1186/s12889-022-13057-4.

[85]Erika Raley, Lesliam Quirós-Alcalá, and Elizabeth C. Matsui, "Chemical Exposures via Personal Care Products and the Disproportionate Asthma Burden among the U.S. Black Population," *The Journal of Allergy and Clinical Immunology: In Practice* 9, no. 9 (2021): 3290–92, https://doi.org/10.1016/j.jaip.2021.04.063.

[86]Gwen Ottinger and Benjamin R. Cohen, eds., *Technoscience and Environmental Justice: Expert Cultures in a Grassroots Movement* (Cambridge, MA: MIT Press, 2011).

[87]For an example, see Steve Lerner, *Diamond: A Struggle for Environmental Justice in Louisiana's Chemical Corridor* (Cambridge, MA: MIT Press, 2006); and Amy M. Hay, "A New Earthly Vision: Religious Community Activ-

ism in the Love Canal Chemical Disaster," *Environmental History* 14, no. 3 (2009): 502–26, https://www.jstor.org/stable/40608502. For an important early example of a church seeking to address racial and economic justice issues associated with chemistry, see Commission for Racial Justice, "Toxic Wastes and Race in the United States: A National Report on the Racial and Socio-Economic Characteristics of Communities with Hazardous Waste Sites" (New York: United Church of Christ, 1987), https://www.nrc.gov/docs/ML1310/ML13109A339.pdf. The follow up report is Robert D. Bullard, Paul Mohai, Robin Saha, and Beverly Wright, Toxic Waste and Race at Twenty, 1987–2007 (Cleveland, OH: Justice and Witness Ministries, United Church of Christ, 2007), https://www.ucc.org/wp-content/uploads/2021/03/toxic-wastes-and-race-at-twenty-1987-2007.pdf. In addition, although I could find no evidence that she was religious, the polaroid chemist Caroline Hunter also sought to leverage the influence of church members in her efforts to convince her employer to stop supplying the materials that the Apartheid regime in South Africa used for producing passbooks to track black South Africans. For more on Hunter, see Ainissa Ramirez, *The Alchemy of Us: How Humans and Matter Transformed One Another* (Cambridge, MA: The MIT Press, 2021), 108–118; and Michael McCanne, "When Polaroid Workers Fought Apartheid," *Dissent* (August 14, 2020), https://www.dissentmagazine.org/online_articles/when-polaroid-workers-fought-apartheid. On the ripple effect of Polaroid's divestment in South Africa, see Eric J. Morgan, "The World Is Watching: Polaroid and South Africa," *Enterprise & Society* 7, no. 3 (2006): 520–49, https://www.jstor.org/stable/23700835.

[88]The most common examples involve pharmaceuticals. For a particularly gripping opportunity, now resolved, that chemists had to address, see Albert Sjoerdsma and Paul J. Schechter, "Eflornithine for African Sleeping Sickness," *The Lancet* 354, no. 9174 (1999): 254, https://doi.org/10.1016/S0140-6736(05)66324-6.

[89]For an introduction to some of the problems, see Jarrige, *Contamination of the Earth*, 306–10; Jennifer Clapp, *Toxic Exports: The Transfer of Hazardous Waste from Rich to Poor Countries* (Ithaca, NY: Cornell University Press, 2001); David N. Pellow, *Resisting Global Toxics: Transnational Movements for Environmental Justice* (Cambridge, MA: MIT Press, 2007); and Yogi Hale Hendlin, "Surveying the Chemical Anthropocene," *Environment and Society: Advances in Research* 12, no. 1 (2021): 181–202, https://doi.org/10.3167/ares.2021.120111. For an evangelical perspective, see Cynthia D. Moe-Lobeda, *Resisting Structural Evil: Love as Ecological-Economic Transformation* (Minneapolis, MN: Fortress Press, 2013).

[90]Among the many references addressing the Bhopal disaster, good places to start are Ingrid Eckerman, *The Bhopal Saga: Causes and Consequences of the World's Largest Industrial Disaster* (Hyderabad, India: Universities Press, 2005); and Edward Broughton, "The Bhopal Disaster and Its Aftermath: A Review," *Environmental Health* 4, no. 1 (2005): 6, https://doi.org/10.1186/1476-069X-4-6.

[91]William A. Suk et al., "Environmental Pollution: An Under-recognized Threat to Children's Health, Especially in Low- and Middle-Income Countries," *Environmental Health Perspectives* 124, no. 3 (2016): A41–A45, https://doi.org/10.1289/ehp.1510517.

[92]Daniel Berman and Suerie Moon, eds., *Fatal Imbalance: The Crisis in Research and Development for Drugs for Neglected Diseases* (Geneva, Switzerland: Médecins sans Frontières Access to Essential Medicines Campaign and the Drugs for Neglected Diseases Working Group, 2001), https://msfaccess.org/fatal-imbalance-crisis-research-and-development-drugs-neglected-diseases; and Marco Luchetti, "Global Health and the 10/90 Gap," *British Journal of Medical Practitioners* 7, no. 4 (2014): a731, accessed June 24 2022, https://www.researchgate.net/publication/270048142_Global_health_and_the_1090_gap.

[93]Jorge José Ferrer, "*Research as a Restorative Practice: Catholic Social Teaching and the Ethics of Biomedical Research,*" in M. T. Lysaught and M. McCarthy, eds., *Catholic Bioethics and Social Justice* (Collegeville, MN: Liturgical Press Academic, 2018), 363–75.

[94]Michael J. Saks and Jonathan J. Koehler, "The Coming Paradigm Shift in Forensic Identification Science," *Science* 309, no. 5736 (2005): 893, in part quoting Andre A. Moenssens, "Novel Scientific Evidence in Criminal Cases: Some Words of Caution," *Journal of Criminal Law & Criminology* 84, no. 1 (1993), https://scholarlycommons.law.northwestern.edu/jclc/vol84/iss1/. Chemists tempted to think that issues like this are confined to forensic science would do well to read Walter R. Hearn, "Whole People and Half-Truths," in *The Scientist and Ethical Decision*, ed. Charles Hatfield (Downers Grove, IL: InterVarsity Press, 1973), 83–96.

[95]Here it should be noted that the faithful work of forensic chemists receives little attention while the effects of malpractice and malfeasance can be public and devastating. For a summary of the issues facing forensic science, see Suzanne Bell et al., "A Call for More Science in Forensic Science," ed. Solomon H. Snyder, The Johns Hopkins University School of Medicine, Baltimore, MD, *Proceedings of the National Academy of Sciences* 115, no. 18 (2018): 4541–44, https://www.pnas.org/doi/pdf/10.1073/pnas.1712161115; and National Research Council of the National Academies, *Strengthening Forensic Science in the United States: A Path Forward* (Washington, DC: The National Academies Press, 2009). For the Patricia Stallings case, see Stanley Fields and Mark Johnston, "Proteins Are the Workhorses of the Cell: Misdiagnosis of a Metabolic Malady," in *Genetic Twists of Fate* (Cambridge, MA: MIT Press, 2010), 21–32. For an introduction to the Annie Dookhan case, see Sam Kean, "Why Did Annie Dookhan Lie?," *Distillations* (2021), published electronically, July 13, 2021, https://www.sciencehistory.org/distillations/why-did-annie-dookhan-lie.

[96]For notes on these practices and their connection with the accessibility of chemistry careers, see Celia Henry Arnaud, "Clearing the Way for Reform of General Chemistry Classes," *Chemical and Engineering News* 99, no. 19 (2021), https://cen.acs.org/education/undergraduate-education/Clearing-way-reform-general-chemistry/99/i19; Marjorie Caserio et al., "Responses to Changing Needs in U.S. Doctoral Education," *Journal of Chemical Education* 81, no. 12 (2004): 1698–1703, https://doi.org/10.1021/ed081p1698.1; Michael T. Ashby and Michelle A. Maher, "The Mantra of Graduate Education Reform: Why the Prayers Aren't Answered," *Journal of Chemical Education* 95, no. 7 (2018): 1083–85, https://doi.org/10.1021/acs.jchemed.8b00354; Ale Palermo et al., *Breaking the Barriers: Women's Retention and Progression in the Chemical Sciences* (Cambridge, UK: Royal Society of Chemistry, 2018), https://www.rsc.org/globalassets/02-about-us/our-strategy/inclusion-diversity/womens-progression/media-pack

/v18_vo_inclusion-and-diversity-_womans-progression_report-web-.pdf; Linda Wang and Andrea Widener, "Confronting Sexual Harassment in Chemistry," *Chemical and Engineering News* 95, no. 37 (2017), https://cen.acs.org/articles/95/i37/Confronting-sexual-harassment-chemistry.html; and Roald Hoffmann, "Tension in Chemistry and Its Contents," *Accountability in Research* 22, no. 6 (2015): 330–45, https://doi.org/10.1080/08989621.2015.1047708. For an example of issues that Christian chemists in academic chemistry navigate that contributed to one leaving the profession, see Hearn, "Whole People and Half-Truths," in *The Scientist and Ethical Decision*, ed. Hatfield, 83–96.

[97]Ibid.

[98]Guillermo Foladori and Noela Invernizzi, "Nanotechnology for the Poor?," *PLOS Medicine* 2, no. 8 (2005): e280, https://doi.org/10.1371/journal.pmed.0020280.

[99]For these see Jeffrey Kovac, *The Ethical Chemist: Professionalism and Ethics in Science* (Upper Saddle River, NJ: Pearson Prentice Hall, 2004).

[100]For an important recent summary of key social issues, see Jan Mehlich et al., "The Ethical and Social Dimensions of Chemistry: Reflections, Considerations, and Clarifications," *Chemistry–A European Journal* 23, no. 6 (2017): 1210–18, https://doi.org/10.1002/chem.201605259. A textbook that addresses these issues is Jan Mehlich, *Good Chemistry: Methodological, Ethical, and Social Dimensions* (London, UK: Royal Society of Chemistry, 2021). For a collection of ethical cases, see Joachim Schummer and Tom Børsen, eds, *Ethics of Chemistry: From Poison Gas to Climate Engineering* (London, UK: World Scientific Publishing, 2021). Most of these have been reproduced from special issues of *Hyle—International Journal for the Philosophy of Chemistry* between 2016 and 2020. Hyle published a similar special issue in 2001 that is worth consulting. Notably, it includes Joachim Schummer, "Ethics of Chemical Synthesis," *HYLE—International Journal for the Philosophy of Chemistry* 7, no. 2 (2001): 103–24, https://www.hyle.org/journal/issues/7/schummer.htm. Additional general treatments of the social dimensions of chemistry include Luciano Caglioti, *The Two Faces of Chemistry* (Cambridge, MA: MIT Press, 1985); Roald Hoffmann, *The Same and Not the Same* (New York: Columbia University Press, 1995); ___, "Tension in Chemistry and Its Contents"; and Jeffrey Kovac, "Ethics in Science: The Unique Consequences of Chemistry," *Accountability in Research* 22, no. 6 (2015): 312–29, https://doi.org/10.1080%2F08989621.2015.1047709.

[101]For a well-intentioned example that raises important issues about chemical sensitivity while badly mishandling the chemistry involved, see Martha McLaughlin, *Chemicals and Christians: Compassion and Caution* (Enumclaw, WA: Redemption Press, 2020).

[102]Normand M. Laurendeau, "An Energy Primer: From Thermodynamics to Theology," *Zygon*® 46, no. 4 (2011): 890–914, https://doi.org/10.1111/j.1467-9744.2011.01222.x.

[103]One caveat is that DDT was not a case of unforeseeable harms but of moving forward without considering foreseeable harms. Afterwards, cases of DDT's adverse effects were documented but widely ignored—at least prior to the publication of Rachel Carson's *Silent Spring*. For details, see Thomas R. Dunlap, *DDT, Silent Spring, and the Rise of Environmentalism: Classic Texts* (Seattle, WA: University of Washington Press, 2008).

[104]Mehlich et al., "The Ethical and Social Dimensions of Chemistry"; Claus Jacob and Adam Walters, "Risk and Responsibility in Chemical Research: The Case of Agent Orange," *HYLE—International Journal for the Philosophy of Chemistry* 11, no. 2 (2005): 147–66, https://www.researchgate.net/publication/282676052_Risk_and_Responsibility_in_Chemical_Research_The_Case_of_Agent_Orange; and many of the cases in Schummer and Børsen, eds., *Ethics of Chemistry*. Respondents might also consider the intersection between chemistry, business ethics, and law, and some of the issues raised in Apostolos K. Gerontas, "Review of 'Ethics of Chemistry: From Poison Gas to Climate Engineering' by Joachim Schummer & Tom Børsen, eds. World Scientific Publishing, Singapore, 2021," *Substantia* 5, no. 2 (2021): 165–67, https://doi.org/10.36253/Substantia-1372.

[105]For an outstanding summary of the issues, see Anne Chapman, *Democratizing Technology: Risk, Responsibility and the Regulation of Chemicals* (London, UK: Routledge, 2016). On risk analysis, see Joseph V. Rodricks, *Calculated Risks: The Toxicity and Human Health Risks of Chemicals in Our Environment,* 2nd edition (Cambridge, UK: Cambridge University Press, 2007). On the application of chemical risk-management in industrial chemistry and chemical engineering, see David Shonnard et al., "Green Engineering: Integration of Green Chemistry, Pollution Prevention, and Risk-Based Considerations," chap. 6 in *Kent and Riegel's Handbook of Industrial Chemistry and Biotechnology,* 11th edition, ed. James A. Kent (New York: Springer, 2007), 210–70.

[106]Niels Henrik Gregersen, "Risk and Religion: Toward a Theology of Risk Taking," *Zygon*® 38, no. 2 (2003): 355–76, https://doi.org/10.1111/1467-9744.00504.

[107]Exodus 21:28–36.

[108]Proverbs 22:3; 27:12.

[109]Matthew 26:41. Notice also Jesus's salutary mention of prudence in building and diplomacy when discussing the cost of discipleship in Luke 14:25–34.

[110]For an example, see Donald M. Bruce, "Playing Dice with Creation: How Risky Should the New Genetics Be?," in *Reordering Nature: Theology, Society, and the New Genetics,* ed. Celia Deane-Drummond and Bronislaw Szerszynski, with Robin Grove-White (London, UK: T & T Clark, 2003): 151–64; and Donald Bruce, *Modifying Creation? GM Crops and Foods: A Christian Perspective* (Carlisle, UK: Paternoster Press, 2001), 61–83.

[111]For an example of theological concerns over differential impacts of climate mitigation on the poor, see Arianne van Andel, "Geoengineering, Sacrifice, and the Scale of Love," in Clingerman and Gardner, eds., *Playing God? Multi-faith Responses to the Prospect of Climate Engineering*, 43–48.

[112]Amy Donovan, "Finding Security in the Risk Society," *Cambridge Papers* 24, no. 4 (2015): 1–6.

[113]R. T. Mullins and Emanuela Sani, "Open Theism and Risk Management: A Philosophical and Biological Perspective," *Zygon*® 56, no. 3 (2021): 591–613, https://doi.org/10.1111/zygo.12723.

[114]Susan Bratton, "Marine Contaminants, Environmental Chemistry and Toxicology: The Virtues of Christian Vigilance and Accountability," *Christian Scholar's Review*, *Christ Animating Learning Blog*, posted October 21, 2021, https://christianscholars.com/marine-contaminants-environmental-chemistry-and-toxicology-and-the-virtues-of-christian-vigilance-and-accountability/. Some of the ideas therein were expounded in more detail in an earlier article that more superficially addressed chemicals: Susan Power Bratton, "The Precautionary Principle and the

Book of Proverbs: Toward an Ethic of Ecological Prudence in Ocean Management," *Worldviews: Global Religions, Culture, and Ecology* 7, no. 3 (2003): 253–73, https://doi.org/10.1163/156853503322709137.

[115]For an example, see The Advisory Committee on Social Witness, PCUSA, "The Precautionary Principle: Managing Technological Risks to Protect Humanity and Our Planet," Presbyterian Church USA, 2018.

[116]I deliberately use riskiness here to indicate a combination of both probabilistic risk and potential for harm. For more on this point, see Chapman, *Democratizing Technology*, 84–86.

[117]Jan Mehlich, "Chemistry and Dual Use: From Scientific Integrity to Social Responsibility," *Helvetica Chimica Acta* 101, no. 9 (2018): e1800098, https://doi.org/10.1002/hlca.201800098.

[118]Catherine Jefferson, "Protein Engineering," in *Innovation, Dual Use, and Security: Managing the Risks of Emerging Biological and Chemical Technologies,* ed. Jonathan B. Tucker (Cambridge, MA: MIT Press, 2012), 119–32.

[119]Gerald L. Epstein, "DNA Shuffling and Directed Evolution," in *Innovation, Dual Use, and Security*, ed. Tucker, 101–16.

[120]Jonathan B. Tucker, "Combinatorial Chemistry and High-Throughput Screening," in *Innovation, Dual Use, and Security*, ed. Tucker, 89–100.

[121]Amy E. Smithson, "Chemical Micro Process Devices," in *Innovation, Dual Use, and Security*, ed. Tucker, 235–48.

[122]Jamie Durrani, "Drug Discovery AI That Developed New Nerve Agents Raises Difficult Questions," *Chemistry World* (March 31, 2022), https://www.chemistryworld.com/news/drug-discovery-ai-that-developed-new-nerve-agents-raises-difficult-questions/4015462.article.

[123]Roald Hoffman, *Should've*, http://www.roaldhoffmann.com/shouldve.

[124]Lorraine Cuddeback-Gedeon, "On Plastic Straws and the Preferential Option," *Catholic Moral Theology,* July 27, 2018, https://catholicmoraltheology.com/on-plastic-straws-and-the-preferential-option/.

[125]Although it is incidental to the main themes of this paper, for an interesting discussion of the soil chemistry behind Jesus's description of believers as salt, see Eugene P. Deatrick, "Salt, Soil, Savior," *The Biblical Archaeologist* 25, no. 2 (1962): 41–48, https://doi.org/10.2307/3210991. An even-broader-ranging discussion of chemical substances in the scriptures is Mary Elvira Weeks, "An Exhibit of Chemical Substances Mentioned in the Bible," *Journal of Chemical Education* 20, no. 2 (1943): 62–76, https://doi.org/10.1021/ed020p63. On perfume in the Bible, see Charles Sell, *Perfume in the Bible* (London, UK: Royal Society of Chemistry, 2019).

[126]This number is likely considerable given that a half million people work in chemistry or chemistry-related industries in the USA alone.

[127]This phenomenon is sometimes termed "organized irresponsibility." See Ulrich Beck, "Risk Society Revisited: Theory, Politics and Research Programmes," in *The Risk Society and Beyond: Critical Issues for Social Theory*, ed. Barbara Adam, Ulrich Beck, and Joost van Loon (London, UK: SAGE Publications Ltd, 2000), 211–29. For a concrete chemical example, see Jacob and Walters, "Risk and Responsibility in Chemical Research."

[128]One observer even described the actual marketing campaign as "very similar to the role of the apple in the Bible." See Matthew Boyle, "Convincing Women in China They're Too Hairy," *Bloomberg Businessweek,* October 2012, published electronically October 18, 2012, http://www.businessweek.com/articles/2012-10-18/convincing-women-in-china-theyre-too-hairy; https://www.sfgate.com/business/article/Veet-s-hairy-strategy-for-Chinese-women-3969580.php. The company was trying to gain market share in China's $1.5 trillion dollar SHEconomy, in which there is growing demand for cosmetic products. See Li Xiaoyang, "Sheconomy surges as females show greater financial clout and independence," *Beijing Review* (April 9, 2021), https://www.bjreview.com/Business/202104/t20210409_800243136.html.

[129]This is from a report by Richard Fernandez as reported in Tom Wells, *The War Within: America's Battle over Vietnam* (La Vergne, TN: Open Road Distribution, 2016), 452. The book in question is almost certainly Joseph F. Fletcher, *Situation Ethics: The New Morality* (Philadelphia, PA: Westminster Press, 1966). For a case of another Christian business leader who struggled over the ethics of his company's actions, see Benjamin Ross and Steven Amter, *The Polluters: The Making of Our Chemically Altered Environment* (London, UK: Oxford University Press, 2010), 68 and 146.

[130]American Chemical Society, "Chemical Professional's Code of Conduct," 2007, https://www.acs.org/content/dam/acsorg/careers/profdev/ethics/chemical-professionals-code-of-conduct-2012.pdf; American Chemical Society, "Global Chemists' Code of Ethics," 2016, https://www.acs.org/content/dam/acsorg/global/international/scifreedom/global-chemists-code-of-ethics-fi-2016.pdf; and American Institute of Chemists, "Code of Ethics," 1983, https://www.theaic.org/about_ethics.html.

[131]Schummer and Børsen, eds., *Ethics of Chemistry*.

[132]One starting place is Michael Freemantle, "Chemistry & War: How Chemistry Underpinned the Great War," *Chemistry International* 38, no. 1 (2016): 8–12, https://www.degruyter.com/document/doi/10.1515/ci-2016-0106/html?lang=en#:~:text=Various%20types%20of%20chemical%20warfare,such%20as%20bromine%20or%20iodine. For more extensive treatments, see Michael Freemantle, *Gas! Gas! Quick Boys! How Chemistry Changed the First World War* (Stroud, UK: Spellmount, 2013); and ___, *The Chemists' War: 1914–1918* (Cambridge, UK: Royal Society of Chemistry, 2015).

[133]For a summary of how such views featured in early chemical weapons research, see Hugh R. Slotten, "Humane Chemistry or Scientific Barbarism? American Responses to World War I Poison Gas, 1915–1930," *The Journal of American History* 77, no. 2 (1990): 476–98, https://doi.org/10.2307/2079180. Some starting points for the vast literature on the morality of weapons research are Joachim Schummer, "Ethics of Chemical Weapons Research: Poison Gas in World War One," *HYLE – International Journal for Philosophy of Chemistry* 24 (2018): 5–28, http://www.hyle.org/journal/issues/24-1/schummer.pdf; Jeffrey Kovac, "The Ethics of Chemical Research (1)," *Bulletin for the History of Chemistry* 41, no. 1/2 (2016): 56–63; and Stephen M. Contakes and Taylor Jashinsky, "Ethical Responsibilities in Military-Related Work: The Case of Napalm," *HYLE – International Journal for the Philosophy of Chemistry* 22, no. 1 (2016): 31–53, https://www.hyle.org/journal/issues/22-1/contakes.htm.

[134]For an example, see Kylie Miller and Stephen M. Contakes, "Crystallographer, Quaker, Pacifist, & Trailblazing Woman of Science: Kathleen Lonsdale's Christian Life 'Lived Experimentally,'" *God and Nature* (Summer 2014), https://

godandnature.asa3.org/essay-crystallographer-quaker-pacifist--trailblazing-woman-of-science-kathleen-lonsdalersquos-christian-life-lived-experimentallyrdquo-by-kylie-miller-and-stephen-m-contakes.html.

[135]For a review of issues and opportunities, see C. J. Rhodes, "Endangered Elements, Critical Raw Materials and Conflict Minerals," *Science Progress* 102, no. 4 (2019): 304–50, https://doi.org/10.1177/0036850419884873. For a recent example of chemists addressing this issue, see Celia Henry Arnaud, "Fingerprinting Conflict Minerals," *Chemical and Engineering News* 90, no. 18 (2012), published electronically April 30, 2012, https://cen.acs.org/articles/90/i18/Fingerprinting-Conflict-Minerals.html; Frank Melcher et al., "Fingerprinting of Conflict Minerals: Columbite-Tantalite ('Coltan') Ores," *SGA News* 23 (2008): 1, 7–14, http://www.e-sga.org/fileadmin/sga/newsletter/news23/SGANews23.pdf; and Alireza K. Somarin, "Geochemical Fingerprinting of Conflict Minerals Using Handheld XRF: An Example for Coltan, Cassiterite, and Wolframite Ores from Democratic Republic of the Congo, Africa," *Minerals* 9, no. 9 (2019): 564, https://doi.org/10.3390/min9090564.

[136]Some Christians did publicly object to early poison gas work. For an example, see Anonymous, "Christian Conscience and Poison Gas," *The Literary Digest* (1921): 38.

[137]Haber seems to have employed a mix of just war and "Supreme Emergency" similar to those that Second World War leaders offered to justify civilian bombing. For those see Michael Walzer, *Just and Unjust Wars: A Moral Argument with Historical Illustrations,* 4th edition (New York: Basic Books, 2006). Among the numerous books detailing chemists' involvement in chemical warfare, some good places to start are Freemantle, *The Chemists' War;* ___, *Gas! Gas! Quick Boys!*; and L. F. Haber, *The Poisonous Cloud: Chemical Warfare in the First World War* (Oxford, UK: Oxford University Press, 1986). For an account that explores the racially charged and medically and environmentally insensitive context in which mustard gas was used in the United States, see Susan Lynn Smith, *Toxic Exposures: Mustard Gas and the Health Consequences of World War II in the United States* (New Brunswick, NJ: Rutgers University Press, 2017). For an interesting study of US chemists' moral understanding of First World War chemical research, see Gilbert F. Whittemore, "World War I, Poison Gas Research, and the Ideals of American Chemists," *Social Studies of Science* 5, no. 2 (1975): 135–63, and Slotten, "Humane Chemistry or Scientific Barbarism?" For a more formal ethical analysis, see Schummer, "Ethics of Chemical Weapons Research."

[138]Contakes and Jashinsky, "Ethical Responsibilities in Military-Related Work."

[139]On chemists operating the holocaust's only privately run concentration camp, see Josiah Ellis DuBois, *The Devil's Chemists: 24 Conspirators of the International Farben Cartel Who Manufacture Wars* (Boston, MA: Beacon Press, 1952); John Cornwell, *Hitler's Scientists: Science, War, and the Devil's Pact* (New York: Viking, 2003); and Diarmuid Jeffreys, *Hell's Cartel: IG Farben and the Making of Hitler's War Machine* (New York: Metropolitan Books, 2008). On chemists' involvement in providing warning malodorant-free Zyklon B for use in the gas chambers, see Peter Hayes, *From Cooperation to Complicity: Degussa in the Third Reich* (Cambridge, UK: Cambridge University Press, 2005).

[140]Pierre Joffroy, *A Spy for God: The Ordeal of Kurt Gerstein* (New York: Grosset & Dunlap, 1972); Saul Friedländer, *Kurt Gerstein: The Ambiguity of Good* (New York: Knopf, 1972); and Valerie Hébert, "Disguised Resistance? The Story of Kurt Gerstein," *Holocaust and Genocide Studies* 20, no. 1 (2006): 1–33, https://doi.org/10.1093/hgs/dcj001.

[141]DuBois, *The Devil's Chemists*, 40. For a case of a pharmacist who claimed to have maintained a "Christian worldview," see Patricia Posner, *The Pharmacist of Auschwitz: The Untold Story of Victor Capesius* (United Kingdom: Crux Publishing, 2017), 128.

[142]On the role of theology in the justification of atrocities by Christians in the military, see David A. Harrisville, *The Virtuous Wehrmacht: Crafting the Myth of the German Soldier on the Eastern Front, 1941–1944* (Ithaca, NY: Cornell University Press, 2021), 90–125. On the theological and social factors which contributed, see Robert P. Ericksen, *Theologians under Hitler: Gerhard Kittel, Paul Althaus, and Emanuel Hirsch* (New Haven, CT: Yale University Press, 1985); and Doris L. Bergen, *Twisted Cross: The German Christian Movement in the Third Reich* (Chapel Hill, NC: University of North Carolina Press, 1996).

[143]For accessible treatments of Coulson's social thought, see David Hawkin and Eileen Hawkin, *The Word of Science: Religious and Social Thought of C. A. Coulson* (London, UK: Epworth Press, 1989); Arie Leegwater, "Charles Alfred Coulson: Mixing Methodism and Quantum Chemistry," in *Eminent Lives in Twentieth-Century Science and Religion,* 2nd edition, ed. Nicolaas A. Rupke (Frankfurt am Main, DEU: Peter Lang AG, 2009), 73–103; C. A. Coulson, *Science, Technology, and the Christian* (New York: Abingdon Press, 1960); and ___, *Science and Christian Belief* (Chapel Hill, NC: University of North Carolina Press, 1955).

[144]While most popular biology and physics books (and *Physics Today*) highlight new scientific developments, a large proportion of popular chemistry books (and many articles in *Chemistry World* and *Chemical & Engineering News*) celebrate chemistry's impacts. Among the more provocatively titled are Sharon Bertsch McGrayne, *Prometheans in the Lab: Chemistry and the Making of the Modern World* (New York: McGraw-Hill, 2001); K. C. Nicolaou and T. Montagnon, *Molecules That Changed the World: A Brief History of the Art and Science of Synthesis and Its Impact on Society* (Weinheim, Germany: Wiley-VCH, 2008); and John Emsley, *Better Looking, Better Living, Better Loving: How Chemistry Can Help You Achieve Life's Goals* (Weinheim, Germany: Wiley-VCH, 2007).

[145]Margaret Sanger, *The Pivot of Civilization* (London, UK: Humanities Press, 2022); Sanger was quoting the "Great Agnostic" Robert Ingersoll's anti-religion address, "What Is Religion?," which may be found in *The Works of Robert G. Ingersoll* (New York: The Dresden Publishing Company, 1902).

[146]Morrison, *Man in a Chemical World*. It is not clear to what extent Morrison was responsible for the illustrations, given his later authorship of works of Christian apologetics. For more details, see Andrew Ede, "Abraham Cressy Morrison in the Agora: Bringing Chemistry to the Public," *HYLE – International Journal for Philosophy of Chemistry* 12, no. 2 (2006): 193–214. For Morrison's apologetics work, see Morrison, *Man Does Not Stand Alone (Seven Reasons Why a Scientist Believes in God).*

[147]Peter Burke, *The New Cambridge Modern History. Vol. XIII, Companion Volume* (Cambridge, UK: Cambridge University Press, 1994); and Drees, "Playing God? Yes.," 652.

[148]Drees, "Playing God? Yes.," 645.

[149]On the role of Dow, Du Pont, Bakelite, and other companies in promoting consumerism, see Hillary S. Kativa, "It's

a Mad, Mad World: Dow and the Age of Consumption," *Distillations* (2015), published electronically September 22, 2015, https://www.sciencehistory.org/distillations/its-a-mad-mad-world-dow-and-the-age-of-consumption. A sober analysis of the ad campaigns reveals that they were not necessarily driven by chemistry but involved wider business aims. See Andrew M. Shanken, "Better Living: Toward a Cultural History of a Business Slogan," *Enterprise & Society* 7, no. 3 (2006): 485–519, https://doi.org/10.1093/es/khl001. The relationship between consumerism and idolatry forms a theme in Francis, *Laudato Si',* and is developed in suggestive ways in Richard Lints, *Identity and Idolatry* (Downers Grove, IL: InterVarsity Press, 2015): 158–72.

[150]This quote from Frank von Hippel is taken from the dust jacket to Daniel Charles, *Between Genius and Genocide: The Tragedy of Fritz Haber, Father of Chemical Warfare* (London, UK: Jonathan Cape, 2005). For Christian evaluations of Fritz Haber, see Daniel Charles, "The Idol of Progress," *Sojourners Magazine* (2006): 24–27, https://sojo.net/magazine/august-2006/idol-progress; Vern Thiessen, *Einstein's Gift* (Toronto, ON: Playwrights Canada Press, 2003); and Brouwer, "Better Living through Chemistry."

[151]Fritz Stern, "Fritz Haber: Flawed Greatness of Person and Country," *Angewandte Chemie International Edition* 51, no. 1 (2012): 50–56, https://doi.org/10.1002/anie.201107900.

[152]"Throwaway Living," *Life* (August 1, 1955): 43–44, https://books.google.com/books?id=xlYEAAAAMBAJ&pg=PA#v=onepage&q&f=false.

[153]For a discussion of how materialist conceptions of reality can fuel ecological exploitation, see Alister McGrath, *The Reenchantment of Nature: The Denial of Religion and the Ecological Crisis* (New York: Image, 2013).

[154]Carl Djerassi, *This Man's Pill: Reflections on the 50th Birthday of the Pill* (Oxford, UK: Oxford University Press, 2003), 293.

[155]Michael C. Banner, *The Ethics of Everyday Life: Moral Theology, Social Anthropology, and the Imagination of the Human* (Oxford, UK: Oxford University Press, 2014), 9. An analysis of technology similar to Banner's is Brian Brock, *Christian Ethics in a Technological Age* (Grand Rapids, MI: Eerdmans, 2010).

[156]For calls to focus on practices in science and religion dialogue, see Matthew Walhout, "Looking to Charles Taylor and Joseph Rouse for Best Practices in Science and Religion," *Zygon*® 45, no. 3 (2010): 558–74, https://doi.org/10.1111/j.1467-9744.2010.01113.x; and James K. A. Smith, "Our Chalcedonian Moment: Christological Imagination for Scientific Challenges," chapter 10 in *Christ and the Created Order: Perspectives from Theology, Philosophy, and Science*, vol. 2, ed. Andrew B. Torrance and Thomas H. McCall (Grand Rapids, MI: Zondervan, 2018), 179–93. Note that it may be possible to read more than one theological narrative into a given technology. For an analysis of Christian responses to carbon capture and solar radiation management as falling between concerns over hubris and optimism over humanity's ability to control nature, see Forrest Clingerman, "Between Babel and Pelagius: Religion, Theology and Geoengineering," in *The Ethics of Solar Radiation Management*, ed. Christopher J. Preston (New York: Lexington Books, 2012), 201–19. For a third metaphor, see the discussion of geoengineering as an opportunity to pastor Earth in Matthew Kearnes, "Miraculous Engineering and the Climate Emergency: Climate Modification as Divine Economy," in *Technofutures, Nature and the Sacred: Transdisciplinary Perspectives,* ed. Celia Deane-Drummond, Sigurd Bergmann, and Bronislaw Szerszynski (Surrey, UK: Ashgate Publishing, 2015), 219–37. In terms of the green chemistry movement, respondents might consider whether it reinforces those secular "mastery of nature"-approaches to the environment which arose in the early modern period as explained in James C. Ungureanu, "Retrieving an Ancient Sacramental Ecology, Part 3: 'On the Dignity of Man' and the New World," *Credo* (June 11, 2021), https://credomag.com/2021/06/retrieving-an-ancient-sacramental-ecology-part-3-on-the-dignity-of-man-and-the-new-world/. In terms of risk discourses a helpful start has been made by Tom McLeish. See McLeish, *Faith and Wisdom in Science*, 248–59; and ___, "The Science-and-Religion Delusion," in *Christ and the Created Order: Perspectives from Theology, Philosophy, and Science*, vol. 1, ed. Andrew B. Torrance and Thomas H. McCall (Grand Rapids, MI: Zondervan, 2018), 305–25.

[157]For example, chemists generally employ fuzzy concepts such as oxidation states and hard and soft acid-base theory and employ simple bonding models such as Lewis structures, valence bonds, and linear combinations of "hydrogenlike" atomic orbitals to describe molecular structure. Even the concept of a chemical bond itself is flexible. For more examples of this tendency in chemistry, see Michael Weisberg, Paul Needham, and Robin Hendry, "Philosophy of Chemistry," *The Stanford Encyclopedia of Philosophy* (Spring 2019 Edition), ed. Edward N. Zalta, https://plato.stanford.edu/archives/spr2019/entries/chemistry/. For the conceptual difficulties involved in developing chemically useful quantum mechanical models for chemical systems, see Gavroglou Kōstas and Ana Simões, *Neither Physics nor Chemistry: A History of Quantum Chemistry* (Cambridge, MA: MIT Press, 2012). For a philosophical analysis that addresses the main issues but, in my judgment, goes a bit too far in denying realism in chemistry, see Bensaude-Vincent and Simon, *Chemistry: The Impure Science*, 201–14.

[158]This is not to say that this absolutely precludes ideological challenges. For an example of an ideological challenge to chemistry and its applications to science-faith dialogue, see Stephen M. Contakes and Garrett Johnson, "Suggestions for Thinking and Talking about Science and Religion from the Soviet Resonance Controversy, a Chemical Counterpoint to Lysenkoism," *Perspectives on Science and Christian Faith* 65, no. 4 (2013): 219–32, https://www.asa3.org/ASA/PSCF/2013/PSCF12-13Contakes.pdf.

[159]The classical discussion of methodological parallels between theological and scientific reasoning is Nancey C. Murphy, *Theology in the Age of Scientific Reasoning* (Ithaca, NY: Cornell University Press, 1993).

[160]Among these, the writings of John Hedley Brooke, David Knight, Lawrence Principe, and William R. Newmann are perhaps the most useful starting points. These include Brooke, "Chemistry"; ___, "Chemistry with and without God," in *Science without God? Rethinking the History of Scientific Naturalism*, ed. Peter Harrison and Jon H. Roberts (Oxford, UK: Oxford University Press, 2019), 110–29; ___, *Science and Religion: Some Historical Perspectives* (Cambridge, UK: Cambridge University Press, 1991); ___, "Science and Theology in the Enlightenment," in *Religion and Science: History, Method, Dialogue*, ed. W. M. Richardson and W. J. Wildman (London, UK: Routledge, 1996); ___ and G. N. Cantor, "Improving on Nature?," in *Reconstructing Nature: The Engagement of Science and Reli-*

gion (Oxford, UK: Oxford University Press, 2000): 314–46; Knight, "Chemical Sciences and Natural Theology"; ___, "Chemistry," in *Encyclopedia of Science and Religion*, ed. Jay Wentzel van Huyssteen (New York: Macmillan Reference, 2003), 103–6; ___, *Ideas in Chemistry: A History of the Science* (New Brunswick, NJ: Rutgers University Press, 1992); Peter Harrison, "Theology and the Meaning of Matter in the Early Modern Period," in *Matter and Meaning: Is Matter Sacred or Profane?,* ed. Michael Fuller (Newcastle upon Tyne, UK: Cambridge Scholars, 2010), 40–56; John Henry, "Theology and the Meaning of Matter"; Principe, *The Secrets of Alchemy*; ___ and Robert Boyle, *The Aspiring Adept: Robert Boyle and His Alchemical Quest: Including Boyle's "Lost" Dialogue on the Transmutation of Metals* (Princeton, NJ: Princeton University Press, 1998); and William R. Newman, *Promethean Ambitions: Alchemy and the Quest to Perfect Nature* (Chicago, IL: University of Chicago Press, 2004).

[161]For a broad overview of Early Christian thinking about nature and its relevance for contemporary applications, see Paul M. Blowers, *Drama of the Divine Economy: Creator and Creation in Early Christian Theology and Piety* (Oxford, UK: Oxford University Press, 2013).

[162]Here it should be noted that there is no sharp dividing line in time at which chemistry became differentiated from alchemy. For more on this point, see Principe, *The Secrets of Alchemy*; William R. Newman, *Atoms and Alchemy* (Chicago, IL: University of Chicago Press, 2010); and William R. Newman and Lawrence M. Principe, *Alchemy Tried in the Fire: Starkey, Boyle, and the Fate of Helmontian Chymistry* (Chicago IL: University of Chicago Press, 2010).

[163]It would detract from the purposes of this essay to present the vast literature on the history of atomism. An accessible, if slightly dated, starting point is Bernard Pullman, *The Atom in the History of Human Thought* (Oxford, UK: Oxford University Press, 1998).

[164]Modern chemical atoms differ markedly from the indivisible classical atoms of Epicurus, Leucippus, and Democritus; unlike classical atoms, they can explain the structure and properties of matter at the molecular level. A failure to understand this has led to significant misunderstandings about early Christian objections to atomism. In fact, to the extent the church fathers addressed atomism (which was not often) they rightly objected that atomic thinkers (namely, Epicureans) lacked the sort of coherent theory of chemical structure and bonding needed to actually explain chemistry. Similar objections also undergirded many nineteenth-century chemists' reluctance to fully accept Dalton's ideas as true. The classic statement of ateleological Epicurean atomism is Titus Lucretius Carus, *On the Nature of Things,* trans. Martin Ferguson Smith (Indianapolis, IN: Hackett Publishing, 2001). For the early Christian reception of atomism, see John W. Haas Jr., "Atoms and Atheism: The Changing Ways That Christians Have Viewed the Nature of Matter," American Scientific Affiliation, June 2007, http://www.asa3.org/ASA/topics/Physical%20Science/atomism.html; and Karissa D. Carlson, "The Other 'Atom' in Christianity and Science," *God and Nature* (Fall 2014) and the references therein, https://godandnature.asa3.org/essay-the-other-atom-in-christianity-and-science-by-karissa-d-carlson.html. On the connection between teleology and atomism, see David Sedley, *Creationism and Its Critics in Antiquity* (Berkeley, CA: University of California Press, 2008). For early Christian engagement with ateleological thinking, see Arthur Stanley Pease, "Caeli Enarrant," *The Harvard Theological Review* 34, no. 3 (1941): 163–200, https://www.jstor.org/stable/1508031.

[165]On the rehabilitation of the vacuum and its consequences for the development of atomism, see Edward Grant, *Much Ado about Nothing: Theories of Space and Vacuum from the Middle Ages to the Scientific Revolution* (Cambridge, UK: Cambridge University Press, 1981); and Andrew Pyle, *Atomism and Its Critics: From Democritus to Newton* (Bristol, UK: Thoemmes Press, 1997).

[166]Gassendi's program was part of a larger revival of interest in classical learning (humanism) and mechanistic explanations (the mechanical philosophy). For more on Gassendi, see Lynn Sumida Joy, *Gassendi the Atomist: Advocate of History in an Age of Science* (Cambridge, UK: Cambridge University Press, 1987). On the Christian appropriation of Epicureanism more generally, see Ada Palmer, "Humanist Dissemination of Epicureanism," in *The Oxford Handbook of Epicurus and Epicureanism*, ed. Phillip Mitsis (Oxford, UK: Oxford University Press, 2020), https://doi.org/10.1093/oxfordhb/9780199744213.013.34. For more on the early modern rehabilitation of atomism, see William B. Ashworth Jr., "Christianity and the Mechanistic Universe," in *When Science & Christianity Meet*, ed. David C. Lindberg and Ronald L. Numbers (Chicago, IL: University of Chicago Press, 2003), 61–84; and Carlson, "The Other 'Atom' in Christianity and Science."

[167]Stoichiometric chemistry research would culminate in the recognition of the laws of mass conservation by Lavoisier, definite proportions by Proust, and multiple proportions by Dalton, and ultimately atomic-molecular theory.

[168]Frank M. Turner, "Ancient Materialism and Modern Science: Lucretius among the Victorians," in *Contesting Cultural Authority: Essays in Victorian Intellectual Life* (Cambridge, UK: Cambridge University Press, 1993), 262–83. For a modern example of a highly selective revisionist history, see Victor J. Stenger, *God and the Atom* (Amherst, NY: Prometheus Books, 2013).

[169]Hebrews 13:7.

[170]Moran, *Paracelsus;* Debus, *The Chemical Philosophy;* Walton, *Genesis and the Chemical Philosophy*; Charles Webster, *Paracelsus: Medicine, Magic and Mission at the End of Time* (New Haven, CT: Yale University Press, 2008); and Walter Pagel, *Paracelsus: An Introduction to Philosophical Medicine in the Era of the Renaissance,* 2nd, revised edition (Basel, Switzerland: Karger, 1982).

[171]Debus, *The Chemical Philosophy,* 117–26.

[172]Walter Pagel, *Jan Baptista van Helmont: Reformer of Science and Medicine* (Cambridge, UK: Cambridge University Press, 2002); and Walton, *Genesis and the Chemical Philosophy.*

[173]Walton, Ibid.

[174]For starting points, see Hunter, *Boyle: Between God and Science*; R. Hooykaas, *Robert Boyle: A Study in Science and Christian Belief* (Lanham, MD: University Press of America, 1997); Davis, "A Priest Serving in Nature's Temple"; and Principe, *The Aspiring Adept.*

[175]The literature on Dalton's religious views is sparse. For starting points, see A. L. Smyth, *John Dalton, 1766–1844: A Bibliography of Works by and about Him,* 2nd edition (London, UK: Routledge, 2020).

[176]For starting points, see Cantor, *Michael Faraday: Sandemanian and Scientist*; Colin A. Russell, "Faraday Paper No. 13: Science and Faith in the Life of Michael Faraday," Cambridge, UK: The Faraday Institute for Science and

Religion, 2007, https://www.faraday.cam.ac.uk/shop/paper-13-science-and-faith-in-the-life-of-michael-faraday/; and the references in Stephen M. Contakes, "Faraday, Michael," in *Dictionary of Christianity and Science*, ed. Paul Copan et al. (Grand Rapids, MI: Zondervan, 2017), 279–80.

[177]Contakes and Kyle, "Josiah Parsons Cooke Jr." Cooke's work was well received by some leading Protestant thinkers, but as a Unitarian, he might also be considered to have a more complicated relationship with orthodox Christianity.

[178]For starting points on Draper's thought, see James C. Ungureanu, *Science, Religion, and the Protestant Tradition: Retracing the Origins of Conflict* (Pittsburgh, PA: University of Pittsburgh Press, 2019); Donald Fleming, *John William Draper and the Religion of Science* (New York: Octagon Books, 1972); and Stephen M. Contakes, "Draper, John," in *Dictionary of Christianity and Science*, ed. Copan et al., 190–91.

[179]Alan J. Rocke, *The Quiet Revolution: Hermann Kolbe and the Science of Organic Chemistry* (Berkeley, CA: University of California Press, 1993), 39–41, and Brooke, "Chemistry with and without God."

[180]Judah Ginsberg, "George Washington Carver: Chemist, Teacher, Symbol" (Washington, DC: American Chemical Society, 2006), https://www.acs.org/content/dam/acsorg/education/whatischemistry/landmarks/carver/george-washington-carver-commemorative-booklet.pdf; and Gary R. Kremer, *George Washington Carver: In His Own Words,* 2nd edition (Columbia, MO: University of Missouri Press, 2017).

[181]Charles M. A. Stine, *A Chemist and His Bible*, 3rd edition (Philadelphia, PA: Sunday School Times, 1947).

[182]Agustí Nieto-Galan, *The Politics of Chemistry: Science and Power in Twentieth-Century Spain* (Cambridge, UK: Cambridge University Press, 2019), 126–35; and Antoni Malet, "José María Albareda (1902–1966) and the Formation of the Spanish Consejo Superior de Investigaciones Científicas," *Annals of Science* 66, no. 3: 307–32, https://doi.org/10.1080/00033790902961819.

[183]E. F. Caldin, "The Structure of Chemistry in Relation to the Philosophy of Science," *Hyle – International Journal for the Philosophy of Chemistry* 8, no. 2 (2002): 103–21, http://www.hyle.org/journal/issues/8-2/caldin.pdf.

[184]Bernhard Witkop, *Biographical Memoir of Percy Lavon Julian* (Washington, DC: National Academy of Sciences, 1980). See also the essays by and about Julian in *The Chemist* 42, no. 3 (1965), https://archive.org/details/sim_chemist_1965-03_42_3.

[185]The literature on Polanyi is too vast to do justice here. For starting points, see the references in Stephen M. Contakes, "Polanyi, Michael," in *Dictionary of Christianity and Science*, ed. Copan et al., 519–21.

[186]Miller and Contakes, "Crystallographer, Quaker, Pacifist."

[187]Hawkin and Hawkin, *The Word of Science*; and Leegwater, "Charles Alfred Coulson."

[188]Alister McGrath, "Arthur Peacocke (1924–2006)," in *Science and Religion: A New Introduction,* 2nd edition (Chichester, UK: Wiley-Blackwell, 2010). 209–12; and T. A. Smedes, "Arthur Peacocke," in *The Blackwell Companion to Science and Christianity*, ed. J. B. Stump and Alan G. Padgett (Chichester, UK: Wiley-Blackwell, 2012), 589–99.

[189]Peter J. T. Morris, "Professor C. A. Russell CChem FRSC, 1928–2013," Royal Society of Chemistry, Obituaries of RSC Members, 2010–2015, https://www.rsc.org/membership-and-community/member-obituaries/2010-2015/professor-c-a-russell-cchem-frsc/.

[190]Alister McGrath, "Brief Biography," http://alistermcgrath.weebly.com/biography.html.

[191]John B. Goodenough, *Witness to Grace* (Baltimore, MD: PublishAmerica, 2008).

[192]Richard Greene, "Renowned Chemist Is a Bold Witness for Christ," *Decision* (March 1, 2019), https://decisionmagazine.com/renowned-chemist-is-a-bold-witness-for-christ/.

[193]A slightly dated starting point is Stephen M. Contakes, "Henry F. Schaefer III," in *Dictionary of Christianity and Science*, ed. Copan et al., 585–87.

[194]Jonathan Howard Fisher, "Gish, Duane," in *Dictionary of Christianity and Science*, ed. Paul Copan et al., 332–33.

[195]One starting point is Stephen M. Contakes, "Behe, Michael," in *Dictionary of Christianity and Science*, ed. Paul Copan et al., 62–64.

[196]Fazale "Fuz" Rana, President and CEO of Reasons to Believe, https://reasons.org/team/fazale-rana.

[197]Eberlin, *Foresight*.

[198]Karl E. Johnson and Keith Yoder, "Chemist as Complementarian: An Interview with Robert C. Fay," *Perspectives on Science and Christian Faith* 61, no. 4 (2009): 233–39, https://www.asa3.org/ASA/PSCF/2009/PSCF12-09Johnson.pdf.

[199]Troy Van Voorhis, *Certainty: Is Science All You Need?* (Cambridge, MA: The Veritas Forum, 2014).

[200]David A. Vosburg, "The Personal Journey of a Faith-Filled Scientist," *The Claremont Ekklesia: A Journal of Christian Thought at the Claremont Colleges* (Fall 2013), https://issuu.com/claremontekklesia/docs/the-claremont-ekklesia-fall-2013/2; also on *BioLogos* (September 24, 2013), https://biologos.org/personal-stories/the-personal-journey-of-a-faith-filled-scientist; and David A. Vosburg and Kate Vosburg, *Jesus, Beginnings, and Science: A Guide for Group Conversation* (Farmville, VA: Pier Press, 2017).

[201]Sy Garte, *The Works of His Hands: A Scientist's Journey from Atheism to Faith* (Grand Rapids, IL: Kregel Publications, 2019).

[202]Ashutosh Jogalekar, "Jesuits, Science and a Pope with a Chemistry Degree: A Productive Pairing?," *Scientific American* (March 13, 2013), https://blogs.scientificamerican.com/the-curious-wavefunction/jesuits-science-and-a-pope-with-a-chemistry-degree-a-productive-pairing/.

[203]Leegwater, "A Brief Excursion in Chemistry." Examples include Leegwater, "Charles Alfred Coulson"; Contakes and Kyle, "Josiah Parsons Cooke"; Nieto-Galan, *The Politics of Chemistry*; and Malet, "José María Albareda."

[204]The debate is framed by H. Richard Niebuhr, *Christ and Culture* (New York: Harper & Brothers, 1956) which has been nuanced in D. A. Carson, *Christ and Culture Revisited* (Cambridge, UK: Eerdmans, 2013); with additional influential perspectives in Stanley Hauerwas and William H. Willimon, *Resident Aliens: Life in the Christian Colony* (Nashville, TN: Abingdon Press, 1989); and James Davison Hunter, *To Change the World: The Irony, Tragedy, and Possibility of Christianity in the Late Modern World* (Oxford, UK: Oxford University Press, 2010).

[205]For more on work and vocation, see Miroslav Volf, *Work in the Spirit: Toward a Theology of Work* (New York: Oxford University Press, 1991); Darrell Cosden, *A Theology of Work: Work and the New Creation* (Eugene, OR: Wipf & Stock, 2006); Timothy Keller, *Every Good Endeavor: Con-*

necting Your Work to God's Work (New York: Dutton, 2012); and Scott Waalkes, "Rethinking Work as Vocation," *Christian Scholar's Review* 44, no. 2 (2015): 135–53.

[206]On chemistry as a political activity, see Nieto-Galan, *The Politics of Chemistry*. For science as politics more generally, see Sheila Jasanoff, *States of Knowledge: The Co-Production of Science and Social Order* (London, UK: Routledge, 2004). For Anabaptist, Lutheran, Black Church, Calvinist, and Catholic Natural Law perspectives on Christian engagement with politics, see Amy E. Black, ed., *Five Views on the Church and Politics* (Grand Rapids, MI: Zondervan, 2015).

[207]This incident also awaits adequate exploration. The contours of the debate may be gleaned from my account of the Dow Napalm controversy in Contakes and Jashinsky, "Ethical Responsibilities in Military-Related Work"; along with insights into the religious perspectives of the main actors given in E. N. Brandt, *Chairman of the Board: A Biography of Carl A. Gerstacker* (East Lansing, MI: Michigan State University Press, 2003), 93–103, 206; and Wells, *The War Within*, 449–52. For a concise summary of Dow's position, see "1968 Dow Chemical Response to Its Production of Napalm," *Resistance and Revolution: The Anti-Vietnam War Movement at the University of Michigan, 1965–1972*, http://michiganintheworld.history.lsa.umich.edu/antivietnamwar/items/show/139.

[208]For more on this point, see Kristen Deede Johnson, "Justice, Creation, and New Creation: In Christ All Things Hold Together," in *Creation and Doxology: The Beginning and End of God's Good World,* ed. G. Hiestand and Todd Wilson (Downers Grove, IL: IVP Academic, 2018), 183–200.

[209]For more on Bacon's context, see Power, *Roger Bacon and the Defence of Christendom.* Note also that the moral status of chemical weapons was in flux prior to the twentieth century. Some early twentieth-century advocates even claimed chemical weapons would be more humane than conventional weapons and recently it has even been argued that there is a taboo over chemical weapons rather than a considered moral judgment. See Richard M. Price, *The Chemical Weapons Taboo* (Ithaca, NY: Cornell University Press, 1997).

[210]Peter J. Bowler, "Ideology and Futurology in Early 20th-Century Britain: Wells, Haldane, Bernal, and Their Critics," in *Defending the Faith: Global Histories of Apologetics and Politics in the Twentieth Century,* ed. Todd Weir and Hugh McLeod (Oxford, UK: Oxford University Press, 2020), published online at British Academy Scholarship Online, January 11, 2021, https://doi.org/10.5871/bacad/9780197266915.001.0001; and J. D. Bernal, *The World, the Flesh and the Devil: An Enquiry into the Future of the Three Enemies of the Rational Soul* (London, UK: Kegan Paul, Trench & Trübner, 1929).

[211]P. W. Atkins, "Awesome Versus Adipose: Who Really Works Hardest to Banish Ignorance?," *Free Inquiry* 18, no. 2 (1998): 18; ___, *The Creation* (Oxford, UK: W.H. Freeman, 1981); ___, *Creation Revisited* (London, UK: Penguin Books, 1994); and ___, *On Being: A Scientist's Exploration of the Great Questions of Existence* (Oxford, UK: Oxford University Press, 2011).

[212]Harry Kroto, "An Essay on My Present 'Skeptical' Philosophical Perspective and 'Good Enough Theories,'" The Nobel Prizes 1996, ed. Tore Frängsmyr (1997), https://www.sheffield.ac.uk/kroto/legacy/life/opinions.

[213]L. Cardellini, "Looking for Connections: An Interview with Roald Hoffmann," *Journal of Chemical Education* 84, no. 10 (2007): 1634.

[214]William B. Jensen, *Frankenstein's Cat and Other Assorted Lectures on Skepticism and Secular Humanism,* rev. edition (Cincinnati, OH: The Epicurean Press, 2015).

[215]Reino Virtanen, *Marcelin Berthelot: A Study of a Scientist's Public Role* (Lincoln, NE: University of Nebraska, 1965).

[216]Arrhenius put forward an early argument for panspermia in "The Transmission of Life through the Universe," *The Monist* 18, no. 2 (1908): 161–75, https://doi.org/10.5840/monist190818224, as well as secular views of the universe as infinite in "Infinity of the Universe," *The Monist* 21, no. 2 (1911): 161–73, https://doi.org/10.5840/monist191121228.

[217]Caspar Hakfoort, "Science Deified: Wilhelm Ostwald's Energeticist World-View and the History of Scientism," *Annals of Science* 49 (1992): 525–44, https://doi.org/10.1080/00033799200200441. Among the more interesting of Ostwald's works are Wilhelm Ostwald, *Monism as the Goal of Civilization,* ed. The International Committee of Monism (Leipzig, DEU: Druck der Spamerschen, 1913); and Wilhelm Ostwald, *Monistische Sonntagspredigten, Reihe 1–5* [Monist Sunday Sermons] (Leipzig, DEU: Unesma, 1911–1916).

[218]For examples, see Colin A. Russell, *Edward Frankland: Chemistry, Controversy and Conspiracy in Victorian England* (Cambridge, UK: Cambridge University Press, 2003); Robert E. Schofield, *The Enlightenment of Joseph Priestley: A Study of His Life and Work from 1733 to 1773* (University Park, PA: Pennsylvania State University Press, 1997); ___, *The Enlightened Joseph Priestley: A Study of His Life and Work from 1773 to 1804* (University Park, PA: Pennsylvania State University Press, 2004); John Brooke, "Joining Natural Philosophy to Christianity: The Case of Joseph Priestley," *Heterodoxy in Early Modern Science and Religion,* ed. John Brooke and Ian Maclean (Oxford, UK: Oxford University Press, 2005), 319–36; and David Knight, *Humphrey Davy: Science & Power* (Cambridge, UK: Cambridge University Press, 1996).

[219]For an attempt to engage materialism in chemistry, see Greta Bryson, "Is There Meaning beyond the Biomolecular?," in *Not Just Science: Questions Where Christian Faith and Natural Science Intersect,* ed. Dorothy F. Chappell and E. David Cook (Grand Rapids, MI: Zondervan, 2005), 234–42. For an analysis of noncognitive elements in organized skepticism, see Jay A. Labinger, "Organized Skepticism, Naive Methodism, and Other -ISMS," *Foundations of Chemistry* 8, no. 2 (2006): 97–110, https://doi.org/10.1007/s10698-004-3531-2.

[220]Drees, "Playing God? Yes."

[221]Noah J. Efron, "The Meeting of Science and Religion in Real Life," *The BLOG*, published electronically January 28, 2011, and updated May 25, 2011, http://www.huffingtonpost.com/noah-efron/what-science-religion-are_b_814295.html.

[222]To my knowledge, this connection has not been explored in the literature, although some authors have explored the connection between plastics and materialist culture, albeit sometimes in only analogical terms. See Dave Bookless, "Plastic Theology," *A Rocha Blog,* July 31, 2018, https://blog.arocha.org/en/plastic-theology/; and Lints, *Identity and Idolatry*, 153–65.