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In This Issue …

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

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Editorial

James C. Peterson

All Together Now

It is a delight to see insightful essays in my inbox, whether long anticipated or out of the blue. Over the last seven issues of this journal, I have been describing in editorials what is present in those essays that have potential for publication. Even the best are rarely submitted as ready in every aspect, but the standards listed below can serve as a helpful checklist to take into account when preparing a piece to offer. The editorial team looks for these characteristics, investing its time to guard and serve the reader's time.

On Mission

The Christian tradition is the world's largest global movement. More than two billion people call themselves Christians. Combining sheer numbers with two thousand years of reflection and analysis in the tradition, there are rich resources to refine and launch thoughtful exploration. The sciences are ever extending their insight and reach as well. These two interact at a myriad of interesting and important points. Explaining and furthering that dialogue is the core mission of *PSCF*. The journal cannot publish everything for everyone, but it does seek to report and move forward the most constructive work in this interdisciplinary field. The selected articles serve people interested in how the life-giving Christian tradition interacts with the best of science.

Informed

Someone should be able to see in the essay and endnotes what is available on the topic for and against the author's thesis, including from the previous discussion in this journal. The relevant dialogue on the topic, past and current, will be in full view. This brings up to speed the reader who may be an expert in a different field, and it keeps the article appropriately focused and modest.

Few journals are able to draw, as *PSCF* does, from so many disciplines for the most complex problems such as origins or the nature of being human. There is unusual opportunity here for cross-disciplinary insight and correction, though that is not a claim to offer the final word. While each essay will show mastery of the involved disciplines—no easy task in an interdisciplinary journal—there will always be more to discover and discern. It is not unusual for substantially contrary articles to appear in the same issue of the journal or in subsequent issues as the discussion develops. The first word in the journal's title, "Perspectives," is intentionally plural. At the leading edge of inquiry, multiple views are almost always in play. Publication means that the approach merits attention, not that it is the end of the discussion. Those who are already absolutely sure probably do not fully understand what they are discussing. Those who are not as sure are probably more aware of what is being considered. Or, at least, so it seems to me.

New

There is always more to learn. There can be recurring questions and themes, but each new article brings forward some aspect worthy of consideration that was not part of the literature before. The author has taken into account and explained the byways on the subject, and now establishes a new contribution. The contribution could be in the conclusion, or in an argument, or in a way of explaining the issue, but there will always be something new.

New approaches or insights may be disruptive. They may be perceived as undermining other careful work. Yet they may present an opportunity to understand better—which is, after all, the point. The role of this journal is not to repeat what is already commonplace or to articulate a party line.

Editorial

Challenges brought by the essays may call for a change in perspective or at least an improvement. Such might not always be comfortable, but it should be appreciated and compelling. Those who publish this journal hold to the historic and life-giving Christian faith because it continues to make the most sense. Challenges and implications are welcome and can be fruitful.

The long-fulfilled expectation is that the readers of this journal will delight not only in supportive evidence for what has convinced them before, but also that they will find here some ideas, or ways of description, that lead to fresh perspectives. If they find a new proposal here persuasive, they will have learned something. If they do not find a colleague's proposal here persuasive, they will hopefully write and submit a better reading for the journal's blind peer-review process and potential publication. We would all be better for it.

Valuable Contribution

Sometimes an article will offer a grand synthesis, but more often it will offer something more modest in scope. An article that thoroughly works through a focused but important point can make a real contribution to the scholars drawn to this journal from a wide range of fields. While this diverse audience is a distinctive strength, it does mean that forty pages on a detail of an eighteenth-century scientist are not likely to carry interest beyond the five other historians thinking about that particular scientist's work. Yet, even a study that is minutely focused can make a fruitful contribution to the journal's full audience if the author notes how it illustrates or illuminates an insight of broader import.

Indeed, if it appears here, the proffered view has been tested and found compelling by experts in the involved fields. The journal is not published as instantly as a blog; rather, it is carefully verified to be more considered and worthy of trust. It cannot be as extended in argument as a monograph, but it is more timely, with many authors and approaches presented. In a search-engine world, we do not lack for input. The problem is not in having enough volume. The need is to sort through copious information to find what is potentially worthy of attention and to verify its accuracy. The editors, coordinators, peer reviewers, and board members of *PSCF* invest countless hours in evaluating what is offered to the journal, and in scanning for what else should be considered to launch the further investigations of our readers.

Clear

There is no point in publishing an article that meets every standard above but then presents in a way that is difficult to decode. While our readers are erudite, they cannot know the insider's jargon in every specialty. Time is always short for people in demand, and that is the life of our readers. Authors should be sure that their case includes the tools and explanations that might help readers to follow the argument. The content in this field will usually be challenging, but the communication of it should not be any more difficult than it has to be. The work in this journal is too important to be left inchoate.

In Summary

The contents of this journal can be counted on to be on task, informed, new, valuable, and clear. Contributions with these facets are most welcome. *PSCF* offers a forum where there is a good chance that readers can be oriented and launched beyond old mistakes into promising new territory. That such a head start can be found here is a gift to be appreciated and put to good further work.

James C. Peterson, *Editor* ★

Article

Suggestions for Thinking and Talking about Science and Religion from the Soviet Resonance Controversy, a Chemical Counterpoint to Lysenkoism

Stephen M. Contakes

Garrett Johnson

Stephen M. Contakes and Garrett Johnson

The Soviet resonance controversy was a chemical counterpart to Lysenkoism in which Soviet ideologues charged that Linus Pauling's resonance concept was hostile to Marxism. We study it here to illustrate the role of social factors in science-faith dialogue. Because Soviet chemists were attentive to ideological dimensions of the controversy, they were not only willing to engage in public dialogue but also offered a response that decoupled the scientific aspects of resonance from ideological hostility, largely by modifying how they talked about delocalized chemical bonds. This enabled them to criticize and reject a pseudoscientific alternative to resonance and to avoid a Lysenko-like takeover of theoretical chemistry without threatening the wider Soviet social system. A potential lesson is that Christians in science who wish to promote fellow believers' acceptance of their work would do well to account for the role of ideology in religiously motivated antimainstream science efforts.

One of us recently had the opportunity to examine a "creation-based" physical science textbook published by a Christian educational ministry.[1] Although the book used atoms to discuss matter, the author considered it important to point out that the scanning tunneling microscopy (STM) images commonly cited as evidence for their existence do not really show atoms. As the book's author correctly noted, the images are reconstructions calculated from the variation in the current between the microscope probe and surface, and there can be legitimate questions about their interpretation.[2] The author went beyond a salutary critique of naive scientific realism, however, in claiming that the images "may or may not be right" as they depended on two "big 'ifs'"—the "correctness" of quantum theory and the "theory" governing electron flow between the STM probe and tip.

At first glance, these rhetorical dismissals seemed surprising given that atoms, quantum mechanics, and theories of electron flow are hardly controversial in Christian circles. However, they are easier to understand if one considers that the parents who adopt such

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textbooks might have broad-ranging concerns over the implications of science's view of the world and its privileged status in contemporary culture.

Recent historical scholarship has done much to show how social factors can influence individual and communal responses to scientific claims.[3] For example, the Catholic response to Galileo is now known to be anything but an instance of religious bigotry standing in the way of well-established science. Instead, it represents a "Reformation-sensitive" response to the reasonable but as yet unestablished scientific hypotheses of a scientist who was also making theological claims about how the Bible should be interpreted. Similarly, Victorian Christian anxiety over Darwinian evolution, when present, had more to do with how evolution seemed to undercut eighteenth-century natural theology arguments and challenge contemporary perceptions of human uniqueness than it had to do with any feelings that evolution was fundamentally incompatible with Christianity. Furthermore, how particular communities responded depended heavily on local conditions and personalities.[4]

The influence of social factors is also apparent in evangelical approaches to evolution today. According to the sociologists Raymond Eve and Francis Harrold,

> [Young earth creationists] and their opponents tend not to differ over competing theories within the same intellectual framework, but in their most profound understandings of reality, religion, American society, and the nature of the scientific enterprise.[5]

Eve and Harrold also point out that young earth creationism has the characteristics of a movement ideology.[6] First, its ultimate aims are moral in that they are aimed at reforming science, education, and other elements of society around particular literal approaches to the Christian scriptures. Second, creationism "reevaluates the worth" of its adherents against that of its opponents by viewing them as defenders of truth and a morally good society over against the "villains" of secularism and liberal theology. Third, it has internally credible goals which include both tangible realizable short-term goals, such as enhancing the plausibility of the Christian message for evangelistic or apologetics purposes, and more nebulous, difficult-to-attain goals, such as establishing creationist ideas as the dominant contemporary intellectual framework. The intelligent design movement has similar characteristics, particularly in its "wedge strategy" for defeating "scientific materialism and its destructive moral, cultural, and political legacies" and replacing it with "the 'theistic' understanding that nature and human beings are created by God."[7] Religious opposition to mainstream climate change science can also fit this pattern when environmental claims, such as global warming, are identified with "antichristian" or "antihuman" forces in a larger culture war.[8]

In short, some religious groups oppose scientific ideas because they perceive them as part of an attack on authentically Christian ways of thinking about and living in the world.[9] Because of this, it should come as little surprise that these groups identify their views on these issues with orthopraxis as well as orthodoxy, promote them via the rhetoric of popular apologetics, and enforce them using group identity taboos. Although unhelpful episodes can arise from this situation, it is important to recognize that these groups are engaging science in a broad-ranging dialogue involving the scriptures, gospel, church life, and the world. It is just that little of this takes place in the rarefied atmosphere of academic inquiry. Instead, it is embedded in the myriad of individual and communal practices that characterize everyday Christian living.[10]

Nevertheless, apologists for mainstream science have been understandably more concerned with narrow interests such as defending the teaching of evolution in schools. Consequently, they rarely engage their opponents at the level of competing social visions, theological assumptions, and community practices. While this unfortunately leaves the 46 percent of Americans who do not believe in human evolution estranged in part from mainstream science,[11] it also provides an opportunity for Christians in the sciences to exercise spiritual care for their fellow believers' intellectual integrity and the witness of the church. As one step toward promoting that care, we suggest that a close study of the history of science and secular ideology might suggest potential pastoral strategies for alleviating American Christians' fear of scientific ideas. Here we consider one such interaction—the Soviet resonance controversy of the late 1940s and 1950s,[12] in which the concept of resonance used in organic and theoretical chemistry was charged with being incompatible with Soviet ideology. It is significant because it was the only Soviet ideological controversy in which the scientists involved were reasonably successful in defending the intellectual integrity of their discipline.[13]

Before we begin, however, we wish to make several things clear. First, we use the term "ideology" to denote beliefs, actions, and motivations that are held, at least in part, due to social and organizational commitments. We explicitly reject the notion that such commitments are necessarily illicit. Since Christianity is as much about a shared life as a belief system, such commitments can have legitimate functions and should be taken seriously when addressing faith-science issues in any Christian community.

Second, we offer the resonance controversy merely as an illustrative story for considering some pastoral aspects of science-faith dialogue and do not claim that it represents an exact parallel to any contemporary issue. No sort of moral equivalence between communist ideologues' criticism of mainstream science and religiously motivated efforts to oppose mainstream science is implied or intended. We sympathize with many of the theological and pastoral concerns mainstream science can raise in religious communities, and one of our goals here is to suggest ways in which science-faith dialogue might be used to encourage faith communities to examine and, as appropriate, to reevaluate the underlying assumptions which drive their apprehensions.

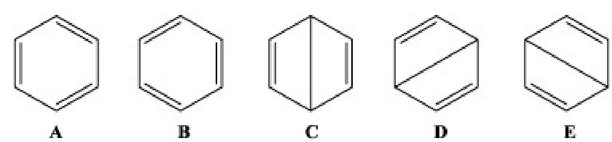
Third, although we do not deny that anti-evolutionism may pose a real threat to American science and science education, we do not wish to imply that the threat is in any way equivalent to the dangers facing Soviet chemists in Stalinist Russia. We deplore the tendency of some controversialists to liken critics of their position to Trofim Lysenko, the ignorant Soviet agrarian who condoned—if not promoted—the persecution of mainstream geneticists as part of his politically savvy promotion of pseudoscientific ideas. The scientific status of the resonance concept and the role of theoretical chemistry in late Stalinist Russia were very different from those of Mendelian genetics and biology, respectively.

Finally, we write as Christians in the sciences who are concerned with engaging the concerns of our fellow believers who oppose mainstream science. Thus, we will not address the implications of the resonance controversy for the philosophy of science,[14] how religious movements' ideologies affect how they respond to scientific ideas they accept, or the role of ideology in scientific materialist movements, such as the new atheism.[15]

The Scientific Theory of Resonance

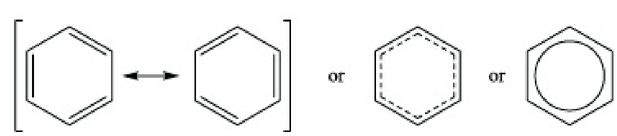
As it is typically presented in general and organic chemistry courses, the resonance concept applies to molecules for which more than one Lewis structure with pairwise bonds between the atoms may be written. It holds that the actual electronic structure of the molecule is a *resonance hybrid* of the different possible *resonance structures*. The paradigmatic example is benzene, which may be represented by the five irreducible resonance structures given in Scheme 1. All other valid Lewis structures are linear combinations of these five.

Scheme I. The five irreducible resonance forms of benzene used by Pauling to calculate the resonance energy in benzene.[16]



Not all structures contribute equally to the hybrid. For example, the actual ground state electronic structure of benzene is largely a combination of the Kekulé structures A and B with minor contributions from the Dewar structures C–E. Consequently, most textbooks represent benzene as shown in Scheme II.

Scheme II. Common representations of the benzene molecule.



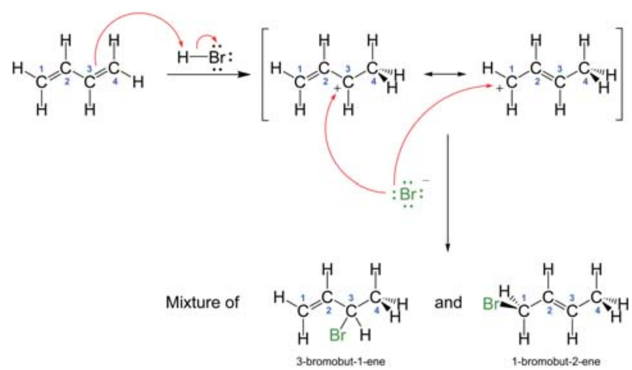
These representations emphasize that all of the carbons in benzene are electronically equivalent although they might imply alternate ways of conceptualizing the bonding in benzene. For instance, the double arrow in the brackets at left is sometimes said to represent the benzene molecule "resonating" between the two structures, an unfortunate use of language that can obscure the idea that benzene is a hybrid or mix of the two contributing structures. In contrast, the two rightmost structures use a dashed line and a circle, respectively, to represent delocalized bonding and to emphasize that all the C-C bonds are equivalent, with bond orders neither single nor double but rather somewhere in between.

The American chemist Linus Pauling developed the resonance concept in the 1920s and 1930s as part of his valence bond approach to molecular structure, which he hoped would enable relatively mathematically unsophisticated chemists to use the new quantum mechanics[17] to obtain a pragmatically useful understanding of the structure and bonding in molecules.[18] In valence bond structures, the pairwise bonds of Lewis structures are reconceptualized in terms of pairwise overlap of unhybridized (*s*, *p*, *d*, *f*) or hybrid (*sp*, sp^2, sp^3, etc.) atomic orbitals. Resonance occurs when more than one possible valence bond description can be written. In this case, the wavefunctions describing each structure are quantum mechanically mixed to generate lower and higher energy wavefunctions, the former of which more closely corresponds to the molecule's true ground state.

In practice Pauling applied resonance theory by writing all possible valence bond structures, such as those shown in Scheme I for benzene, and taking linear combinations to obtain the lowest energy state.[19] He then correlated the resulting energy lowering with thermochemical measurements, showing that molecules which exhibit resonance are lower in energy than would be expected from their contributing structures. For example, benzene was considered "resonance stabilized" by 155 kcal/mol[20] relative to structures like A and B, with three single and three double C-C bonds. Pauling even used these resonance stabilization energies to calculate each valence bond structure's fractional contribution to the molecule's ground state, although even his collaborator George Wheland noted that the results could be "quite arbitrary" and should not be taken "too seriously."[21] In this connection, it is important to note that Pauling was not aiming for methodological rigor. He deliberately made several approximations and assumptions in formulating his valence bond approach, namely, in the use of trial functions involving pairwise bonding and in the use of linear combinations for his minimization procedure. Resonance theory's real appeal was not in its ontological validity but in its practical utility.

Today, resonance theory is primarily used for the qualitative prediction and rationalization of organic chemicals' reactivity. For example, in the addition of HBr to buta-1,3-diene, as shown in Scheme III, the resultant mixture of 3-bromobut-1-ene and 1-bromobut-2-ene may be thought of as arising from the addition of Br^- to different allylic carbocation resonance forms.[22] Alternatively, the electrophilicity of the allylic carbocation's 1 and 3 carbons is expected from their +½ partial charges in the resonance hybrid. Other models, such as frontier molecular orbital theory, give similar results but require calculation or prediction of the allylic cation's molecular orbital diagram first.

Scheme III. Mechanism for the hydrobromination of butadiene to give a mixture of 3-bromobut-1-ene and 1-bromobut-2-ene.



Although Pauling took the lead in applying and popularizing the resonance concept,[23] other workers made significant contributions to its development. Notably, Christopher Ingold described resonance under the term "mesomerism," which literally refers to structures in-between (*meso-*) multiple classical ones.[24] Ingold, in fact, was the first to apply resonance to the problem of organic reactivity.[25] Wheland also did much to develop and promote the use of resonance in organic chemistry, particularly through his 1944 monograph, *The Theory of Resonance and Its Application to Organic Chemistry*.[26]

Resonance theory was widely accepted by Soviet chemists in the 1930s and 1940s. After the Second World War, it was popularized by Iakov K. Syrkin and M. E. Diatkina via their influential textbook *Structure of Molecules and the Chemical Bond*[27] and by the Russian translation of Pauling's *The Nature of the Chemical Bond*.[28] During this time, resonance was largely regarded as uncontroversial. A few Marxists, including J. B. S. Haldane, even offered it as an example of a Marxist dialectic.[29]

By the time controversy broke out, however, resonance theory was rapidly losing ground to molecular orbital theory—at least in theoretical chemistry. Although, in principle, the two methods should give equivalent results, molecular orbital theory seemed to more naturally accommodate delocalized bonding and was easier to apply to large molecules.[30] Furthermore, since it used conventional atomic orbitals, it was often regarded as more consistent with the spectroscopically verified results of atomic physics.[31] Practically, this meant that Soviet theoretical chemists would be more concerned to defend the use of quantum mechanics in chemistry than to defend the use of resonance theory in particular, although they also desired to preserve it as a highly useful reasoning aid.

Chemistry in Late Stalinist Russia

To understand why Soviet theoretical chemists responded to the controversy the way they did, it is helpful to consider the overall position of science and its role in Soviet society.[32] Prior to the 1917 Bolshevik takeover, Russia was a developing nation with an autocratic social structure and a respectable scientific establishment directed toward basic research and concentrated in university departments and academies such as the Imperial Academy of Sciences. The latter was particularly adept at building a productive relationship with the new regime, which provided it with increased funding and largely left the scientists alone to pursue their work. Indeed, the early Bolshevik leaders recognized that science and technology might be useful for transforming the relatively backward Russian economy into what they hoped would be a self-sustaining socialist one. Consequently, although most scientists did not necessarily approve of the regime, they were generally willing to accommodate themselves to it.

All this changed during the Great Break of the 1929–1931 Cultural Revolution that occurred after Stalin's rise to power. Industry, agriculture, and other forms of private enterprise were nationalized, and most areas of arts and culture, including the scientific academies, were subject to political purges. Those targeted faced dismissal, imprisonment, or death at the hands of Communist zealots, who looked on the purges as an opportunity to make established "proletarian" institutions more responsive to the needs and aims of the state.[33] The Soviet Academy of Sciences lost much of its independence through the state-mandated admission of engineers and Communist party members, the latter of which could be used to monitor scientists and censor the scientific literature. State control of scientific work was also facilitated through the centralization and bureaucratization of decision making in All-Union and local scientific academies, each of which functioned as a hybrid between a national laboratory and government ministry.[34]

Following the cultural revolution, Stalin attempted to modernize the Soviet economy rapidly through a series of grandiose agricultural and industrial projects. These largely technological efforts were intended to demonstrate the superiority of the Soviet system and to make the USSR more secure against internal and external threats. Lysenko's rule over Soviet biology in the early 1930s is explicable, at least in part, by Stalin's desire to achieve significant increases in agricultural production on the schedule of these "five-year" plans. Mainstream geneticists could offer only modest improvements to crop yields or livestock production on timescales comparable to several plant or animal life cycles. In contrast, the flamboyant, politically astute, and ruthless Lysenko—who never mastered statistics or bothered to collect the sort of data that would definitively establish or disprove his ideas—was always ready with promises of a quick fix.

As might be expected from their grandiose scale, breakneck pace, and narrow technological focus, many of Stalin's modernization projects failed while others caused massive social upheaval. The collectivization of agriculture in the Ukraine alone led to millions of deaths from famine. The Soviet leadership looked for scapegoats who could be accused of trying to "wreck" the country's progress, leading to relatively indiscriminate purges in which capable scientists were replaced with party functionaries. A culture of fear arose in which Soviet citizens learned to carefully maintain an appearance of political loyalty and to follow leaders' cues.[35] After ideologists suggested that science itself (exemplified by modern physics and Mendelian genetics) was "bourgeois" and intrinsically associated with the capitalism of the societies in which it originated, there was a conscious effort to publicly align Soviet science with nationalism and Marxist ideology.[36] Soviet science was publicly touted as superior to the science arising from capitalist societies, and Lysenko was propelled to the status of a cult hero for his opposition to "Weismanist-Mendelist-Morganist" genetics.[37] Because Lysenko had a propensity for charging opponents with obstructing progress, his ascendancy revealed just how dangerous state interference in science could be. Soviet biology was effectively ruined by the persecution of mainstream geneticists who opposed Lysenko's unsupported ideas.[38] The everyday practice of chemistry and most other sciences was marginally affected, but the influx of nationalism would eventually play a role in the resonance controversy.

More deliberate efforts to align science with Marxist ideology occurred once the Cold War developed between the USSR and the West in the late 1940s. Seeking to present communism as an intellectually worthy alternative to democracy, Stalin attempted to align different scientific fields with Marxism's dialectical materialist philosophy.[39] Given that this philosophy emphasizes the reality of the physical and material universe described by empirical science, even claiming that everything which exists is explicable in terms of matter and energy organized according to orderly physical laws, it might seem straightforward.

Dialectical materialism, however, conflicts with conventional science in two important ways. First, dialectical materialism is set against idealism, the claim that the reality we perceive is the construct of our own minds. Thus, somewhat idealized but highly useful theoretical constructs such as resonance can be viewed with suspicion. Second, dialectical materialists are highly resistant to reductionism, even to the point of claiming that qualitatively different scientific laws operate in different disciplines because phenomena which operate at one level cannot be reduced to lower-order phenomena. For example, in the Marxist account of material origins—that is, from a primordial soup to the first primitive life forms all the way to modern humans and complex social networks—matter periodically undergoes *qualitative* transitions to higher "dialectical levels" in which different physical laws operate.[40] Because each scientific discipline operates on its own level in this scheme, each scientific discipline had to be aligned with Soviet ideology on its own terms. Thus ideological disputes in one discipline could not serve to resolve issues in others.[41]

The alignment of various sciences with Marxist ideology largely took the form of ideological "struggles," a series of public state-tolerated or initiated discussions among (mainly) scientists and (some) philosophers. Their potential for harm was revealed near their start when Lysenkoism was declared the official scientific orthodoxy in 1948, although the disputes reached their zenith between 1949 and 1951. Strikingly, the topics covered read like the table-of-contents section in a contemporary science and religion textbook:[42]

> These issues included, in the physical sciences, the problem of causality, the role of the observer in measurement, the concept of complementarity, the nature of space and time, the origin and structure of the universe, and the role of models in scientific explanation. In the biological sciences, relevant problems included those of the origin of life, the nature of evolution, and the problem of reductionism. In physiology and psychology, discussions arose concerning the nature of consciousness, the question of determinism and free will, the mind-body problem, and the validity of materialism as an approach to psychology. In cybernetics, problems concerned the nature of information, the universality of the cybernetics approach, and the potentiality of computers.[43]

The campaigns largely followed a predictable pattern. An ideological zealot or ambitious but mediocre scientist raised ideological objections to a mainstream scientific idea which were subsequently trumpeted in the Soviet press. Leading scientists in the affected discipline were then invited to a public meeting at which the official Soviet position was declared scientific orthodoxy, and mainstream scientists engaged in ideological criticism of their former views.

Despite structural similarities, however, the involvement of Stalin and other Soviet leaders was quite dynamic. The official Soviet position in each case ultimately depended in part on the importance of the activity to Soviet Cold War aims and the response of its practitioners.[44] For instance, the physicists managed to preclude a significant amount of discussion in their discipline by arguing that it would be unproductive and would detract from work on the Soviet atomic bomb project. Soviet theoretical chemists were not so fortunate.

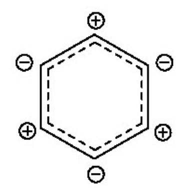
The Soviet Resonance Controversy and Its Aftermath

The resonance controversy originated in the writings of Gennadi V. Chelintsev, a professor of chemical warfare at the Voroshilov Military Academy whose primary area of expertise appears to have been in synthetic, not theoretical, chemistry.[45] In 1949, Chelintsev published a small monograph entitled *Essays on the Theory of Organic Chemistry*,[46] which attacked the concept of resonance on both ideological and nationalistic grounds. His ideological objections centered on resonance's use of idealized structures, which he charged was "mechanistic"—a euphemism for a form of scientific idealism opposed to dialectical materialism.[47] This charge has a basis in the nature of resonance theory itself, but Chelintsev put forward a second charge based on his misapprehension of resonance as a form of valence tautomerism in which bonds were continually interchanging.[48] Chelintsev claimed that Soviet chemists who supported resonance theory failed to properly emphasize the achievements of the nineteenth-century Russian chemist Alexander Butlerov, who advanced the idea that unique compounds must possess a single physical structure.[49]

Chelintsev offered his own "New Structural Theory," which he had earlier attempted to outline in the scientific literature,[50] as a way to avoid resonance's shortcomings. In it he effectively rejected quantum chemistry[51] in favor of classical valence theory's localized pairwise bonding[52] in the form of what he called "orbital" and "contact bonds."[53] These were akin to covalent bonds (although they did not really involve orbitals as in valence bond theory but something more like orbits) and ionic attractions between pairs of charged atoms, respectively.

To see how these ideas work, it is helpful to consider Chelintsev's conception of the bonding in benzene shown in Scheme IV. Instead of invoking delocalized or "resonating" pi bonds, Chelintsev localized electron pairs on alternating carbons, giving the alternating positive and negative charges shown. Benzene's ability to accommodate these alternating positive and negative charges was used to explain its special stability relative to odd-numbered carbon rings,[54] although Chelintsev's explanations for small and large rings were somewhat less convincing, and he had to downplay his model's inconvenient prediction that benzene has two sets of nonquivalent carbons and C-H bonds. Moreover, since Chelintsev's scheme treated all C-C multiple bonds as ionic, his theory predicted such howlers as the polarity of ethene.[55]

Scheme IV. Chelintsev's representation of the bonding in benzene in which the dotted line represents "the leveling out of charge," an ill-defined concept that his detractors felt could not overcome his scheme's prediction of polar C-C bonds in benzene.[56]



Given that Chelintsev extensively employed Marxist rhetoric, referred to by his opponents as the Lysenko-esque pejorative of Pauling-Ingoldites,[57] and did not use the "new structural theory" in his conventional scientific work,[58] he likely sought to provoke an ideological takeover of theoretical chemistry similar to that effected by Lysenko in biology. Indeed, that was the opinion of some of his contemporaries.[59] Nevertheless, Chelintsev's ideas found few scientific supporters and merely provided an opportunity for a broader ideological attack made by the chemists V. M. Tatevskii and M. I. Shakhparanov of Moscow University. In an article provocatively entitled "About a Machistic Theory in Chemistry and Its Propagandists,"[60] Tatevskii and Shakhparanov charged that resonance's advocates followed the idealist philosophy of Ernst Mach, which Lenin explicitly condemned in his *Materialism and Empirio-Criticism*.[61] This allowed Tatevskii and Shakhparanov to claim that scientists who defended resonance were hostile to the entire Marxist worldview:

> … the physical content of the theory of resonance is erroneous and (that) the philosophical setting of its authors and propagandists is Machistic. The Machistic theoretico-perceptional settings of the theory of resonance can serve as one of the examples of those world outlooks hostile to the

> Marxist view. They lead bourgeois scientists and their followers to pseudoscientific conclusions in the solution of concrete physical and chemical problems.[62]

More importantly, Tatevskii and Shakhparanov charged resonance's main Russian promoters, Syrkin and Dyatkina, with hindering Soviet science by failing to subject the resonance concept to ideological critique, or to give credit to Russian chemists who contributed to the development of structural chemistry.

> Directing the attention of Soviet chemists along the fallacious path of the vicious theory of resonance [resonance's supporters] demobilize Soviet chemical science in its struggle to fulfill the basic tasks of the Soviet scientists—"not only to attain, but to excel, in the shortest time, the achievement of science beyond the boundaries of our country" (Stalin).
>
> … Ya. K. Syrkin and M. E. Dyatkina have appeared before the Soviet public in the unenviable role of propagandists for the avowedly erroneous and vicious [resonance] theory of the American chemist, Pauling.
>
> … [Syrkin and Dyatkina's monograph, *Structure of molecules and the chemical bond*, is] permeated with a Machistic and cosmopolitanistic ideology [and] a slavish uncritical attitude toward bourgeois science and a contemptuous attitude toward native science … diverts Soviet chemistry from the solution of practical problems, in the direction of the bankrupt and sterile theory of resonance. The publication of this book, as well as Pauling's and Wheland's monographs, is a serious error committed by the publishers of chemical and foreign literature. The Ministry of Higher (University) Education, which has admitted the Machistic and cosmopolitanistic book by Ya. K. Syrkin and M. E. Dyatkina to serve as a study aid for the chemical faculties of the universities, has also committed a great error.[63]

In the event any Soviet chemists did not get these points, similar critiques appeared in the communist party newspaper, *Pravda*, and the journals, *Zhurnal Fizicheskoi Khimii* (Journal of Physical Chemistry) and *Uspekhi Khimii* (Russian Chemistry),[64] the latter of which was written by Yuri Zhdanov, head of the Communist party's central committee's Department of Science.[65]

Mainstream chemists were aware of the danger they faced having recently witnessed Lysenko's triumph over Soviet biology. However, they also had some appreciation for the social and political roles that open discussion of the ideological issues played in Soviet society.[66] Consequently, they did not merely engage Chelintsev's ideas but deliberately led the way in guiding the public discussion. Prominent chemists such as Alexandr Nesmejanov[67] and Oleg Reutov[68] publicly disavowed both resonance and Chelintsev's theory, the latter through a critical review of Chelintsev's monograph.[69]

The basic structure of Soviet chemists' response to Tatevskii, Shakhparanov, and Chelintsev's allegations more clearly took shape at the 1950 meeting of the Academy of Sciences's Institute of Organic Chemistry. The resulting report, *The Present State of the Chemical Structural Theory*, emphasized the contributions of Butlerov and other Russian chemists to structural chemistry, but it also sharply criticized the concept of resonance, often in grossly exaggerated and self-critical terms, echoing Tatevskii and Shakhparanov's charges.[70] However, the report's authors, which included many of the USSR's most eminent chemists, also constructed an independent and, at times, deploringly self-critical analysis of how particular construals of resonance might be incompatible with Marxist philosophy. While this ideological pandering led them to shamefully accuse Syrkin, Dyatkina, and other Soviet chemists of ideological failings, it also enabled them to present themselves as faithful guardians of Marxist ideology as they resisted Chelintsev's ideological criticisms, and dismissed his "new structural theory" as not merely misguided but also as a work of gross incompetence. They even charged Chelintsev with misunderstanding both Soviet ideology and quantum theory, a contention that was ironically confirmed when Chelintsev attempted to defend his theory against these and other critics.[71] In his "Answers to the Critics of the New Structural Theory," Chelintsev demonstrated a miscomprehension of quantum mechanics so profound that the article has the feel of a chemically sophisticated *Onion* satire. As a result, Chelintsev was rapidly isolated, and his ideas posed little threat of becoming scientific orthodoxy, official or otherwise.

The 1950 meeting's report, *The Present State of Chemical Structural Theory,* contained an elaborate and unashamedly overstated endorsement of Butlerov that connected virtually all important features of modern bonding theory with Butlerov, including quantum mechanics and a diluted version of resonance known as the "theory of mutual influences."[72] In doing so, the report's authors effectively argued that recent advances in structural chemistry should not only be accepted but also that only Soviet science truly understood their full significance. This ideological posturing strengthened their arguments for retaining the core of modern bonding theory, including the use of resonance-like ideas (but not resonance itself, since that had effectively been officially condemned) as an analogical reasoning tool, plus the molecular orbital-based methods which were rising to prominence. Chelintsev, who associated rejection of resonance with acceptance of his own ideas, protested these moves but was powerless to stop them.[73]

The outcome of the resonance controversy had effectively been decided. A 1951 All-Union meeting devoted to the "Problem of Chemical Structure in Organic Chemistry," nominally organized to discuss the preceding meeting's report, really had a predetermined mandate to find an acceptable alternative to resonance while upholding the preceding meeting's decisions. Alexander Pechenkin even describes the meeting as a ritual in which Syrkin, Diatkina, and other defenders of resonance confessed and abjured their former views while others took an "oath of allegiance" either by condemning resonance or by extolling Butlerov's contributions to chemistry.[74] Although the conference criticized leading Soviet chemists, physicists, and philosophers for various failures to properly uphold Marxist principles because the meeting largely upheld the 1950 report's conclusions, the potentially most damaging consequences of the antiresonance campaign—the threat to quantum chemistry as a discipline—were averted. However, even though Soviet chemists could talk about electron delocalization and use resonance structures as computational aids, they would not be able to use the term "resonance" or employ resonance structures pedagogically.

The resonance controversy adversely affected Soviet chemistry in other ways as well. Since Syrkin, Diatkina, and others who had done much to help keep Soviet scientists up-to-date on the latest Western advances lost their influential posts, important Western scientific works such as Coulson's *Valence* were not disseminated widely when they appeared.[75] More importantly, the controversy discouraged bright students from pursuing careers in what was seen as an ideologically suspect area.[76] It also deprived Soviet chemists of resonance structures' power as a pedagogical tool and reasoning aid, since Soviet organic chemistry textbooks avoided mentioning resonance by name well into the 1980s.[77] Zhores Medvedev estimated that the controversy led the Russian chemical industry to fall seven to nine years behind that of Western nations.[78]

Can the Soviet Resonance Controversy Help Us to Think and Talk about Science and Religion?

There are a number of parallels between religiously motivated opposition to science and the Soviet resonance controversy. Creationists, intelligent design advocates, and resonance opponents alike use opposition to science to defend traditional subcultures.[79] Just as capitalism was demonized by communist ideologues, many Christian communities view secular learning or more liberal approaches to theology as pernicious influences. In these cases, ideological opposition to science serves to validate in-group epistemic practices and knowledge claims.[80] Young earth creationism represents a defense of theological populism and commonsense literal interpretations of Genesis,[81] analogous to the antiresonance campaign's role as an enforcer of Marxist-Leninist epistemology. For many of its adherents, the intelligent design movement's opposition to methodological naturalism largely serves an apologetics purpose. By carving out space for a Paleysian natural theology within the scientific enterprise, the intelligent design movement seeks to reinforce the plausibility of religious knowledge claims in a culture in which science and technology are held in high regard.

Like some science opposition movements, the resonance controversy also saw the proffering of verifiably incorrect scientific alternatives,[82] chosen more for their fit to a priori metaphysical assumptions and plausibility in explaining a narrow range of phenomena than for their consistency with wider bodies of scientific facts. Chelintsev's alternative theory was not used in the same way that creation science and intelligent design ideas are used by some religious communities; it was offered as an alternative to quantum chemistry and never really adopted for apologetics purposes. Indeed, there is little indication that popular American science opposition movements intend to supplant the everyday practice of science with pseudoscientific alternatives.[83] Instead, they tend to be more tightly focused on criticizing mainstream scientific models than on promoting workable alternatives—a narrowing of aims that ironically makes them more far-reaching in their implications for science as a whole since a wide range of strategies can be employed to propose gaps or to magnify uncertainty in the scientific models that are used in many disciplines.

If American antievolutionists have more options than Chelintsev, Christians in science in many respects have fewer options than his opponents did. The original theory of resonance served primarily as an approximate guide for thinking about organic reactions; it lost ground to alternative computational approaches even as the controversy raged. In contrast, evolutionary theory has steadily proven itself as an increasingly powerful theory over the past fifty years, and climate change models, though incorporating a host of assumptions and approximations, universally predict dire outcomes which can be ignored only at great cost to even the most minimal ideas of Christian environmental stewardship, not to mention the Christian values of care for the poor and vulnerable. In short, efforts to repudiate the results of mainstream science or the scientists who practice it, run the risk of being inconsistent with intellectual honesty and Christian charity, as well as wisdom.[84]

Despite the aforementioned reservations and the difficulty inherent in generalizing from contingent historical events, it seems to us that the Soviet resonance controversy suggests several useful lessons for those who are concerned about religious apprehension of science. First, the ideological dimensions of religious objections to science need to be addressed directly. Practically, this will require Christians in the sciences to engage religious communities in dialogue over issues such as hermeneutics,[85] culture war metanarratives, and the role of the church in the world. While scientists may find it expedient to use their disciplinary expertise to address scientific fallacies motivated by religious apprehension, such critiques should be subsumed to the goal of strengthening and deepening faith. In this vein, it is reasonable to expect that scientists who think deeply about affected communities' underlying concerns, internal logic, and ethos will be most effective at alleviating their unnecessary fears.[86]

Second, scientists who wish to promote believers' appreciation of their work should take the lead in demonstrating consonance between their disciplines and religion. The Soviet chemists who led public discussion of the relevant scientific, philosophical, and cultural aspects of the controversy (rather than by attacking Chelintsev directly or by responding to his charges with vague disclaimers about Marxists who found resonance compatible with their beliefs) gained the ideological high ground and took political momentum away from resonance's detractors, securing a position they could use to neutralize the unfruitful ideas of Chelintsev without threatening the wider culture.

Finally, the resonance controversy indicates that the existing academic science-faith dialogue needs to be brought into the public arena. What is needed is a host of theologically and pastorally sophisticated public intellectuals who are sensitive to the concerns of religious communities and are willing to work to help shape religious adherents' engagement with science at the church, diocese, denomination, and international levels. Unfortunately, such work is not widely valued in Western scientific communities,[87] and so far it has been primarily the pseudoscience-advocacy groups who have brought a remarkable combination of grassroots effort and finely honed rhetorical, organizational, and cultural understanding to bear in their efforts to win the hearts and minds of American Christians. ★

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Notes

[1]Jay Wile, *Exploring Creation with Physical Science* (Anderson, IN: Apologia Educational Ministries, 1999).

[2]For example, there has been a large amount of discussion over the legitimacy of claims that atomic orbitals have been visualized by STM. See Eric R. Scerri, "Have Orbitals Really Been Observed?," *Journal of Chemical Education* 77, no. 11, (2000): 1492–4; and P. Multer, "Are Orbitals Observable," *Hyle* 17, no. 1 (2011): 24–35. However, in the present context, it seems doubtful that many chemists or physicists would object to the claim that these images support the idea that matter is discontinuous on the atomic-molecular scale.

[3]Notable accounts include David C. Lindberg and Ronald L. Numbers, eds., *When Science and Christianity Meet* (Chicago, IL: University of Chicago Press, 2003); David N. Livingstone, D. G. Hart, and Mark A. Noll, eds., *Evangelicals and Science in Historical Perspective*, Religion in America Series (New York: Oxford University Press, 1999); John Hedley Brooke, *Science and Religion: Some Historical Perspectives*, Cambridge Studies in the History of Science (New York: Cambridge University Press, 1991); John H. Brooke and Geoffrey Cantor, *Reconstructing Nature: The Engagement of Science and Religion*, Glasgow Gifford Lectures (New York: Oxford University Press, 2000).

[4]David N. Livingstone, "Situating Evangelical Responses to Evolution," in *Evangelicals and Science in Historical Perspective,* ed. Livingstone, Hart, and Noll, 193–219.

[5]Raymond A. Eve and Francis B. Harrold, *The Creationist Movement in Modern America,* Social Movements Past and Present (Boston, MA: Twayne Publishers, 1990), 67.

[6]Ibid., 68–9.

[7]*The Wedge,* Discovery Institute Center for the Renewal of Science and Culture, 1999.

[8]Much religious opposition to climate change science is probably just an outgrowth of concerns over biological accounts of human origins, or the age of the earth, or a consequence of confusing Christianity with particular brands of conservative politics. However, some Christian groups denigrate environmental scientists' predictions precisely because they contextualize them in a culture war. See James Wanliss, *Resisting the Green Dragon: Dominion, Not Death* (Burke, VA: Cornwall Alliance for the Stewardship of Creation, 2010) as a particularly vivid example of how the denigration of climate change science can be connected to concerns over the theologically questionable ethos of some elements of the environmental movement.

[9]These general features of creationism are discussed in Eve and Harrold, *The Creationist Movement in Modern America*, and Randall J. Stephens and Karl W. Giberson, *The Anointed: Evangelical Truth in a Secular Age* (Cambridge, MA: Belknap Press of Harvard University Press, 2011). Particularly illuminating and nuanced accounts of the social structure of groups that tend to reject evolution are given in James M. Ault Jr., *Spirit and Flesh: Life in a Fundamentalist Baptist Church* (New York: Alfred A. Knopf, 2004), particularly the chapter on "Fundamentalism and Tradition," 201–20, and the account of Multnomah Bible School given in Randall Balmer, *Mine Eyes Have Seen the Glory: A Journey into the Evangelical Subculture in America,* 4th ed. (New York: Oxford University Press, 2006).

[10]This is as true for fundamentalist communities that are nominally based on a literal reading of biblical norms as for more liberal Christian communities. For a particularly vivid and illuminating account of the role of social factors and tradition in one fundamentalist community, see the chapters on "Biblical Morality" and "Fundamentalism and Tradition" in Ault, *Spirit and Flesh*, 186–220.

[11]Frank Newport, "In U.S., 46% Hold Creationist View of Human Origins: Highly Religious Americans Most Likely to Believe in Creationism," *Gallup Politics* (June 1, 2012), http://www.gallup.com/poll/155003/Hold-Creationist-View-Human-Origins.aspx?utm_source=alert&utm_medium=email&utm_campaign=syndication&utm_content=morelink&utm_term=Religion.

[12]This controversy is sometimes called the Chelintsev affair after the name of the main Soviet critic of resonance theory.

[13]We have also selected to use the resonance controversy as an example because of our disciplinary expertise in chemistry. Indeed, we also consider this article part of a broader program of bringing chemistry into the science-faith dialogue.

[14]The importance of the resonance controversy for the philosophy of chemistry is treated in Jaap van Brakel, *Philosophy of Chemistry: Between the Manifest and the Scientific Image*, Louvain Philosophical Studies 15 (Leuven, Belgium: Leuven University Press, 2000).

[15]In the future, we hope to explore the role that social factors play in the new atheism by examining the life of the early twentieth-century German chemist Wilhelm Ostwald and his work with the Monist league.

[16]Linus Pauling and G. W. Wheland, "The Nature of the Chemical Bond. V. The Quantum-Mechanical Calculation of the Resonance Energy of Benzene and Naphthalene and the Hydrocarbon Free Radicals," *The Journal of Chemical Physics* 1 (1933): 362–74.

[17]The new quantum mechanics refers to wave mechanics as opposed to the classical quantum mechanics epitomized by the Bohr model of the atom.

[18]Since the Schrödinger equation cannot be solved exactly for polyelectronic atoms, molecules, and ions, a variety of approaches were developed to apply the results of quantum mechanics to these systems, all of which employ different assumptions about the nature of electronic structure and chemical bonding. Of these approaches, Pauling's most broadly appealed to bench chemists and is still the most commonly used approach in the American undergraduate curriculum. See Kostas Gavroglu and Ana Simões, *Neither Physics nor Chemistry: A History of Quantum Chemistry* (Cambridge, MA: The MIT Press, 2012) for an excellent discussion of the role these approaches played in the development of quantum chemistry.

[19]Readers familiar with molecular orbital theory may find this description strange. In molecular orbital theory, hydrogen-like atomic orbitals on individual atoms are used as a basis set. In resonance theory, the same procedure was applied to the entire bonding pattern represented by the different resonance forms. This essentially allowed the pi-type orbitals to quantum mechanically mix.

[20]This lowered energy is referred to as the "resonance stabilization energy."

[21]Thomas Hager, *Force of Nature: The Life of Linus Pauling* (New York: Simon & Schuster, 1995), 328.

[22]Note that this account is not fully consistent with the idea of the true structure being a resonance hybrid, although it still is pragmatically useful for understanding the chemical properties of the allylic carbocation.

[23]See Pauling, "The Nature of the Chemical Bond. V"; Linus Pauling and E. Bright Wilson Jr., *Introduction to Quantum Mechanics, with Applications to Chemistry* (New York: McGraw-Hill Book Company, 1935); Linus Pauling, *The Nature of the Chemical Bond and the Structure of Molecules and Crystals: An Introduction to Modern Structural Chemistry*, 2nd ed., The George Fisher Baker Nonresident Lectureship in Chemistry at Cornell University, vol. 18 (Ithaca, NY: Cornell University Press, 1940); Linus Pauling, "The Application of the Quantum Mechanics to the Structure of the Hydrogen Molecule and Hydrogen Molecule-Ion and to Related Problems," *Chemical Reviews* 5 (1928), 173–213.

[24]Classical valence bond theory looks at bonding in terms of electrons between pairs of atoms. Today, valence bond theory is often associated with bonding descriptions involving hybrid orbitals and sigma and pi bonds. These orbital descriptions of bonding are consistent with the classical valence bond picture embodied in Lewis structures, in that they retain the pairwise bonding of classical valence bond theory. Resonance theory thinks about sigma bonds in pairwise terms but allows for the possibility of pi-bonds delocalized over three or more atoms.

[25]C. K. Ingold and E. H. Ingold, "The Nature of the Alternating Effect in Carbon Chains. Part V. A Discussion of Aromatic Substitution with Special Reference to the Respective Roles of Polar and Non-Polar Dissociation," *Journal of the Chemical Society* (1926): 1310–28.

[26]George Willard Wheland, *The Theory of Resonance and Its Application to Organic Chemistry* (New York: John Wiley and Sons, 1944).

[27]I. K. Syrkin and M. E. Diatkina, *Structure of Molecules and the Chemical Bond* (New York: Interscience Publishers, 1950), originally published as *Khimicheskaia sviaz* (1946).

[28]Syrkin and Diatkina were also preparing a translation of Wheland's *Theory of Resonance* at the time the resonance controversy broke out.

[29]J. B. S. Haldane, *The Marxist Philosophy and the Sciences* (New York: Random House, 1939).

[30]While Pauling and Wheland's resonance treatment of benzene involved five irreducible resonance structures, a full treatment of naphthalene requires forty-two.

[31]Alexander A. Pechenkin, "The 1949–1951 Anti-Resonance Campaign in Soviet Science," *LLULL* 18 (1995): 135–66.

[32]Excellent general overviews of the role of science in the Soviet Union can be found in the work of Loren Graham, Paul Josephson, and Ethan Pollock. See especially Loren R. Graham, *Science, Philosophy, and Human Behavior in the Soviet Union* (New York: Columbia University Press, 1987); Loren R. Graham, *Science in Russia and the Soviet Union: A Short History*, Cambridge Studies in the History of Science (Cambridge: Cambridge University Press, 1993); Paul R. Josephson, *Totalitarian Science and Technology,* 2nd ed. (Amherst, NY: Prometheus Books, 2005); Ethan Pollock, *Stalin and the Soviet Science Wars* (Princeton, NJ: Princeton University Press, 2006).

[33]See especially Graham, "The Russian Revolution and the Scientific Community," in *Science in Russia and the Soviet Union,* 79–98.

[34]Ibid., 93–8; Graham, "The Organizational Features of Soviet Science," in *Science in Russia and the Soviet Union,* 173–96; and Pechenkin, "The 1949–1951 Anti-Resonance Campaign in Soviet Science," gives a good indication of the impact of these control measures.

[35]See Pechenkin, "The 1949–1951 Anti-Resonance Campaign in Soviet Science," 137, for a description of the form of these cues and their importance in everyday Soviet life.

[36]Graham, *Science in Russia and the Soviet Union*, 121–3.

[37]See especially the account of Lysenkoism given in Walter B. Gratzer, *The Undergrowth of Science: Delusion, Self-Deception and Human Frailty* (New York: Oxford University Press, 2000).

[38]David Joravsky, *The Lysenko Affair* (Chicago, IL: University of Chicago Press, 1986).

[39]Pollock, *Stalin and the Soviet Science Wars.*

[40]The sympathetic historian of Soviet science, Loren Graham, notes that dialectical materialism's antireductionism helps its adherents ease the tensions between philosophical materialism and the everyday world of value and meaning. See especially Graham, *Science in Russia and the Soviet Union*, 100–2.

[41]For example, biology could not be reduced to chemistry which in turn could not be reduced to physics—even in principle. Dialectical materialism regards each of these disciplines as having their own laws. Thus, the issue of quantum mechanics in physics, itself the subject of a controversy, could be separated from its status in chemistry. This is one reason why Soviet chemists were careful to protect the use of quantum mechanics when they responded to the resonance controversy.

[42]As chemists, we limit our consideration to the main controversy in chemistry. Readers with other disciplinary backgrounds are invited to consider the possible merit of close study of these controversies for science-faith dialogue in their disciplines.

[43]Graham, *Science, Philosophy, and Human Behavior in the Soviet Union*, 17.

[44]See especially Pollock, *Stalin and the Soviet Science Wars*; and Slava Gerovitch, "'Normal Pseudo-Science,'" in *From Newspeak to Cyberspeak: A History of Soviet Cybernetics* (Cambridge, MA: MIT Press, 2002), 103–52.

[45]We suspect that Pechenkin ("The 1949–1951 Anti-Resonance Campaign in Soviet Science," 135) is right in claiming that Chelintsev was not the undistinguished chemist most English-language sources make him out to be, although his expertise appears to have been in synthesis and his stature was hardly comparable to that of the Russian chemists he criticized, let alone to that of Pauling. The Voroshilov Military Academy at which he taught trained general staff officers and was the most prestigious military academy in the Soviet Union. A SciFinder scholarly search of Chelintsev's writings reveals that he published a very respectable thirty-four papers on various organic reactions and syntheses between 1935 and 1947, at which time his writings began to focus more heavily on theoretical structural chemistry. In fact, he published only two synthetic

papers thereafter, both in 1950, although it is not clear whether this was due to censorship of his synthetic work or a genuine drop-off in scientific productivity. It is notable that Chelintsev's publication record begins in 1935, in the midst of the Stalinist purges, although it is not clear whether Chelintsev's ideological views played a role in securing his position.

[46]G. V. Chelintsev, *Essays on the Theory of Organic Chemistry* (Goskhimizdat [State Chemistry Publishers], 1949).

[47]In particular, Chelintsev charged that resonance's idealized structures were "mechanistic," a reference to mechanistic materialism, which Marxists equated with scientific idealism. See Loren R. Graham, "A Soviet Marxist View of Structural Chemistry: The Theory of Resonance Controversy," *ISIS* 55 (1964): 20–31; and Graham, *Science, Philosophy, and Human Behavior in the Soviet Union*, 299–300.

[48]G. V. Chelintsev, "Tautomerism," *Izv. Akad. Nauk SSSR, Ser. Khim.* (1946): 313–24.

[49]Butlerov formulated this principle in the midst of discussions about the relationship between physical structure and chemical identity in which he was one of the main champions of the idea that structure determines chemical identity. In doing so, he made genuine and important contributions to chemical bonding theory that had indeed been somewhat overlooked by Western writers. See A. J. Rocke, "Kekulé, Butlerov, and the Historiography of the Theory of Chemical Structure," *The British Journal for the History of Science* 14 (1981): 27, for a fuller description of these issues. Thus, in laying down the charge that compounds which exhibit resonance fail to possess a single structure, Chelintsev not only ignored or misunderstood Pauling and Wheland's disclaimers, but also apparently failed to appreciate the true aim of Butlerov's principle.

[50]See Chelintsev, "Tautomerism"; G. V. Chelintsev, "Valence and Bonds," *Izv. Akad. Nauk SSSR, Ser. Khim.* (1946): 549–56; V. K. Kuskov, "Dyadic Tautomerism," *Zh. Obshch. Khim.* 16 (1946): 1481–4; G. V. Chelintsev, "The Aromatic Bond," *Izv. Akad. Nauk SSSR, Ser. Khim.* (1947): 81–8.

[51]In this connection, it is interesting to note that Soviet ideologues were also uncomfortable with quantum mechanics due to its association with indeterminism (at least in the Copenhagen interpretation), although they tolerated its usefulness as a computational tool.

[52]Hans Vermeeren helpfully describes how resonance presented a genuine challenge to G. N. Lewis and Irving Langmuir's classical bonding ideas in H. P. W. Vermeeren, "Controversies and Existence Claims in Chemistry: The Resonance Controversy," *Synthese* 69 (1986): 273. However, in our opinion Vermeeren's presentation of Chelintsev's opposition to resonance as a legitimate scientific controversy does violence to its true nature.

[53]D. N. Kursanov, M. G. Gonikberg, B. M. Dubinin, M. I. Kabachnik, E. D. Káverzneva, E. N. Prilezhaeva, N. D. Sokolov, and R. K. Freidlina, "The Present State of the Chemical Structural Theory," *Journal of Chemical Education* 29 (1952): 9.

[54]Chelintsev, "The Aromatic Bond."

[55]Chelintsev's opponents were quick to point out these inconsistencies. See Kursanov et al., "The Present State of the Chemical Structural Theory," 2. It is noteworthy that Pauling included such structures in his resonance treatments as well. However, since these electronic structures were allowed to mix with a corresponding structure of opposite polarity, the resulting resonance hybrids were nonpolar.

[56]Graham, "A Soviet Marxist View of Structural Chemistry," 22; Graham, *Science, Philosophy, and Human Behavior in the Soviet Union*, 299.

[57]Chelintsev apparently copied Lysenko's tactic of referring to his opponents' doctrine as Morganism-Weismanism, Mendelism-Morganism, or even Mendelism-Morganism-Weismanism, which implied that they were advocating the ideas of foreign bourgeois scientists.

[58]Kursanov et al., "The Present State of the Chemical Structural Theory," 8.

[59]Graham, *Science, Philosophy, and Human Behavior in the Soviet Union*, 307.

[60]V. M. Tatevskii and M. I. Shakhparanov, "About a Machistic Theory in Chemistry and Its Propagandists," *Journal of Chemical Education* 29 (1952): 13–4.

[61]V. I. Lenin and A. Fineberg, *Materialism and Empirio-Criticism; Critical Comments on a Reactionary Philosophy* (Moscow: Foreign Languages Publishing House, 1947).

[62]Tatevskii and Shakhparanov, "About a Machistic Theory in Chemistry and its Propagandists," 13.

[63]Ibid., 14.

[64]Y. Zhdanov, "The Main Features of Butlerov's Theory of Chemical Structure," *Uspekhi Khimii* no. 18 (1949): 472–80, cited in Pechenkin, "The 1949–1951 Anti-Resonance Campaign in Soviet Science."

[65]Graham, "A Soviet Marxist View of Structural Chemistry," 24–5; Graham, *Science, Philosophy, and Human Behavior in the Soviet Union*, 300.

[66]See Pechenkin, "The 1949–51 Anti-Resonance Campaign in Soviet Science"; and Gerovitch, *From Newspeak to Cyberspeak*, 115–8. Gerovitch, in particular, notes that savvy scientists could sometimes shape ideological campaigns to their own ends.

[67]*Complete Dictionary of Scientific Biography* (2008), s.v. "Nesmejanov, Aleksandr Nikolaevich," http://www.encyclopedia.com/doc/1G2-2830905946.html.

[68]O. A. Reutov, "O knige G. V. Chelintseva 'Ocherki po teorii organicheskoy khimii'" [On the Book by G. V. Chelintsev 'Essays on the theory of organic chemistry'], *Voprosu Filosofii (Problems of Philosophy)* 3 (1949): 309–17.

[69]Nesmeyanov and Reutov also attempted to demarcate between resonance and mesomerism, although their efforts never quite caught on.

[70]Kursanov et al., "The Present State of the Chemical Structural Theory," 2–13.

[71]G. V. Chelintsev, "Theory of Chemical Structure of A. M. Butlerov and Its New Successes," *Zh. Obshch. Khim.* 22 (1952): 417–30; G. V. Chelintsev, "Answers to the Critics of the New Structural Theory," *Izvest. Akad. Nauk S.S.S.R. Otdel. Khim. Nauk* (1952): 190–6 (pages 205–13 in English).

[72]Like resonance, the theory of mutual influences involved delocalized bonding.

[73]G. V. Chelintsev, "On the New Position by Chemists-Machists," *Voprosy filosofii* 2 (1950), cited in Pechenkin, "The 1949–1951 Anti-Resonance Campaign in Soviet Science."

[74]Pechenkin, "The 1949–1951 Anti-Resonance Campaign in Soviet Science," 145–52.

75Ibid., 155.

76István N. Hargittai, "Fukui and Hoffmann: Two Conversations," *The Chemical Intelligencer* 1, no. 2 (1995): 14–25.

77Graham, *Science, Philosophy, and Human Behavior in the Soviet Union*, 311–7.

78Z. A. Medvedev, *Soviet Science* (New York: W.W. Norton and Company, 1978), 52–4.

79This is not to say that there are no differences between evolution and resonance theory on this score. There is little evidence that chemical bonding theory ever caused the sort of unease among grassroots Marxists that evolution has caused in American religious communities. However, it was portrayed as such a threat in Pravda and key journals. Given Stalin's interest in demonstrating that science was consistent with Marxism, this meant that these accusations required a politically sensitive response. Of course, this means that there is another significant difference between the Soviet resonance controversy and American antievolutionism. Mainstream Soviet chemists appealed to the Soviet *leadership* in their defense of structural chemistry, an option not available to mainstream biologists in America where (the ability of the courts to influence the shape of debates notwithstanding) much of the debate over creation and evolution takes place at the grassroots level.

80Stephens and Giberson, *The Anointed: Evangelical Truth in a Secular Age.*

81Although it is not always appreciated by their opponents, the young earth creationism movement tends to be rather clear on this point. See, for example, Henry Morris and John Whitcomb's reply to reviews of their *Genesis Flood*, in which reply they chastise their critics for failing to recognize the central issue—"not the correctness of the [geological] data … but what God has said in his word concerning these matters." H. Morris and J. Whitcomb, "Reply to Reviews in the March 1964 Issue," *Journal of the American Scientific Affiliation* 16, no. 2 (1964): 59–61.

82In our use of the term, models refer both to scientific models (such as Chelintsev's model of bonding in benzene) and to more comprehensive pictures of the world (such as various antievolutionist models for what constitutes legitimate science).

83There is some parallel between the antiresonance movement and antievolutionism's apologetics goals in that Stalin and other Soviet leaders were also genuinely concerned about demonstrating the intellectual consistency of their ideological system, Marxism. The comparison breaks down in that the Soviet leaders tended to be more flexible about how different sciences were to be brought in line. Thus, in the Soviet resonance controversy, the idea behind resonance was not really at stake—only how it was talked about and represented. In contrast, it is doubtful that many American antievolutionists would accept any idea that meant humans actually evolved from nonhuman primate ancestors—regardless of the language and symbolism used.

84However, it may be appropriate to graciously point out the fallacies of scientists who promote science as a sort of knockdown argument for atheism or theism.

85According to George Marsden, hermeneutics is an excellent place to start since hermeneutical principles can be criticized without threatening foundational beliefs, and evangelicals have been willing to adapt their hermeneutical principles to new knowledge before. See George Marsden, "Understanding Fundamentalist Views of Science," in *Science and Creationism,* ed. Ashley Montagu (New York: Oxford University Press, 1984), 95–116.

86Christian apologists who have taken the New Atheism seriously provide a good example of what it means to meaningfully engage a movement with which one is unsympathetic. For example, Alister McGrath and David Bentley Hart have developed some of the most insightful and far-reaching critiques of the New Atheist movement: McGrath, by unpacking its internal logic; Hart, by exploring its ethos. See Alister E. McGrath, *Dawkins' God: Genes, Memes, and the Meaning of Life* (Malden, MA: Blackwell Publishing, 2005); Alister E. McGrath, *Why God Won't Go Away: Is the New Atheism Running on Empty?* (Nashville, TN: Thomas Nelson, 2010); and David Bentley Hart, *Atheist Delusions: The Christian Revolution and Its Fashionable Enemies* (New Haven, CT: Yale University Press, 2009).

87Elaine Howard Ecklund, *Science vs. Religion: What Scientists Really Think* (New York: Oxford University Press, 2010).

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Article

Emergence: A Biologist's Look at Complexity in Nature

Harry Cook

Harry Cook

Emergence theory states that nature presents itself to us in a hierarchy of levels. Compared to a lower level, emergent levels are novel; they cannot be reduced to, or predicted from, a lower level. Hierarchies of levels and the various kinds of emergence that have been presented in the literature are described. I express my preference for a strong version of emergence, seen both synchronically and diachronically. Emergence theory does justice to the complexity we encounter in creation, and can contribute to a Christian understanding of evolution.

When we walk in a rainforest, dissect a squid, or observe a muscle cell under the electron microscope, we encounter nature's diversity and complexity. In current discussions about complexity, particularly as it pertains to biology, the idea of emergence is playing an increasingly prominent role. "Emergence" denotes both a process and the novelty resulting from that process. Philip Clayton who has written extensively on the topic recognizes this dual meaning. He describes emergence as follows:

> Three general claims undergird emergence theory in the philosophy of science. First, empirical reality divides naturally into multiple levels … Over the course of natural history, new emergent levels evolve. Second, emergent wholes that are more than the sum of the parts require new types of explanation adequate to each new level of phenomena. Third, such emergent wholes manifest new types of causal interactions; they include irreducibly biological interactions and must be explained in biological terms.[1]

This description suggests that we need both the idea of emergence and of organizational levels to counter the reductionism that is advanced by many theoreticians of science, to recognize the complexity we actually observe in the world of living things, and to do justice to the integrity of created things. I will develop these ideas in this article, which is the second of two papers dealing with biological complexity and emergence, respectively.[2]

I describe emergence as it pertains to biological organisms and, in a preliminary way, to human beings. In this paper, I will examine the classic view of Ernst Mayr on emergence and express a reservation I have about his view. I will then give an overview of current thinkers on emergence. Subsequently, I describe how emergence can be classified into several kinds and approaches. Finally, I conclude by showing how emergence thought can do justice to the pluriform structure of creation.

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Ernst Mayr on Emergence in Biology: What about Other Levels?

Many biologists and theoreticians of science suggest that biology can be, and eventually will be, reduced to physics. For example, James Watson, co-discoverer of the helical structure of DNA, states: "There is only one science, physics: all else is social work."[3] However, this viewpoint seems to be waning, for many biologists now support the idea of emergence, namely that biological phenomena are fundamentally different from the physical level of being. One of the architects of evolution's modern synthesis, Ernst Mayr (1904–2005), takes a nonphysicalist view, stating that "a full understanding of organisms cannot be secured through the theories of physics and chemistry alone." He adds,

> [T]he patterned complexity of living systems is hierarchically organized and … higher levels in the hierarchy are characterized by the emergence of novelties … The problems and findings at other levels are usually largely irrelevant at a given hierarchical level … When a well-known Nobel laureate in biochemistry said, "There is only one biology, and it is molecular biology," he simply revealed his ignorance and lack of understanding of biology.[4]

Mayr's viewpoint has support in the biological community. In a textbook by Campbell et al., used in introductory biology courses at many North American universities, the concepts of emergence and the uniqueness of biological phenomena are stated clearly in the opening pages: "New properties emerge at each level in the biological hierarchy … These emergent properties are due to the arrangement and interaction of parts as complexity increases."[5] Numerous modern biologists recognize the phenomenon of emergence and the unique qualities of biological entities and processes.

Mayr's and Campbell's discussions of biological hierarchy are a clear recognition of the qualitative uniqueness of biological phenomena. Mayr's hierarchy falls short, however, because he does not recognize the uniqueness of above-biological levels. Mayr states:

> To characterize man by such criteria as consciousness, or by the possession of mind and of intelligence, is not very helpful, because there is good evidence that man differs from the apes and many other animals (even the dog!) in these characteristics only quantitatively. It is language more than anything else that permits the transmission of information from generation to generation … Speech, thus is the most characteristic human feature. It is often said that culture is man's most unique characteristic. Actually, this is very much a matter of definition. If one defines culture as that which is transmitted (by example and learning) from older to younger individuals, then culture is very widespread among animals. Thus even in the evolution of culture there is not a sharp break between animal and man. Though culture is more important in man, perhaps by several orders of magnitude, the capacity for culture is not unique with him but a product of gradual evolution.[6]

We note that for Mayr the distinction between animal and human culture is not an essential one, and that is where my criticism of Mayr's thought lies. David Sloan Wilson takes a similar position when it comes to phenomena such as human language, culture, and religion.[7]

Emergence Comes Back into the Limelight

The originators of the idea of emergence, Conwy Lloyd Morgan, Samuel Alexander, and their followers, proposed a theory of emergence that dealt with a very limited hierarchy of levels of being.[8] Their initial discussions of emergence are the basis of the debates that are now taking place. While the idea of emergence has not entered many of the discussions on evolution in this journal,[9] there has been a flurry of publications on the topic. However, as Jaegwon Kim warns us,[10] and as may be evident from this article, emergence means different things to different people. We will see that many versions of emergence are offered, and will consider which versions can be integral to a Christian worldview. Kim advises his readers to keep in mind the principles, known as "British Emergentism," laid down by Alexander, C. D. Broad, and Morgan.[11] In keeping with this school, Australian philosopher John D. Collier suggests that "causal autonomy, holistic nature, novelty, irreducibility, and unpredictability" characterize emergent levels;[12] these are important features of emergence.

Harold J. Morowitz, in his book *The Emergence of Everything,* refers to twenty-eight examples of emergence.[13] These examples include the physical universe and parts of it (the periodic table—i.e., the elements—and the solar system), parts of cells (e.g., neurons), different kinds of organisms (e.g., chordates, vertebrates, mammals), hominids, and the products of human culture (such as tools, language, and philosophy). Morowitz's book shows that it is important to understand what kind of categories are to be included in emergence, a topic addressed in this article.

Theologian Philip Clayton has published extensively on the subject of emergence. Reacting against physicalism and dualism when it comes to levels of complexity, he suggests that emergence can provide an attractive *via media.* When considering physical and biological entities, Clayton bases his emergence theory on a hierarchy of parts and wholes (e.g., atoms, molecules, cells).[14] When it comes to the topic of the emergence of the mind from the brain, Clayton takes a strong antireductionist stand and stresses the uniqueness of the human mind. He briefly mentions the emergence of other human phenomena, such as aesthetics, ethics, and spirituality.[15] In a subsequent book, Clayton develops his views in more detail and defines emergence as

> the view that new and unpredictable phenomena are naturally produced by interactions in nature; that these new structures, organisms, and ideas are not reducible to the sub-systems on which they depend; and that the newly evolved realities in turn exercise a causal influence on the parts out of which they arose.[16]

Clayton also co-edited a book with Paul Davies, *The Re-Emergence of Emergence,* which provides a useful introduction to the history of the idea, current discussions on theories of emergence, physicalism as it relates to emergence, top-down causation, and supervenience.[17] The thirteen authors contributing to this essay collection focus on the emergence of life and on the emergence of mind and consciousness. Levels of emergence other than those of living things, mind, and consciousness are mentioned by other authors.[18] In the final section of the book, three authors—Arthur Peacocke, Niels Henrik Gregersen, and Clayton—focus on the relationship between emergence, theism, and the emergence of religion, and on the role they think God may have in emergence.[19] Clayton, in the concluding chapter, is supportive of the idea of emergence as he and many others have defined it in the edited volume. He states:

> [T]he evolution of more and more complex systems in the natural world turned out not to be continuous but to involve the periodic appearance of new systems of qualitatively different structures, evidencing ever more intricate systems with qualitatively different structures, evidencing ever more intricate forms of interaction with their environments … [A]lthough emergent systems, organisms, and properties are not reducible—the dynamics of self-reproducing cells cannot be explained in terms of the sorts of dynamics that physics studies—emergent entities don't contradict the physics on which they continue to depend … I wager that no level of explanation short of irreducibly mental explanations will finally do an adequate job of accounting for the human person … [E]mergentists argue the question of mind can best be addressed by looking for the ways in which mental phenomena emerge from neurological structures and processes, and by studying how these phenomena in turn begin to play a role within broader wholes or contexts (language, culture, social institutions, value judgments, the construction of self-identity), in terms of which alone they can be understood.[20]

Kinds of Emergence

The thinkers I have mentioned thus far relate emergence to processes of evolution. Emergence can also be associated with an approach that focuses entirely on an ontological hierarchy. Indeed, the word "emergence" is used in a multitude of ways. Even when we restrict our view to how "emergence" is used in the context of biological complexity, we see that the word has different meanings for different people. In this section, I will attempt to sort this out and to create some order and structure to the topic.

Strong and Weak Emergence

A distinction is often made between strong and weak versions of emergence. Theories of strong emergence hold that properties of entities at a given level are not reducible to the properties of components at a lower level, whereas theories of weak emergence hold that these properties can, at least potentially, be reduced to properties at a lower level.

In an excellent discussion on the ontology of emergent levels, Carl Gillett is more specific; he distinguishes "weak, ontological, and strong emergence."[21] Weak emergence, Gillett suggests, recognizes emergent novelty yet allows (potential) room for reductionist views. This view is supported by Jaegwon Kim who has written extensively on the topic of emergence.[22] In ontological emergence, an emergent level is considered to be ontologically fundamental and not reducible to the physical or another lower level. Clayton, who is categorized as an ontological emergentist by Gillett, sees Kim's position on emergence as "not strong enough."[23] Clayton characterizes his own view of emergence as "strong"[24] and "ontological,"[25] thus taking a different view of the categories of emergence than Gillett does.

Gillett's preferred view, which he labels as strong emergence, allows for both physicalist and higher ontological categories ("the Argument from Composition"),[26] making possible a nonreductive physicalism; here the emergent level is part of a scala of levels, namely, a "compositional hierarchy."[27] The distinction between ontological and strong emergence in the writings of various authors is not always as clear as Gillett suggests. The strength of Gillett's paper is that it puts the ideas of important authors on emergence into a philosophical context; this is useful even if one does not share all of Gillett's views.

Synchronic and Diachronic Emergence

A second distinction, related to the first, is the one between synchronic and diachronic emergence. We have seen that "emergence" is based on the idea that reality presents itself to us in levels. Synchronic emergence describes or discusses the levels in reality at a point in time, usually the present, whereas diachronic emergence looks at the complexity in nature or in a given situation or entity as it develops over time. We will look at each in turn.

Synchronic emergence "emphasizes the co-existence of novel 'higher level' objects or properties with objects or properties at some 'lower level.'"[28] Thus, it deals with the ontological diversity of reality or parts of reality. This is related to strong emergence because the synchronic view, as it perceives levels, assumes that there are levels that are distinct and irreducible.[29]

Diachronic emergence, on the other hand, looks at the complexity in nature or in a given situation or entity as it develops over time. Evolutionary development of various organisms is the most commonly used example of diachronic emergence; another example would be the embryonic and childhood development of a human person.[30] In his article, Achim Stephan discusses diachronic emergence as it relates to evolution.[31] Paul Humphreys favors the diachronic view of emergence because a historical element is "ineliminable."[32] Diachronic emergence is not necessarily equated with weak emergence, although this has been posited by some authors. In my view of biology, diachronic emergence, as described by an evolutionary process that is seen through the eyes of faith, gives rise to a reality that also invites an investigation of synchronic emergence.

Jitse van der Meer discusses diachronic emergence as it relates to the origin of life and to biological evolution. He states, "There is no empirical evidence that the boundary between non-life and life can be crossed." Indeed, the literature about the origin of living cells is large and inconclusive.[33] However, van der Meer adds, "Therefore, I take the claim that entities displaying one kind of order can produce entities with a new kind of order as a metaphysical research program looking for empirical support."[34] This statement may be true when it comes to the topic of the origin of life, but other instances of emergence, such as the origin of human beings from nonhuman ancestors, have more evidence to support them.[35]

Emergence and Hierarchy

A third and final distinction should be mentioned here: the characteristics of the emergence that will be described will depend on the type of hierarchy that is being employed, and the topic of emergence is inextricably bound with the topic of hierarchies. The writings of Stanley Salthe, Uko Zylstra, and van der Meer, among others, show that the topic of hierarchies is a complicated one,[36] and includes many subjects not discussed in this article. Here I will confine my discussion to hierarchical relationships in biological entities and organisms, focusing first on part-whole relationships and then on organizational levels.

The relationship between parts, more inclusive parts, and so forth, and wholes, is one kind of hierarchy that has been mentioned when emergence is discussed. We saw above that Mayr ties the topic of emergence in biology directly to a part-whole hierarchy. Mayr speaks of "new and previously unpredictable characters [that] emerge at higher levels of complexity in hierarchical systems." For Mayr, these hierarchies are biological in nature and could take several forms. One example of hierarchy could be cellular organelle, cell, tissue, organ, "and so forth, up to biogeography and the study of ecosystems," namely, what he calls a "constitutive hierarchy."[37] Mayr explicitly notes that the hierarchy on which his emergence is based is one of components and wholes, where the wholes can, in turn, be components of wholes that are higher up on the hierarchy.[38] If molecules are included in the hierarchy, as Mayr does at times, I would stress that an essential boundary, the one from nonliving to living, is crossed when one goes from molecules to cells.[39] Furthermore, part-whole hierarchies are more difficult to visualize when one deals with subject matter studied in disciplines such as ethics or economics.

While some subdisciplines, particularly in the natural sciences, can be related to wholes and parts of wholes, the hierarchy of major academic disciplines can more easily be discerned when one considers the kinds of properties and laws that one encounters in creation, that is, what van der Meer entitles "modes of existence."[40] Some of the authors we cited above mention levels that are studied in, for example, biology, psychology, sociology, economics, and theology.[41]

A Hierarchy of Organizational Levels

Christian philosopher Jacob Klapwijk bases his views of emergence on a different hierarchy, namely, a hierarchy of organizational levels. In a book and article, he proposes that the concept of emergence presents an opportunity to recognize the diversity in creation.[42] To describe this diversity, he distinguishes five kinds of realms in nature: physical things, unicellular organisms, multicellular plants, multicellular animals, and human beings, and he discusses their evolution. These realms display a hierarchy of what he calls organizational levels of reality and culture. The number of these levels increases as one moves successively from examining physical things to unicellular organisms, plants, animals, and human beings. He suggests that at crucial moments in evolutionary history, emergent phenomena occurred. As a new level arose in the dynamic history of life on Earth, there should be openness for partial or lower-level explanations, but these should "not touch the unpredictable and irreducible newness of the emerging phenomenon."[43] Klapwijk applies these ideas not only to organizational levels displayed by physical and living organisms, but he also extends it to levels of organization in the realm of human existence and culture, such as logic, language, sociality, economics, aesthetics (or music and art), ethics, and religion.[44] These ideas are based to a significant extent on the hierarchy of "modal aspects" developed by Herman Dooyeweerd.[45]

Picking up on the topic of organizational levels, van der Meer describes the difference between a hierarchy of entities, such as cells, tissues, and organs, and a hierarchy of modes of existence as proposed by Dooyeweerd, namely, organizational levels.[46] As we have seen, it is upon the latter that Klapwijk bases his idea of emergence. He does not specify the exact nature and number of organizational levels, stressing that he wants to be empirical and leave this topic open to further study.[47] In the book and paper, Klapwijk emphasizes that the levels of being are distinguished by *idionomy,* that is, by having laws of their own, laws that reflect the will of the Creator for the world he brought into being.[48] In this way, Klapwijk expresses his belief that the world, in all its evolutionary dynamics and structural diversity, is the temporal expression of the divine creation order. As the title of his book, *Purpose in the Living World,* indicates, Klapwijk proposes—correctly in my view—that emergence realizes God's purposes for creation.[49] Klapwijk's work has elicited numerous reviews and responses.[50]

Klapwijk criticizes "one-level physicalism" in numerous places in the book, directing his aim particularly at the view that biological and mental phenomena and entities can be explained by physics.[51] We have noted Mayr's objection to physicalism in biology above. Zylstra underlines Klapwijk's view that biological phenomena cannot be elucidated by deterministic, physical explanations.[52] Although he agrees with this point, Arnold Sikkema demonstrates that even the physical realm is not as determined as Klapwijk suggests, and that there is emergence within the physical domain.[53]

What are the mechanisms by which one level emerges from a lower level? As Tony Jelsma states, this is a question that Klapwijk does not answer.[54] Klapwijk describes postulated mechanisms of transition from physical aggregations to living cells,[55] and writes imaginatively about the origin of religious awareness.[56] Nevertheless, he states that causality is level-bound, that new, emergent levels have new ordering principles,[57] and that no causal explanations for emergence can be given. In "Creation Belief," too, Klapwijk states that causal explanations are lacking, for emergence theory is a "theoretical framework, a philosophical or ontological framework in which the diverse explanatory theories of physicists, biologists, etc., level-bound as they are, can take their rightful place."[58] Considering all this, I would not dismiss the possibility that the transitions occur through natural processes.

Clayton and Klapwijk: A Comparison

When we compare and summarize the ideas of Clayton and Klapwijk on emergence, we note similarities and differences. Both recognize the importance of levels below the highest level of an entity, for example, the physical level below the biological in biological organisms, yet they reject physicalism and reductionism. Both accept the reality of evolution and strong, ontological emergence, and thus can be seen as diachronic emergentists. Clayton describes various levels from the physical up and particularly emphasizes the emergence and irreducibility of mind and consciousness, and of the spiritual phenomena that are the basis of theological study. His scheme of emergence is based on a part-whole hierarchy, but then he singles out the emergence of mind and spirituality as deserving a separate discussion.[59] Klapwijk does not reject the importance of part-whole relationships but bases his view of emergence on the important idea of levels of organization.

Klapwijk's emphasis on organizational levels, or modes of existence, brings out an aspect of emergence that is often ignored. Furthermore, it is a useful basis for distinguishing the various scholarly disciplines.[60] I would also suggest that a part-whole hierarchy can then be used for the distinction of subdisciplines, particularly in physics and biology. For example, within animal biology,[61] a part-whole hierarchy can be seen as the basis for molecular biology, cell biology, histology (the study of tissues), physiology, animal behavior, and population ecology, to mention a few of the major subdisciplines that come to mind.

Klapwijk is reticent to posit that parts-whole hierarchies give rise to genuine emergence.[62] Sikkema lauds Klapwijk's emphasis on "intermodal" emergence; Sikkema also states that part-whole emergence and qualitative emergence are both worthy of a place in our theorizing because both give rise to unpredictable novelty.[63] I could add an example from my own research: it is not possible to reduce explanations of the migratory behavior of sockeye salmon to the cellular or molecular level of biology, even though these two levels undoubtedly play an important role.[64] I conclude that both part-whole hierarchies and intermodal, that is, organizational levels, as described by Clayton, Klapwijk, and Sikkema, can reflect genuine emergence.

A remaining challenge to theories of emergence is the tension between continuity and discontinuity. How can diachronic, continuous processes give rise to discontinuous, synchronic levels? Opinions on this topic vary. Clayton states that the relationship between emergent levels is primarily a continuous one.[65] Gregersen, in a response to Clayton, favors the importance of discontinuity in the way that levels present themselves to us in our experience.[66] In his book, Klapwijk accepts that the evolutionary process, by its very nature, implies continuity, but he rejects the philosophical naturalism and reductionism that is often assumed to accompany this continuity.[67] Is a possible solution that synchronic, ontological discontinuity has emerged by diachronic, continuous processes? If this is the case, then one *can* say that in emergence, continuity and discontinuity go hand in hand.[68]

A Biologist's Look at Diversity: A Wider View

I have drawn some conclusions throughout this article; some more inclusive comments are now in order. It is gratifying that emergence is becoming more recognized as a legitimate way to interpret our experience. However, the theory also has its challenges, the chief of which is that the processes which result in emergence, particularly for the transition from nonlife to life, are not known or are only partly known.[69] A second challenge is the tension between continuity and discontinuity; the distinction between synchronic and diachronic emergence made above is only a partial solution to this problem.

The idea of emergence deepens the topic of complexity that Hank Bestman and I explored in our earlier paper in *PSCF*.[70] Like complexity, emergence theory—at least in the thought of most theoreticians who consider it—recognizes the diversity in nature that presents itself to observers; it is a nonreductionist, holistic view. We have seen above that the idea of emergence is also pertinent to levels of human culture. Whether one speaks of a part-whole hierarchy, that is, a hierarchy of entities, or a hierarchy of levels of organization, the emergence that one observes reveals a diversity that finds its origin in God's order for creation.

In my view, a strong, ontological view of emergence, both synchronic and diachronic, honors the Creator. The diversity in creation is also reflected in the wide variety of subdisciplines and disciplines that are part of academia. Thus the idea of emergence can help us when we design curricula, particularly the biological curriculum.

Several of the thinkers whose ideas we have explored suggest that emergence is compatible with their theistic religious belief. Clayton further suggests that an "emergentist understanding of humanity … may even be better explained by theism than by its competitors."[71] Gregersen adds,

> It can even be argued that the general thrust of evolution towards ever more complex forms of creatures—adaptive, sensitive and communicative creatures—can best be accounted for from a theistic perspective, as suggested by Clayton, especially if one is interested in a comprehensive explanation of reality rather than confining oneself to causal explanations of particulars.[72]

Such a theistic view does not necessarily imply a natural theology or a plea in favor of rational proofs for the existence of God. Looking at emergence theory with the eyes of faith, emergence can help us deepen our sense of the world. With the Holy Spirit working in our hearts, our "faith seeks understanding."[74] I suggest that emergence theory can add to that understanding. ★

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Notes

1Philip Clayton, "The Emergence of Spirit: From Complexity to Anthropology to Theology," *Theology and Science* 4 (2006): 291–307. Thus emergence counters the reductionism and physicalism that, nevertheless, still occurs in biology and other disciplines. In the paper from which we cite, Clayton goes on to describe levels of emergence other than the biological, such as language, culture, and theology.

2Harry Cook and Hank D. Bestman, "Biological Complexity," *Perspectives on Science and Christian Faith* 63, no. 3 (2011): 159–69.

3Comment made to Steven Rose, *Lifelines: Life beyond the Gene* (New York: Oxford University Press, 1997), 8.

4Ernst Mayr, *The Growth of Biological Thought* (Cambridge, MA: Harvard University Press, 1982), 64–5, 75–6. Mayr works out his ideas further in *What Makes Biology Unique? Considerations on the Autonomy of a Scientific Discipline* (Cambridge: Cambridge University Press, 2004), chap. 2. This book, published when Mayr was 99 years old, rejects physicalist, Kantian, and idealist approaches to the philosophy of biology and, as he says, attempts to make a start on a new, empirical, philosophy of biology. One of the architects of the new evolutionary synthesis, and for years the dean of American biologists, Mayr opens his book with the statement, "This will be my last survey of controversial subjects in biology." He died at age 101. The Nobel laureate he mentioned was George Wald, who received the Nobel Prize in physiology and medicine in 1967.

5N. A. Campbell, J. B. Reece, L. A. Urry, M. L. Cain, S. A. Wasserman, P. V. Minorsky, and R. B. Jackson, *Biology*, 8th ed. (San Francisco, CA: Pearson Benjamin Cummings, 2008), 3.

6Mayr, *The Growth of Biological Thought*, 622. See also Ernst Mayr, *Toward a New Philosophy of Biology: Observations of an Evolutionist* (Cambridge, MA: Harvard University Press, 1988), 77, 252.

7David Sloan Wilson, *Evolution for Everyone: How Darwin's Theory Can Change the Way We Think about Our Lives* (New York: Delta Trade Paperbacks, 2008). For a review of this book, see Harry Cook, *Perspectives on Science and Christian Faith* 60, no. 3 (2008): 200–1.

8The ideas of Conwy Lloyd Morgan (1852–1936) and Samuel Alexander (1859–1938) are described by Jacob Klapwijk, *Purpose in the Living World? Creation and Emergent Evolution* (Cambridge: Cambridge University Press, 2008), 91–4.

9However, see Richard H. Bube, "Reductionism, Preductionism and Hierarchical Emergence," *Journal of the American Scientific Affiliation* 37, no. 3 (1985): 177–80.

10Jaegwon Kim, "Emergence: Core Ideas and Issues," *Synthese* 151 (2006): 547–59.

11Kim, "Emergence: Core Ideas and Issues." For a discussion of the history of British emergentism, see Brian P. McLaughlin, "The Rise and Fall of British Emergentism," in *Emergence: Contemporary Readings in Philosophy and Science,* ed. Mark A. Bedau and Paul Humphreys (Cambridge, MA: MIT Press, 2008), 19–59.

[12]John D. Collier and Scott J. Muller, "The Dynamical Basis of Emergence in Natural Hierarchies," in *Emergence, Complexity, Hierarchy and Organization; Selected and Edited Papers from the ECHO III Conference. Acta Polytechnica Scandinavica, MA91*, ed. G. L. Farre and T. Oksala (Espoo, Finland: Finnish Academy of Technology, 1998), 1–30.

[13]Harold J. Morowitz, *The Emergence of Everything: How the World Became Complex* (Oxford: Oxford University Press, 2002).

[14]Philip Clayton, *God and Contemporary Science* (Grand Rapids, MI: Wm. B. Eerdmans, 1997), 248.

[15]Ibid., 247–57.

[16]Philip Clayton, *Mind and Emergence: From Quantum to Consciousness* (Oxford: Oxford University Press, 2004), vi.

[17]Philip Clayton and Paul C. W. Davies, eds., *The Re-Emergence of Emergence: The Emergentist Hypothesis from Science to Religion* (Oxford: Oxford University Press, 2006).

[18]Several authors mention social and ethical laws. George F. R. Ellis refers to psychology, sociology, politics, and economics in a table: "On the Nature of Emergent Reality," in *The Re-Emergence of Emergence,* ed. Clayton and Davies, 80. See also G. F. R. Ellis, "Science, Complexity, and the Natures of Existence," in *Evolution and Emergence: Systems, Organisms, Persons*, ed. Nancey Murphy and William R. Stoeger, SJ (Oxford: Oxford University Press, 2007), 114. Barbara Smuts describes sociality in bonobo chimpanzees, "Emergence in Social Evolution: A Great Ape Example," in *The Re-Emergence of Emergence*, ed. Clayton and Davies, 166–86.

[19]Arthur Peacocke, "Emergence, Mind, and Divine Action: The Hierarchy of the Sciences in Relation to the Human Mind-Brain-Body," in *The Re-Emergence of Emergence,* ed. Clayton and Davies, 257–78; Niels Henrik Gregersen, "Emergence: What Is at Stake for Religious Reflection?," in *The Re-Emergence of Emergence*, ed. Clayton and Davies, 279–302; Philip Clayton, "Emergence from Quantum Physics to Religion," in *The Re-Emergence of Emergence*, ed. Clayton and Davies, 303–22.

[20]Clayton, "Emergence from Quantum Physics to Religion," in *The Re-Emergence of Emergence*, ed. Clayton and Davies, 310–5.

[21]Carl Gillett, "The Hidden Battles over Emergence," in *The Oxford Handbook of Religion and Science*, ed. Philip Clayton (Oxford: Oxford University Press, 2006), 801–18.

[22]Gillett classifies Jaegwon Kim as a weak emergentist. Indeed, see Jaegwon Kim, "Emergence: Core Ideas and Issues"; Jaegwon Kim, "From Naturalism to Physicalism: Supervenience Redux," *Proceedings of the American Philosophical Association,* 85 (2011): 109–34.

[23]Clayton, *God and Contemporary Science,* 252.

[24]Ibid., 252–7.

[25]Stuart Kauffman and Philip Clayton, "On Emergence, Agency, and Organization," *Biology and Philosophy* 21 (2006): 501–21.

[26]Gillett, "The Hidden Battles over Emergence," 811.

[27]Ibid., 802, 804.

[28]Paul Humphreys, "Synchronic and Diachronic Emergence," *Minds & Machines* 18 (2008): 431–42.

[29]See, for example, Arnold Sikkema, "Nuancing the Place and Purpose of the Physical Aspect in Biology and Emergence," *International Journal of Multi Aspectual Practice* 1 (2011): 29–39.

[30]Jitse M. van der Meer, "Biology and the Philosophy of Emergence," in *The Future of Creation Order, Proceedings of the Christian Philosophy Conference, Amsterdam, 16-19 August 2011*, ed. Gerrit Glas and Jeroen de Ridder (Heidelberg: Springer, in press).

[31]Achim Stephan, "Varieties of Emergentism," *Evolution and Cognition* 5 (1999): 49–59.

[32]Humphreys, "Synchronic and Diachronic Emergence."

[33]For a good overview of various Christian positions on this subject, see the pages on the ASA website: Craig Rusbult, http://www.asa3.org/ASA/education/origins/cheme.htm.

[34]van der Meer, "Biology and the Philosophy of Emergence," in press.

[35]Visitors to the human origins exhibit at the Smithsonian National Museum of Natural History—perhaps in connection with the 2010 ASA meeting in Washington, DC—will not easily dismiss the reality of nonhuman biological ancestors of *Homo sapiens*; what it means to be human is an important related question.

[36]Stanley N. Salthe, *Evolving Hierarchical Systems: Their Structure and Representation* (New York: Columbia University Press, 1985); Uko Zylstra, "Living Things as Hierarchically Organized Structures," *Synthese* 91 (1992): 111–33; Jitse van der Meer, "Stratified Cosmic Order: Distinguishing Parts, Wholes, and Levels of Organization," in *Science and Faith within Reason: Reality, Creation, Life and Design*, ed. Jaume Navarro (Burlington, VT: Ashgate, 2011), 145–64.

[37]Mayr, *The Growth of Biological Thought*, 64.

[38]Ibid., 64-5; Mayr, *What Makes Biology Unique?,* 74–7. Jitse van der Meer works out further the intricacies of part-whole relationships in his "Stratified Cosmic Order."

[39]Mayr, *What Makes Biology Unique?,* 76. Similarly, writing in the context of the religion-science debate, Gillett, in "The Hidden Battles over Emergence," describes his view of emergence based on "compositional hierarchy," making no further distinctions such as nonliving vs. living (entities or levels).

[40]Jitse M. van der Meer, "The Multi-Modal Hierarchy: Distinguishing Parts, Wholes, and Levels of Organization," in *Proceedings of the 40th Annual Meeting of the International Society for the Systems Sciences*, ed. M. L. H. Hall (Louisville, KY: International Society for the Systems Sciences, 1996), 507–18.

[41]Nancey Murphy and George F. R. Ellis, *On the Moral Nature of the Universe: Theology, Cosmology, and Ethics* (Minneapolis, MN: Fortress Press, 1996) discuss the disciplines; their system is partly based on part-whole hierarchies but also includes the social sciences, ethics, and theology. Scott F. Gilbert and Sahotra Sarkar, "Embracing Complexity: Organicism for the 21st Century," *Developmental Dynamics* 219 (2000): 1–9, state that there are emergent laws for each level of organization, and cite several authors who support their claim.

[42]Klapwijk, *Purpose in the Living World?*; Jacob Klapwijk, "Creation Belief and the Paradigm of Emergent Evolution," *Philosophia Reformata* 76 (2011): 11–31 (declaration of interest: I translated and edited Klapwijk's book and article). Volume 76 of *Philosophia Reformata* includes seven articles responding to Klapwijk's book (see footnote 50 below).

[43]Jacob Klapwijk, personal communication, April 2013.

[44]Klapwijk, *Purpose in the Living World?,* 106–125. One has to be careful when one encounters the phrase, "levels of organization"; some authors use it when they are clearly referring to emergence associated with part-whole hierarchies (a valid point in itself); see, for example, Gilbert and Sarkar, "Embracing Complexity"; William Wimsatt, "The Ontology of Complex Systems: Levels of Organization, Perspectives, and Causal Thickets," *Canadian Journal of Philosophy,* suppl. vol. 20 (1994): 207–74.

[45]Herman Dooyeweerd, *A New Critique of Theoretical Thought*, 3 vols. (Nutley, NJ: The Presbyterian and Reformed Publishing Company, 1969), 1.3–4. For an accessible account of Dooyeweerd's thought on modalities, see Roy Clouser, *The Myth of Religious Neutrality* (Notre Dame, IN: Notre Dame Press, 1991), 51–73; Jonathan Chaplin, *Herman Dooyeweerd: Christian Philosopher of State and Civil Society* (Notre Dame, IN: Notre Dame Press, 2011), 53–63. Also see Andrew Basden: http://www.dooy.Salford.ac.uk/. I am thankful to Clouser (personal communication) for his description of modalities: "kinds of properties and laws" as used above.

[46]Van der Meer, "The Multi-Modal Hierarchy."

[47]Klapwijk, *Purpose in the Living World?,* 156.

[48]Ibid., 120. "Idionomy" is used occasionally with various meanings, but not in the way Klapwijk uses it, as far as I can ascertain. Chalmers and Van Gulick have also mentioned separate laws for emergent levels: David J. Chalmers, "Strong and Weak Emergence," in *The Re-Emergence of Emergence,* ed. Clayton and Davies, 244–54; Robert Van Gulick, "Reduction, Emergence, and the Mind/Body Problem: A Philosophic Overview," in *Evolution and Emergence,* ed. Murphy and Stoeger, 40–73.

[49]Klapwijk, *Purpose in the Living World?;* Denis Lamoureux, *Evolutionary Creation: A Christian Approach to Evolution* (Eugene, OR: Wipf and Stock, 2008), 5–6, 19, speaks of teleological (vs. dysteleological) evolution. See also Conor Cunningham, *Darwin's Pious Idea: Why the Ultra-Darwinists and Creationists Both Get It Wrong* (Grand Rapids, MI: Wm. B. Eerdmans Publishing, 2010), 131–77.

[50]In addition to the article, "Creation Belief," by Klapwijk in *Philosophia Reformata* 76 (2011), there are seven detailed responses to Klapwijk's book, *Purpose in the Living World?*: John Satherley, "Emergence in the Inorganic World," 32–49; Henk Geertsema, "Emergent Evolution? Klapwijk and Dooyeweerd," 50–76; Russ Wolfinger, "Whence the Question Mark?," 77–83; Bruce Wearne, "Some Contextual Reflections on 'Purpose in the Living World?,'" 84–102; Gerben Groenewoud, "Augustine and Emergent Evolution," 103–18; Chris Gousmett, "Emergent Evolution, Augustine, Intelligent Design, and Miracles," 119–37; Harry Cook, "Creation and Becoming in Jacob Klapwijk's Theory of Emergence," 138–52. Klapwijk responds to these articles in "Nothing in Evolutionary Theory Makes Sense except in the Light of Creation," *Philosophia Reformata* (2012): 78–91. For additional responses, see Marinus Dirk Stafleu, "Properties, Propensities and Challenges: Emergence in and from the Natural World," in *The Future of Creation Order, Proceedings of the Christian Philosophy Conference, Amsterdam, 16–19 August 2011*, ed. Glas and de Ridder, in press; Paul Ewart, *Science and Christian Belief* 22 (2010): 189–90.

[51]Klapwijk, *Purpose in the Living World?,* 48-49, 137-8, 159. In several places in his book, Klapwijk emphasizes the importance and rightful place of physical explanations.

[52]Uko Zylstra, book review of Klapwijk's book, *Purpose in the Living World? Creation and Emergent Evolution*, in *Perspectives on Science and Christian Faith* 62, no. 4 (2010): 292–3.

[53]Sikkema, "Nuancing the Place and Purpose of the Physical Aspect in Biology and Emergence"; Arnold E. Sikkema, "Nuancing Emergentist Claims: Lessons from Physics," in *The Future of Creation Order, Proceedings of the Christian Philosophy Conference, Amsterdam, 16–19 August 2011*, ed. Glas and de Ridder, in press.

[54]Tony Jelsma, "Review of Jacob Klapwijk *Purpose in the Living World?* and Stephen C. Meyer *Signature in the Cell*," *Pro Rege* 38 (2010): 29–32. Klapwijk discusses why he does not give mechanisms for emergence in "Creation Belief," *Philosophia Reformata* (2011): 11–31; however, he does discuss postulated mechanisms for the origin of living cells in *Purpose in the Living World?,* 53–9.

[55]Klapwijk, *Purpose in the Living World?,* 53–9.

[56]Ibid., 164–72.

[57]Ibid., 62, 112, 185.

[58]Klapwijk, "Creation Belief," 23 (footnote 13). See also *Purpose in the Living World?,* 150–64.

[59]See the good discussion of Clayton's views in Niels Henrik Gregersen, "Emergence in Theological Perspective: A Corollary to Professor Clayton's *Boyle Lecture*," *Theology and Science* 4 (2006): 309–20.

[60]Klapwijk, *Purpose in the Living World?,* 114.

[61]Or, in the terminology that Klapwijk employs, "sensitively qualified organisms"; see *Purpose in the Living World?,* 106–15, 216–7.

[62]Klapwijk, *Purpose in the Living World?,* 144.

[63]Sikkema, "Nuancing the Place and Purpose of the Physical Aspect in Biology and Emergence." See also Sikkema, "Nuancing Emergentist Claims."

[64]Harry Cook and A. P. van Overbeeke, "Ultrastructure of the Pituitary Gland (Pars Distalis) in Sockeye Salmon (*Oncorhynchus nerka*) during Gonad Maturation," *Zeitschrift f. Zellforschung*, 130 (1972): 338–50; Harry Cook and A. P. van Overbeeke, "Ultrastructure of the Eta Cells in the Pituitary Gland of Adult Migratory Sockeye Salmon (*Oncorhynchus nerka*)," *Canadian Journal of Zoology* 47 (1969): 937–41.

[65]Clayton, "The Emergence of Spirit."

[66]Gregersen, "Emergence in Theological Perspective."

[67]Klapwijk, *Purpose in the Living World?,* 46–51.

[68]See Klapwijk, "Creation Belief."

[69]Conor Cunningham, in *Darwin's Pious Idea*, works this out further by stating that natural selection, a feature of biological organisms, became emergent when life forms were present. To support this he cites Walter Fontana and Leo W. Buss, "'The Arrival of the Fittest': Toward a Theory of Biological Organization," *Bulletin of Mathematical Biology* 56 (1994): 1–64.

[70]Cook and Bestman, "Biological Complexity."

[71]Clayton, "The Emergence of Spirit."

[72]Gregersen, "Emergence in Theological Perspective."

[73]In the spirit of Anselm (with a tip of the hat to Augustine).

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Sy Garte

Communication

Evolution and *Imago Dei*

Sy Garte

The concept of *imago Dei* is under attack. Some militant atheists have tried to use evolutionary theory (among other things) to show that there is nothing at all special about human beings. Mistakenly thinking that science supports this view, some Christian philosophers have put forward the idea that *imago Dei* is not limited to the creation of human beings but to all biological creation. I believe that this is not only bad theology, but also terrible science. The rest of this communication will explain why I maintain the second part of that sentence.

Not only the biological characteristics of each individual animal, but also individual and group behavior, are ultimately of genetic origin. Animal behavior, such as the mating dances of birds, the signaling of bees and ants, the howling of wolves, the family structures of lions, are all examples of behaviors that do not change without a change in genotype. There are exceptions to this rule, and they are all the result of human action.

Humans are an exception to the primacy of genetics on behavior. The behavioral phenotype (or visible characteristics of organisms) of human societies has been changing continuously for at least forty thousand years, and while the direction of that change has been constant, the rate of change has been increasing in an exponential manner. At the same time, there have been very few changes in genotype to account for these phenotypic modifications. Humans have also brought about behavioral phenotype changes in domesticated species such as dogs and cattle, through training, genetic selection, and breeding, and in some wild animals by environmental alterations.

To our knowledge, we are the only species that has done this. Our evolution is no longer genetic, but cultural. And our cultural evolution is driven not by our genes but by our unique brains. The ordinary processes of genetic evolution gave us these brains, but then the brains took over. As a result, the way we live is completely different from the way human beings lived forty thousand years ago. It is different from the way human beings lived four hundred years ago, and even four years ago. For all other species, this is not the case. From what we can tell, the chimpanzees of today live exactly as they did four million years ago.

It is true that other animals can solve problems, show altruism, make pictures, communicate, have emotions, maintain social structures, and do "all" the things that humans do. The neuroscientist Robert Sapolsky has discussed striking new findings on the ways humans are not as unique as we used to think we are. But for each example of how other animals can do what we do, Sapolsky also provides the evidence of how we remain exceptional. In some cases, this uniqueness seems to be a matter of degree, in

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that we do so many things so much better than our closest animal relatives. But in other cases, those quantitative differences amount to an emergent, qualitative effect.

Clearly, what humans do that no other living creature does is change. Humans learn and teach. Humans create and build. Humans progress and investigate. Humans use their huge and complex brains to overcome biological limitations imposed by a genome that changes very, very slowly.

Other hominids in our own lineage might have had some ability to transform their species, but not enough to help them survive. Early human precursors in the genus *homo* were quite fragile as biological entities. They had bad eyesight, were slow and awkward, gave birth rarely and with difficulty. Most *homo* and earlier *Australopithecine* species never had very large populations, and they all went extinct relatively quickly, compared to their nearest relatives, the great apes. We are the only surviving member of the genus *homo*.

After spreading throughout the planet, modern humans never stopped changing their own behavioral phenotype through will, imagination, creativity, consciousness, and intelligence. As a result of these cultural changes, some aspects of human biology have changed as well. We live twice as long as we used to; we have new diseases and have escaped some old ones. From agriculture, to cities, to empires, to religion, science, architecture, and the use of technology, humans have continually changed themselves and their environment independently of their genes.

The idea that humans are uniquely able to overcome the limitations imposed on all other species by natural selection of selfish genes is not limited to those of Christian faith. None other than Richard Dawkins agrees. In a fascinating video on the origin of human altruism, Dawkins says:

> As Darwin recognized, we humans are the first and only species able to escape the brutal force that created us, natural selection … We alone on earth have evolved to the point where we can … overthrow the tyranny of natural selection.[1]

So while the concept of human exceptionalism is consistent with Christian values, Dawkins, the staunch atheist and foremost Darwinian evolutionist alive today, agrees that humans have gone beyond the laws that govern other creatures.

Yes, other animals can appear to think, reason, emote, and worry. We can teach them all kinds of things. But they do not teach each other anything new. Their phenotypes are slaves to their genes. We, and only we, are free. That might be one definition of *imago Dei*, but there are certainly others, especially related to our connection with God.

A while ago, I was driving from New York toward Washington on the New Jersey Turnpike, listening to a book by P. D. James on tape. As I drove past the toll barrier at the Delaware Memorial Bridge, it suddenly dawned on me that I was driving a very large, heavy machine at about eighty miles an hour over a beautiful and elaborate structure, and had then gone through the toll barrier without stopping, because my E-ZPass device had sent a signal to the scanning device which allowed the toll to be automatically deducted from my bank account. And while I was doing this, I was listening to a British actress of amazing talent perform a reading of an elaborate and detailed mystery story. The power of the reading and of the original writing had transported my consciousness from New Jersey to the Dorset countryside, so beautifully described by Ms. James.

And I thought about how amazing all of this is. No primate before the last hundred years or so ever moved at speeds even a fraction of how fast I was traveling, and yet somehow I had no difficulty or fear of doing so. And look at what my fellow humans have made. A lovely car, with a complex engine—what would our ancestors think of an automobile? And that whole E-ZPass thing. What would my father think of that? What incredible technology we have. And what talent. That actress, who brings the written words to life with her voice. And the writer, the one who thinks of the story. Why can we tell such great stories in the first place?

How can my mind deal with all of this, as if it is just an ordinary thing in our world (which, of course, it is)? There is nothing at all unusual about a man driving on a highway listening to a taped novel. But that is only because we are thinking in terms of *our* world, the human world. I would submit that the twenty or thirty amazing phenomena (some of which I have elaborated above) that are included in that simple scenario, are, in any sort of natural world, miraculous. The fact that we do not see them as such means simply that we are used to miracles, and we call them human nature.

I know that I am a primate—a hominid, to be precise. I need food and water. I crave a mate and shelter. I like security, and I am wary of danger. I also am very aware of my evil side, and of the evil history of my fellow beings. We hominids are selfish and greedy; we can be violent and defensive. We can be uncaring about others and the environment in which we live.

And yet, still a hominid, I find myself not staring out at the rain from my cave, wondering when I will eat next, but driving a large machine at impossible speed, listening to the voice of a woman who is not actually anywhere near me, act out a story composed by another woman.

Then all of this is interrupted by a third woman who calls me on my cell phone, which I answer using the earpiece of my Bluetooth device. I hear the voice of the woman I love, and we speak. I make some jokes, hear her laughter. I find this to be a wonderful thing, this being human. And I am very thankful to my Creator. ★

Note

[1]Richard Dawkins, "Richard Dawkins on Kin Altruism, Reciprocity, and 'Tribal Reciprocity,'" Veoh video, 11.46, last accessed September 11, 2013, http://www.veoh.com/watch/v20011764nRA2J3Sn.

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FROM COSMOS TO PSYCHE

"All things hold together in Christ"
Colossians 1:17

Call for Abstracts

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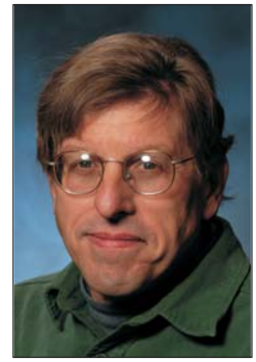
The Cambrian Explosion: How Much Bang for the Buck?



Ralph Stearley

Ralph Stearley

THE RISE OF ANIMALS: Evolution and Diversification of the Kingdom Animalia *by Mikhail A. Fedonkin, James G. Gehling, Kathleen Grey, Guy M. Narbonne, and Patricia Vickers-Rich. Baltimore, MD: Johns Hopkins University Press, 2007. 327 pages; includes an atlas of Precambrian Metazoans, bibliography, index. Hardcover; $79.00. ISBN: 9780801886799.*

THE CAMBRIAN EXPLOSION: The Construction of Animal Biodiversity *by Douglas H. Erwin and James W. Valentine. Greenwood Village, CO: Roberts and Company, 2013. 406 pages; includes one appendix, references, index. Hardcover; $60.00. ISBN: 9781936221035.*

DARWIN'S DOUBT: The Explosive Origin of Animal Life and the Case for Intelligent Design *by Stephen C. Meyer. New York: HarperCollins, 2013. 498 pages; includes bibliography and index. Hardcover; $28.99. ISBN: 9780062071477.*

By the time that Darwin published *On the Origin of Species* in 1859, the principle of biotic succession had been well established and proven to be a powerful aid to correlating strata and deciphering the history of Earth, to which the rock layers testified. However, for Darwin, there remained a major issue regarding fossils for his comprehensive explanation for the history of life. The problem was this: the base of the Cambrian period, originally defined by Adam Sedgwick, was signified by the presence of trilobites, as well as other macroscopic fossils such as linguliform brachiopods and some strange echinoderms. These exotic and aesthetic remains were fairly easy to spot, but problematic in that they were blatantly the remains of complex multicellular organisms overlying rocks in which there were no remains of simpler organisms.

Later on, this dramatic appearance of complicated macroscopic fossils would become known by the shorthand expression "Cambrian explosion." Because the dispute between Sedgwick and Roderick Murchison on the boundary between the Cambrian and Silurian systems had not been fully resolved by 1859, Darwin considered these fossils "Silurian" (and thus for him, the issue would have been labeled the "Silurian explosion"!). Darwin confessed to some puzzlement:

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> Consequently, if my theory be true, it is indisputable that before the lowest Silurian stratum was deposited, long periods elapsed, as long as, or probably far longer than the whole interval from the Silurian age to the present day; and that during these vast, yet quite unknown, periods of time, the world swarmed with living creatures. To the question why we do not find records of these vast primordial periods, I can give no satisfactory answer.[1]

Of course, even during Darwin's day, the presence of large packets of strata lying below the Cambrian were discerned by field geologists; but the seeming absence of fossils in these layers left them resistant to description and analysis.

The perceived magnitude of this dramatic difference was given a boost by the discovery of two extraordinarily well-preserved Middle Cambrian fossil biotas. These two localities are the well-known Burgess locality of British Columbia, discovered in 1909 by Charles D. Walcott of the Smithsonian Institution; and the Chengjiang locality, Yunnan Province, China, discovered by Hou Xianguang in 1984. These are classic fossil "lagerstaetten" (bonanzas), formed as very fine-grained sediments (Burgess locality: the Stephen Formation; Chengjiang locality: the Maotianshan Shale) that were deposited in anoxic environments, providing exceptional preservation of soft anatomy as well as intricate hard structures. Supplemented by contemporaneous fossil assemblages from western Utah, Russia, Greenland, Australia, and elsewhere, these biotas have enabled us to analyze morphology for many dozens of exotic creatures and to reconstruct these in three dimensions.

We thus have been *blessed* to obtain a fairly synoptic picture of the broad taxonomic diversity, morphological complexity, and ecological relationships present in the Middle Cambrian underwater world. The biota includes sponges, sea pens, brachiopods, priapulid and sipunculan worms, onycophorans, many diverse arthropods, sea cucumbers, stalked echinoderms, and chordates. Notably, a large group of magnificent creatures that exhibit morphologies intermediate between onycophorans and arthropods, termed "lobopods," have been discovered. At present, about a dozen extant multicellular animal phyla, plus a few completely extinct phyla, are established from these contexts.

In 1989, Stephen J. Gould provided a popular introduction to the Burgess fauna (the Chengjiang fauna was not yet appreciated) and interpreted its significance for the history of life with his book *Wonderful Life: The Burgess Shale and the Nature of History* (hereafter referred to as *Wonderful Life*).[2] *Wonderful Life* was illustrated with drawings by Marianne Collins of the Royal Ontario Museum, which elegantly highlighted the strangeness and beauty of these animals. Gould recounted the history of discovery of the Burgess locality by Walcott and provided a resume of what was then known about the biology of these organisms. He then used this account as a springboard to a sermon on the nature of the course of evolution. Notably, he argued that the fauna served to illustrate just how quirky the record revealed life's history to be, illustrated by his metaphor of "replaying life's tape" (pp. 45–52). Gould argued that if we could somehow rewind history and then set it going again, we would see different sorts of surviving lineages—and lineages perhaps dramatically unlike our own. My favorite quote is the following:

> We cannot bear the central implication of this brave new world. If humanity arose just yesterday as a small twig on one branch of a flourishing tree, then life may not, in any genuine sense, exist for us or because of us. Perhaps we are only an afterthought, a kind of cosmic accident, just one bauble on the Christmas tree of evolution. (p. 44)

Gould went one step further and argued that the Cambrian diversification event provided the single most significant episode of elaboration of phyletic-level body plans in Earth's history; from that point on, the story was primarily one of deletion of animal lineages. (This last claim was hyperbolic from the start; for example, the kingdom Plantae *did not yet exist* in the Cambrian. If we were literate intelligent plants, how would we evaluate this claim?)

Gould was taken to task on several fronts by critics, most notably, Simon Conway Morris.[3] Conway Morris had devoted many years to the understanding of the Burgess soft-bodied animals, and he is regarded today as one of the world's authorities on the Cambrian biota. He argued that natural selection could predictably favor adaptations that promoted motility, sensory organs, feeding, and ultimately intelligence. Thus, the course of life was less fluky and more predictable. Conway Morris has continued to persuasively argue this case, but that is another story. Meanwhile, there is general consensus that *Wonderful Life* stimulated a larger effort to really fathom the early history of life's diversification. But the elegant picture of Middle Cambrian biodiversity provided by the Burgess and Chengjiang lagerstaetten has left many with the impression that the Cambrian revolution is much more threatening to Darwin's synthesis than he could appreciate.

But there is more to the story …

During the past 150 years, intensive field exploration and occasional episodes of serendipity have provided us with a clearer picture of the kinds of life which existed prior to the Cambrian, as well as rounding out a Cambrian bestiary. While the appearance of visible multicellular life in the rock record is not as abrupt and single-stepped as Darwin and his contemporaries observed, the life forms during the long interval of 600–500 million years before the present (hereafter I will use the geologic convention of "Ma" for "millions of years before the present") have posed other very interesting problems of interpretation. There exists now a dynamic subdiscipline within paleontology devoted to the understanding of Precambrian and Cambrian life forms.

Our understanding of the Cambrian biodiversification event, as well as relevant biological events prior to the Cambrian period, has been greatly clarified since 1859 by the development of radiometric dating techniques. Through the application of several diverse techniques to Precambrian rocks, we now have a chronologic framework to order these biotic clues (fig. 1).[4] A nomenclature is in place so that communication between scientists around the globe can occur. A familiarity with these terms is necessary for grasping the flow of the narrative in the volumes

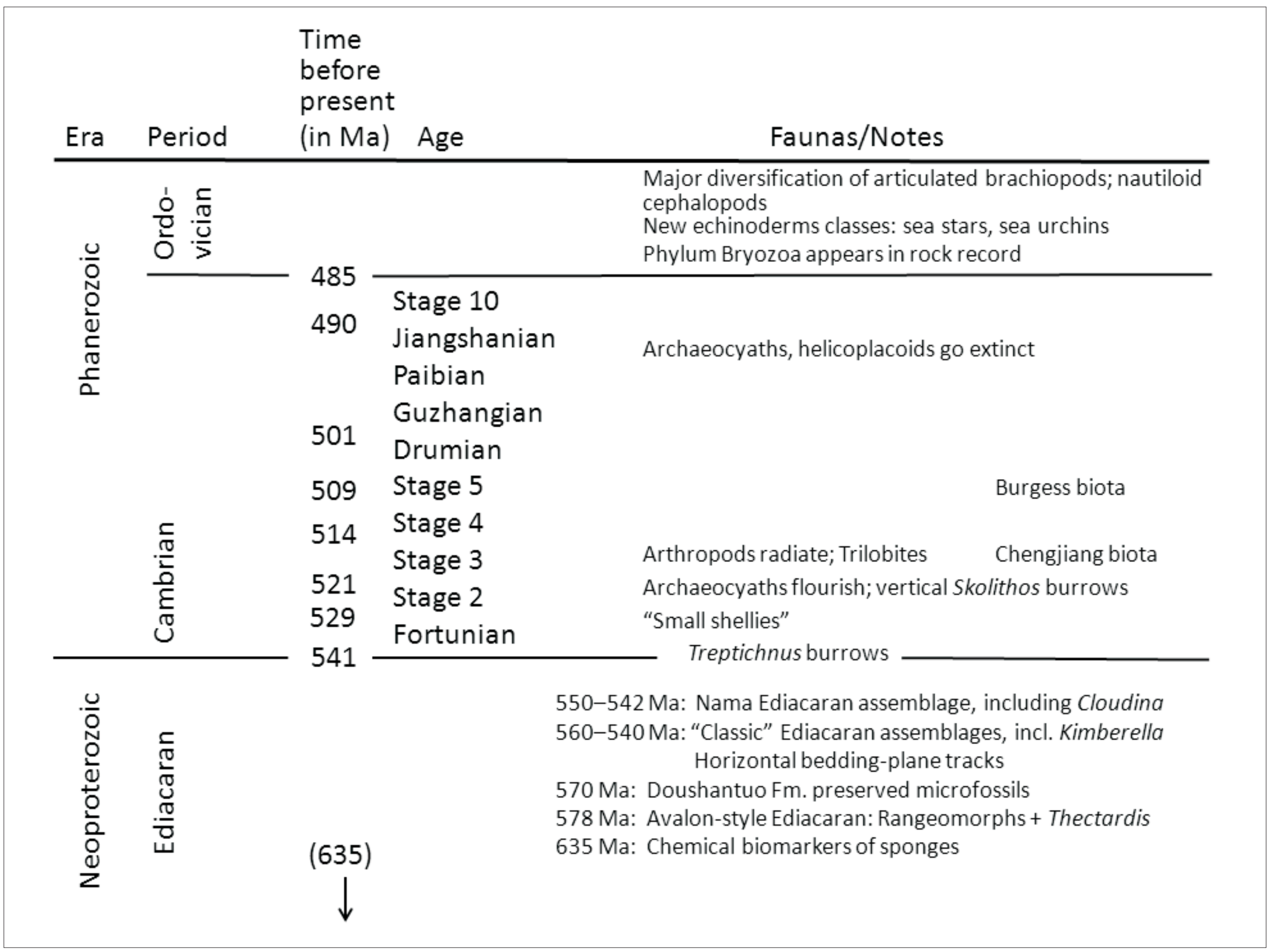

Figure 1: Chronology of Significant Biodiversification Events, Late Neoproterozoic through Early Phanerozoic Periods.
Note: The Neoproterozoic-Phanerozoic boundary equals the Precambrian-Cambrian boundary.

under review. This nomenclature is understood to be a working tool, and hence definitions become modified as more data come in. At present, geochronologists split Earth's history into four large eons: Hadean (4600–4000 Ma); Archean (4000–2500 Ma); Proterozoic (2500–541 Ma); and Phanerozoic (541 Ma–the present). The Cambrian Period (which has been subdivided into ten stages encompassing 541–485 Ma) was originally perceived due to the appearance of macroscopic, complex life forms (e.g., trilobites), thus marking the beginning of the Phanerozoic (which is from the Greek for "visible life") and delineating the Proterozoic-Phanerozoic or Precambrian-Cambrian boundary. The Proterozoic Eon is divided into three eras: Paleoprotoerozoic, Mesoproterozoic, and Neoproterozoic. The last, the Neoproterozoic Era, spans the time frame from 1000–541 Ma; its uppermost unit has been christened the Ediacaran Period (635–541 Ma). In this essay book review, I adhere to the Cambrian stage nomenclature adopted by the International Commission on Stratigraphy; this nomenclature has displaced a prior functional set of terms adopted from the biostratigraphy of the Siberian platform (e.g., Tommotian, Nemakit-Daldynian) which may be familiar to some of this audience.[5]

The record of life during the Archean and early Proterozoic is highly relevant to the biological/ecological events which began during the Neoproterozoic, but can only be briefly mentioned here. Microfossils preserved in the Apex Chert of western Australia, dated to 3450 Ma or slightly older, are regarded as the earliest clear evidence of life, although carbon from earlier deposits may be of organic origin.[6] Thinly laminated rock structures termed "stromatolites" are located in rocks of the same age and younger, extending up into the present. In today's world, these mats are the products of complex miniature ecosystems involving many types of cyanobacteria, other types of bacteria, and algae. By the late Paleoproterozoic, organic-walled unicellular structures, collectively termed "acritarchs" (from the Greek *akritos*, "uncertain"), are present. Later acritarchs of Mesoproterozoic age include recognizable representatives of the green, red, and brown algal clades; some may have been dinoflagellates. Acritarchs exhibit diversity rises and declines during the Mesoproterozoic and Neoproterozoic, and later abundance during the Cambrian and Ordovician periods.[7] Diverse acritarchs would have been part of a Neoproterozoic and Cambrian phytoplankton and hence significant as components in evolving marine food webs during that time. A protracted history of the transition of Earth's surface geochemistry to that correlated to an oxygenated atmosphere can be traced through several types of mineral indicators, revealing that these humble photosynthetic organisms are implicated, at least to some extent, as participants in the first major ecological transformation of our planet.

Only within the past fifteen years has the significance of sponges and sponge-like creatures for Neoproterozoic ecologies been appreciated. Lipids ("biomarkers"), which are today created by sponges, have been discovered in Neoproterozoic sediments >630 Ma in age. "Spongiomorph" body fossils are now known from several intervals within the overall Ediacaran and earliest Cambrian. I use the term spongiomorph because anatomical, biochemical, and genetic evidences reveal that the group of organisms that we all learned as Phylum Porifera is, in fact, a paraphyletic group; our living sponges are relicts of a radiation of erect water-filterers, an initial diversification of metazoans into a colonial lifestyle.[8] Thus, for around 100 million years prior to the classic "Cambrian explosion," sponges would have been filtering the water column. They would have transferred large volumes of accumulated dissolved organic carbon and deposited it as sediments as they died.

During the late 1940s, Reginald Sprigg, an Australian mining geologist, discovered a suite of enigmatic fossils in sandstones located in the Ediacara Hills, Flinders Ranges, South Australia. These fossils consisted solely of impressions of several types of organisms which must have been fairly flat and flimsy during life. Since that time, several diverse biotas resembling those of Ediacara have been discovered. Other principal biotas are known from Newfoundland, Namibia, and several locations in Russia; smaller biotas are known from Charnwood, England, and several locations in the Rocky Mountains of western North America. All these fossils are dated to the late Proterozoic and are collectively referred to as the "Ediacaran" biota. After a complicated and lengthy discussion on nomenclature, the latest Proterozoic period was christened the Ediacaran Period, after these creatures. (The lower boundary of the Ediacaran period, however, is defined by a global climatic event, the Marinoan glaciation.[9]) The fossils themselves have also engendered a long and complicated discussion as to their nature and significance. By far, the best single reference now available on these fossils is the volume, *The Rise of Animals*, which is discussed below.

While preservation of most Ediacaran biotas occurs as impressions, a few fossil biotas scattered in time through the late Precambrian have been discovered that preserve detailed anatomy in fine-grained sediments. This is true especially of the fossil biotas in the Doushantuo Formation, originally described during the 1970s and now known from several localities in southern China. The Doushantuo formation shales and phosphorites, dated to 570 Ma, elegantly preserve acritarchs, multicellular algae, and significantly, animal embryos of uncertain affinity.[10]

Meanwhile, during the last fifty years or so, our biostratigraphic picture of the early Cambrian also has been transformed by the realization that trilobites, long considered as the signature Cambrian organism, appear globally in the record *after* other shelled creatures and *after* complex traces of motile organisms. Lingulate brachiopods with phosphatic shells, small football-shaped echinoderms termed "helicoplacoids," and tiny conical tubes termed "hyoliths," among others, are found in deposits devoid of trilobites and below strata with abundant trilobites. Biostratigraphers now set the appearance of trilobites as the beginning of Cambrian Stage 3, at around 521 Ma (fig. 1). The Chengjiang fossils are assigned to Cambrian Stage 3 and the Burgess fauna assigned to Stage 5.

Already by the middle nineteenth century, biostratigraphers had added to the list of Cambrian actors a group of puzzling fossils termed "archaeocyaths" (Greek for "ancient cup"). These one- to two-inch-long, perforated cup-shaped or tubular fossils are now understood to be an extinct sponge group which created stout calcareous skeletons. This group blossomed in the early Cambrian, and together with diverse algal groups produced one of the earliest undoubted ecologic reef associations.[11] Nearly all archaeocyathan taxa were extinct by the end of Cambrian Stage 2, and the last few did not make it into the Ordovician.

Accompanying the archeocyaths were a large group of tiny tubular phosphatic fossils, plus a series of smaller plates and spines which must have become detached from skeletons.[12] They are mostly extracted from lower Cambrian phosphate deposits; some were probably originally composed of calcium carbonate, but have been replaced by phosphate minerals. These tiny fossils, typically 1 to 2 mm in largest dimension, are collectively known as the "small shellies." These skeletal remains are common in Cambrian Stage 1, achieved peak diversity in Cambrian Stages 2 and 3, and decline thereafter (fig. 1). Some of the isolated plates were eventually matched to dermal armor in middle-Cambrian organisms found in the Burgess or Chengjiang biotas, such as the onycophoran-like *Microdictyon*. Some of the tubes are probable annelid dwelling tubes. Some of the tiny shells exhibit microstructure which mark them as primitive brachiopods, while others are probable molluscs. And a further revelation: the tiny tube *Cloudina* (named after Precambrian paleobiologist Preston Cloud) and a few others are abundant in the uppermost Ediacaran, at least back to 548 Ma, in the Nama Group of southern Africa.

Furthermore, traces of various kinds of burrows and trackways appear in lower Cambrian sediments of Stage 1 and 2, again prior to the appearance of trilobites. Some of these are vertical burrows, evidently the products of creatures endowed with muscles and a hydrostatic body cavity. Some of the horizontal burrows exhibit scratch patterns suggestive of legs—although we do not understand what legged creatures were around to produce them. The appearance of the vertical burrow *Treptichnus pedum* was recognized by the International Commission on Stratigraphy during the 1990s as the boundary marker for the beginning of the Cambrian period. (Trace fossils are assigned binomial labels but not higher taxonomic categories. In most cases, they are not assumed to be the product of a specific biologic taxon, but rather a potential group of taxa.)

Thus, it is very important to understand that the "Cambrian Explosion," evidently a real and profound phenomenon, occurred during a protracted series of major ecosystem transitions which occurred over the period 600–490 Ma (and indeed, beyond, through the Ordovician Period, fig. 1). This Proterozoic/early Phanerozoic ecological context provides an important perspective with which to evaluate any attempt to explain Cambrian biodiversification.

Essay Book Review

The Cambrian Explosion: How Much Bang for the Buck?

THE RISE OF ANIMALS: Evolution and Diversification of the Kingdom Animalia by Mikhail A. Fedonkin, James G. Gehling, Kathleen Grey, Guy M. Narbonne, and Patricia Vickers-Rich.

This elegant volume is unquestionably the best available comprehensive resume of what is known about the Ediacaran creatures. Nearly every page includes a photograph (most in color) or a colored illustration, for a total of 480 figures in 256 initial pages. In addition, there is a 31-page atlas of Precambrian metazoans, with photos for most of the approximately 250 taxa described. The volume even contains a foreword by the science-fiction author Arthur C. Clarke.

The Rise of Animals begins with two background chapters: the first on the Hadean/Archean Eons, the second an overview of the Proterozoic. The next eight chapters treat the major biotas, followed by a chapter on the minor but significant localities. Chapter 12 examines the trace fossils, with their implications for motility of the Ediacaran creatures. Chapter 13 provides an overview of the microfossils, many of these organic-walled plankton, from the deposits. Chapter 14, by Patricia Vickers-Rich, is a nice, succinct discussion about what is currently known and unknown about the transition into the Cambrian world.

As noted previously, almost all of the Ediacaran fossils are impressions. These manifestly demonstrate that there were very few organisms which possessed hard skeletons during that interval of time. Careful attention to the details of bedding surfaces reveals that the organisms which left the impressions were often preserved under slimy mats of algae. Many of the Ediacaran creatures (e.g., *Rangea*) were frondose. The oldest Ediacaran assemblages, preserved in eastern Newfoundland, were composed of fronds ("rangiomorphs") which exhibit fractal branching at three or four scales. Their sedimentological context argues for a deep-water habitat, below the photic zone; thus they were not photosynthetic nor did they house photosynthetic symbionts.[13] They are believed to have obtained their nutrition osmotically through direct absorption from seawater.[14] Hans Pflug proposed that many or most of the Ediacaran frondose creatures were a unique phylum (christened the "Petalonomae") of osmotrophic organisms; Adolf Seilacher went one step further, considering these an extinct kingdom of life, the Vendobionts.

Later Ediacaran soft-bodied biota may have been sessile comb jellies (Phylum Ctenophora). A few forms (e.g., *Charniodiscus*) contain tiny tubes which may have housed zooids, implying these were sea pens (Phylum Cnidaria). Other Ediacarans (e.g., *Aspidella*) are disk-shaped impressions. Early on, they were interpreted as medusans. As more and more specimens became available, most were revealed to be holdfasts for the frondose organisms. Some of the disks (e.g., *Tribrachidium*) have three arms. They have been claimed to be jellyfish, echinoderms, and sponges, and remain problematic. Others are broad, flat, segmented impressions (e.g., *Dickinsonia*). These do not possess stalks and are interpreted alternatively as petalonomans which lay flat during life, or segmented worms of uncertain affinity (perhaps flatworms).

True sponges with a meshwork of spicules are preserved: *Palaeophragmodictya*, from the classical Ediacaran area of south Australia. The conical fossil *Thectardis* from the Avalon assemblage is also probably a sponge.

Some of the segmented organisms exhibit a midline keel and head-shield-like structure which leads some workers to believe that these were early non-skeletonized arthropods (e.g., *Parvancorina*). Some of the Chenjiang and Burgess arthropods resemble *Parvancorina*, for example *Naraoia*, which is a non-calcified strange trilobite with only two dorsal shields.

The fossil *Kimberella quadrata* is an elongated (up to six inches long), "boat-shaped" form with a distinct frill around the edges. It possessed a stiff but unmineralized integument, and is associated with traces of scratching which match those created by modern algae-rasping molluscs such as chitons and monoplacophorans. *Kimberella* is known from several Ediacaran localities; more than eight hundred specimens have been obtained from the White Sea region of Russia.

Thousands of Ediacaran fossils have now been obtained, and these document a marine world which is ecologically very different from that of today. There are no traces of deep burrowing, nor of grazing on the fronds. So, at least part of the explanation for the patent transformation into the world of the Cambrian lies in the elaboration of new ecological niches, which literally undermined and shredded the placid, stable-surface world of the Ediacaran.

The Ediacaran ecosystems of circa 580–540 Ma are still enigmatic. Comprehensive studies of sedimentation patterns combined with fossil clues demonstrate subtle variation in ecologies that correlate with water depth. There were changes over time in the Ediacaran world, too, as new actors came on the scene. *Kimberella* represents an advance guard of a phalanx of sediment plowers and croppers which would ultimately decimate the flimsy, helpless Ediacarans. And the basal Cambrian small shelly fauna, with hard parts appearing simultaneously across a diversity of biotic forms, probably represents a response to croppers which possessed teeth.

However, we do appreciate that some of our standard marine invertebrate phyla are evidenced during the late Precambrian: sponges early on, then diploblastic organisms such as ctenophores and cnidarians, and later, early molluscs, flatworms, and possibly arthropods. These Neoproterozoic representatives require that any comprehensive look at the Cambrian "explosion" must expand the time frame of this biodiversification event into one that took place over several tens of millions of years and involved a cascade of ecosystem transformations pushing a series of turnovers in major ecological actors.[15]

THE CAMBRIAN EXPLOSION: The Construction of Animal Biodiversity by Douglas H. Erwin and James W. Valentine.

Valentine is emeritus professor at the University of California, Berkeley; some aspects of his long (approaching fifty years) career are briefly discussed in the review of *Rereading the Fossil Record* in this issue of *PSCF* (p. 263). Erwin is a curator of paleobiology at the Smithsonian National Museum of Natural History. Like *The Rise of Animals*, this volume is elegantly illustrated. There are over seventy very clear photographs of Ediacaran and Cambrian fossils, plus numerous elegant reconstructions, colored graphs, and anatomical figures. The two dozen life-like organismal reconstructions by Quade Paul and the line art by Tom Webster add considerably to the reader's vision of what life forms were like in these strange ancient seas. The appendix, prepared by Sarah Tweedt, is a compilation of first appearances of major metazoan clades in the fossil record.

The Cambrian Explosion is organized into four parts. Part I outlines the stratigraphic and paleoenvironmental context of the Ediacaran and Cambrian world. Part II, consisting of three chapters and 160 pages (occupying nearly half of the book), is a detailed look at the life of these periods. Part III focuses on explanatory possibilities, in the form of changing ecologies and different genomic regulatory mechanisms. Part IV consists of two chapters summarizing the late Proterozoic and Cambrian biotic revolutions.

Part II (chaps. 4–6) reviews the Ediacaran and Cambrian biota. Chapter 4 lays out the basic taxonomic/morphological framework for classifying these organisms and for grouping them into higher biological categories. Body architectures are illustrated with crisp, multicolor diagrams. A scheme for the classification of metazoans (multicellular animals) is elaborated. This scheme has emerged over the past thirty years through a concerted multidisciplinary examination of the key similarities and differences in major invertebrate groups, much of which was summarized in Valentine's masterful 2004 opus, *On the Origin of Phyla*.[16] Then, in chapters 5 and 6, the groups of Ediacaran and Cambrian organisms are described and illustrated as ecological assemblages, and on a group-by-group basis. Along the way, Erwin and Valentine explain just how the architectures of individual organisms fit into our emerging phylogenetic picture for Metazoa. The top-quality photographs, reconstructions, and clear discussion of these taxa make chapters 5 and 6 the best single one-stop overview of the "explosion biota" to be had.

The book has several other strengths, beyond the clarity and aesthetic value of the illustrations and the extensive treatment of the biology of these organisms in Part II. One is the detailed discussion of the changing ecology of the marine world in the Proterozoic and early Phanerozoic (chaps. 3 and 7). This involves summarizing data from sedimentology, various geochemical indicators (e.g., sulfur minerals) of such important environmental parameters as atmospheric oxygenation, evidences for Neoproterozoic climate swings, and seafloor sediment stability. These environmental evidences dovetail with the clues from the biota, including traces of activity, to provide a picture of changing ecosystems over this period spanning more than 100 million years. As one case in point, noted above: there are no marks of predation on the Ediacaran creatures. The appearance of marine mineralized skeletons is, on the one hand, an indicator of increased oxygen concentrations (permitting the metabolic levels necessary for depositing skeletons), and, on the other hand, a new ecological context: biting, rasping, and drilling.

Other major ecological changes include deeper burrowing:

> The advent of burrowing in the very latest Ediacaran or earliest Cambrian led to a seafloor "agronomic revolution," heralding the disappearance of the firm, microbially stabilized sediments of the Neoproterozoic and the increasing aeration and disturbance of sediments by the burrowers. (p. 225)

Yet a third highly significant biotic revolution was the appearance of mesozooplankton, linking pelagic and benthic ecosystems. Another was the colonization of microbial reefs by tubular shelled creatures, including the archaeocyaths, resulting in a complex, tiered architecture which provided numerous microniches ready for occupation. Based on an analysis of ecological spaces by Richard Bambach, Andrew Bush, and Doug Erwin,[17] Valentine and Erwin identify twelve different ecological roles for Ediacaran organisms, expanding to thirty modes in the first half of the Cambrian. This expansion resulted in middle Cambrian food webs that, surprisingly, are highly similar to modern marine food webs, albeit with different actors.

Chapter 8, "The Evolution of the Metazoan Genome and the Cambrian Explosion," probes the (obligate!) genetic system correlates of Cambrian biodiversification. Erwin and Valentine begin by noting the (unexpected) low number of human genes coding for proteins (<25,000). The key to understanding development of complex organisms lies not in single genes manufacturing proteins (which they term "housekeeping genes") but rather in gene regulatory networks (GRNs).[18] GRNs affect transcription, resulting in cascades of differentiating cell lineages, leading to major architectural or physiological systems. The "kernels" of these systems are modules which are highly conservative; an example provided is the module which specifies endomesoderm development in both sea urchins and starfish (p. 275). Interestingly, this same kernel is present in zebrafish. In general, such kernels are conserved because tinkering with these will result in a nonviable organism. On the other hand, kernels can be interlinked with modular elements termed "plug-ins," which can alter the sequencing of deployment of kernels or their interaction, ultimately influencing gene transcription. There is no doubt that these mechanisms are those that direct construction of major groups of body plans, and underlie the pattern that we are still elucidating for the relationships of phyla.

In Part IV, Erwin and Valentine sum up their review of Cambrian faunal diversification. In chapter 9, "Ghostly Ancestors," they summarize the evidences which are currently available to reconstruct ancestral morphologies and genealogical connections among metazoans. Chapter 10, "Constructing the Cambrian," provides an interpretation of the Ediacaran/early Cambrian phenomenon. They believe that only by integrating three distinct sources of data will we be able to understand the Cambrian diversification event: (1) historical changes in the physical environment; (2) elaborations in developmental mechanisms, particularly in GRNs; and (3) changes in ecological relationships over time, including the elaboration of new adaptive niches. While "the early evolutionary history of metazoans was characterized by a range of innovations unmatched by subsequent Phanerozoic evolution" (p. 319), Erwin and Valentine believe that we are making significant headway in constraining our explanations for these innovations. The Cambrian diversification event is "a tractable but unresolved problem" (p. 330).

Erwin and Valentine admit that there is much yet to be deciphered concerning the Precambrian-Cambrian biotic transition. They see two major unresolved questions:

> First, what evolutionary processes produced the gaps between the morphologies of the major clades? Second, why have the morphologic boundaries of these body plans remained relatively stable over the past half a billion years? (p. 330)

They later term these correlated issues "the conservative and clumpy nature of body plans" (p. 332). The answer, they believe, must involve (historically) fixed discontinuities in patterns of GRNs.

It is the exact when and how these discontinuities were fixed that will continue to provide controversy and impetus to further paleontological field work. Right now, as best we can fathom, these genetic innovations occurred either prior to the advent of mineralized tissues, or during the initiation of this event (i.e., the time of the "small shellies"). Thus we await revelations which might be provided by just the right fossil bonanza, such as preservational circumstances like those of Chengjiang, but dated to 530 Ma, 550 Ma, or 560 Ma. In the meantime, for the best current introduction to the Proterozoic-Cambrian transition and to the fascinating organisms inhabiting the seas way back then, go to this volume.

DARWIN'S DOUBT: The Explosive Origin of Animal Life and the Case for Intelligent Design by Stephen C. Meyer.

Meyer, a philosopher of science with a PhD from Cambridge University, is director of the Discovery Institute's Center for Science and Culture. At less than half the price of Erwin and Valentine's volume, there must be a trade-off, and it comes in the number and quality of illustrations. Meyer's volume features a center section containing twenty-three very nice color plates: 1–3 are photos of the Chengjiang locality; 4–23 are of Cambrian organisms, mostly from Chengjiang. There are about two dozen good black-and-white photos of Ediacaran or Cambrian organisms, plus many line drawings and diagrams drafted by Ray Braun. Some of the line drawings are a bit rough. There are also thirty-eight pages of dense endnotes which grant greater detail to statements made in the course of the narrative.

Part I, "The Mystery of the Missing Fossils," consisting of seven chapters with 150 pages, is an extended review of the Precambrian-Cambrian transition, including a history of paleontological discoveries. Chapters 2 and 3 provide a survey of the Burgess and Chengjiang biotas. Chapter 4, "The *Not* Missing Fossils?," looks at the Ediacaran biota. Part II, "How to Build an Animal," consists of seven chapters treating the role of genes in organismal development, and why Meyer and others are not impressed with classical neo-Darwinian mechanisms as potential explanations for the origin of the Cambrian body plans. Part III includes six chapters explaining why the author feels that intelligence must be provided from without in order to account for the genetic programming necessary to rapidly produce the Cambrian biota. Thus, much of the book is a polemic. Just as in the case of *Wonderful Life*, an opinioned work which had many faults but which engendered much useful labor and thought, this book must be examined from many different angles.

A signal component in Meyer's thesis is the notion that "the main pulse of Cambrian morphological innovation occurred in a sedimentary sequence spanning no more than 6 million years" (p. 73). Meyer cites geochronological studies by Samuel Bowring (MIT) and colleagues, and by Doug Erwin and colleagues.[19] The first study, by Bowring et al., established that the Manykaian stage lasted no less than ten million years, while the Tommotian and Atdabanian stages lasted five to ten million years. Translating into standardized stage dates, the Tommotian plus Adtabanian are the upper part of Stage 2 plus Stage 3, together accounting for at least ten million years. But the Cambrian Stage 1, roughly equivalent to the Manykaian-Daldynian, contains the record of the rapid expansion of the "small shelly fauna" in which we discern elements of the "classic" Cambrian fauna, such as brachiopods, molluscs, and onycophorans. Erwin et al. deliberately include Cambrian Stage 1 along with the very latest Ediacaran in their designated interval for diversification, thus identifying a biodiversification period "with a dramatic rise over about 25 million years in the first several stages of the Cambrian …"[20] Meyer's claim for a span of "not more than 6 million years" represents a minimalist interpretation of these two articles, and particularly the more current Erwin et al.

The absence of any discussion of the "small shellies," along with the stratigraphic subdivisions of the uppermost Ediacaran and Cambrian Stage 1, represents a significant lacuna in Meyer's treatment of the Cambrian explosion. Moreover, while the surface trails of the Ediacaran receive a few pages of discussion (pp. 81, 85–6), the transition to deeper burrowing requiring muscles and/or a hydrostatic skeleton at the beginning of the Cambrian also goes disregarded. Thus, these significant evidences that many kinds of poorly mineralized multicellular animals were living and dying in the earliest Cambrian seas are not made available to the reader. Only by ignoring these evidences can the claim of "not more than 6 million years" be sustained.

There is also no discussion of changing early- to mid-Cambrian ecologies, which, in fact, opened many environmental niches. Such significant innovations as ecological reefs and new planktonic food webs, which would provide new adaptive niches, are simply not mentioned. This general glossing over of significant stratigraphic and paleoecological data helps one to understand the exasperation expressed by paleontologist reviewers such as Donald Prothero.[21]

Chapter 6 is a critique of our fallible efforts to thoroughly understand the phylogenetic organization to life.

> My point in summarizing these disputes is to simply note that the molecular and anatomical data commonly disagree, that one can find partisans on every side, that the debate is persistent and ongoing, and that, therefore, the statements of Dawkins, Coyne, and many others about all the evidence (molecular and anatomical) supporting a single unambiguous tree are manifestly false. (p. 124)

There are ongoing disagreements, to be sure, but some confusion is to be expected when we consider that the further back we probe the initial branching events, the more similarities we expect to see across the boundaries of what we can today easily distinguish as phyla. In fact, the detailed anatomy provided by the Chengjiang and Burgess biotas is proving to be of huge help in resolving our understanding of the branching, hierarchical structure to living creatures.[22]

In Part II, "How to Build an Animal," Meyer mounts a step-by-step critique of standard neo-Darwinian accounts for the origin of phylum-level body plans. Meyer takes his time and builds a case showing that standard "bean-bag" genetics cannot provide the kinds of integrated developmental systems that the metazoan radiation demands. Chapter 13, "The Origin of Body Plans," concludes with a discussion of Eric Davidson's work on GRNs.[23]

> Davidson's findings present a profound challenge to the adequacy of the neo-Darwinian mechanism. Building new animal body plans requires not just new genes and proteins, but new GRNs. (p. 268)

Chapter 14 explains why epigenetic processes in development are important, and why modern evolutionary biology has become much more pluralistic. Many of those who "have raised questions about the adequacy of the standard neo-Darwinian mechanism, and/or the problem of evolutionary novelty in particular" are briefly mentioned, for example, Brian Goodwin, Gerd Mueller, Stuart Kauffman, and Rudolf Raff. Interestingly, several paleontologists are included in Meyer's list of skeptics, including Simon Conway Morris, Robert Carroll, Doug Erwin, and James Valentine (p. 287).

Meyer, following Goodwin, Mueller, and others, is absolutely correct that epigenetics is important for understanding organismal development and animal forms. But I think that the average reader of chapter 14 will be underinformed. Meyer begins the narrative in chapter 14 by outlining the experiments of Hans Spemann and his PhD student Hilda Mangold in the 1920s on developing newts, plus some important subsequent studies during the middle-twentieth century, which demonstrated the significance of the cellular chemical environment for gene expression during development. (Chemical gradients across the developing embryo which determine which genes are expressed are often termed "developmental morphogenetic fields.") Meyer then moves on to the

> groundbreaking collection of scientific essays entitled *Origination of Organismal Form: Beyond the Gene in Developmental and Evolutionary Biology*, edited by two distinguished developmental and evolutionary biologists, Gerd Mueller, of the University of Vienna, and Stuart Newman, of New York Medical College [published in 2003] … Mueller and Newman not only highlighted the importance of epigenetic information for the formation of body plans during development; they also argued that it must have played a similarly important role in the origin and evolution of body plans in the first place. (p. 272)
>
> As they and others in their volume maintain, neo-Darwinism lacks an explanation for the origin of organismal form precisely because it cannot explain the origin of epigenetic information. (p. 273)

Meyer relates,

> I first learned about the problem of epigenetic information and the Spemann and Mangold experiment while driving to a private meeting of Darwin-doubting scientists on the central coast of California in 1993 … On our drive, I asked [Johnathan] Wells why developmental biology was so important to evolutionary theory and to assessing neo-Darwinism. I'll never forget his reply. "Because," he said, "that's where the whole theory is going to unravel." (p. 273)

Certainly it is true that many of the primary architects of the neo-Darwinian synthesis downplayed embryology. But Spemann received the Nobel Prize in 1935 for his work, and the study of morphogenetic fields in development has been standard fare in laboratories and embryology texts since his day. (I first learned about Spemann's experiments in 1973, in an undergraduate class in vertebrate embryology at a state university.) It is a fact that our understanding of gene regulation has grown exponentially since 1970, and that biologists such as Goodwin, Raff, and Davidson have been discovering more and more complexity in the regulation of the developmental process. But, while it is true that Goodwin and others believe that their discoveries pose a major challenge to neo-Darwinian orthodoxy, this does not cause them to abandon their belief that the history of life can be explained as the outcome of biological processes! Indeed, many evolutionary biologists and paleontologists are looking to build the notions provided by morphogenetic fields and developmental constraints into a larger synthesis. Meanwhile, I suspect that the average (nonbiologist) reader will come away from chapter 14 with a mistaken impression that this previously innocuous or neglected topic has just now been revealed to completely overturn our understanding of the history of life.

Part III, "After Darwin, What?," builds a case for considering intelligent design (ID) as a reasonable potential resolution to the enigma of the Cambrian explosion. Chapters 15 and 16 consider non-Darwinian materialistic explanations, such as Stuart Kauffman's suggestion that self-organizational principles dictate the direction for life. I think Meyer makes a good case that self-organizational principles do not get us very far in explaining morphogenesis of intricate organisms. Chapter 17 defends the notion that ID should be at least considered as a reasonable explanation for (some potential) phenomena; chapter 18 looks for "Signs of Design in the Cambrian Explosion." The work of Doug Erwin and Eric Davidson, already noted above, is pivotal. Meyer believes that developmental GRNs, with their intricate circuitry and multiple feedback systems, are too complex to have arisen piecemeal, even granting millions of years culminating in the Cambrian event. Here we have the focal point of the long argument. Chapters 19, "The Rules of Science," and 20, "What Is at Stake," are a plea for a reconsideration of the role of design. Chapter 20 begins with a visit by Meyer and his son to the Burgess site and is a brighter, more upbeat endnote for the volume.

I admit that, by temperament, I am inclined to see design in nature, and so I resonate with some of Meyer's arguments. I think he and I would concur that humans are not "baubles on the Christmas tree of life." I think he has developed a case for the inadequacy of standard "bean-bag" genetic approaches to the production of animal body plans. Does this negate a genealogical organization to life? No. And does the development of this strong case require a glossing over of the series of profound ecological changes which transformed the late Ediacaran world through the early Cambrian, into the middle Cambrian, and beyond? I hope not. A lack of real engagement with long spans of geologic time has long plagued the advocates of ID.[24] And, sadly, the lack of engagement with real time tends to divorce ID arguments from real creatures existing in real history, and perhaps counter-intuitively, render these arguments joyless. Meyer's examination of the Cambrian event employs dates, looks at several of the interesting taxa, and even concludes with a pilgrimage to the Burgess locality—but it could use a dose of pleasure in these wild and weird life forms.

Does *Darwin's Doubt* exhibit irritating flaws? Yes. Is the Erwin and Valentine book, *The Cambrian Explosion*, authoritative and more fun than *Darwin's Doubt*? Yes. But do I think that Meyer makes an argument that folks should think hard about? Yes.

Wonder-Full Life

Our knowledge of the Cambrian diversification event has grown enormously since *Wonderful Life* was published, while our real *wonder* over just what was going on keeps increasing. J.-Y. Chen, in a significant review article, notes that

> the transition of the two-segmental lobopodian head into the first arthropod head required a *quantum leap* (my italics) through multiple, synchronous events, including: transition of the first head appendage into the stalked eyes; specialization of the second head appendage into sensorial organs known as antennae; and displacement of the mouth into a ventral position of the antennal segment.[25]

Erwin and Valentine, near the conclusion of *The Cambrian Explosion*, remark that "the pathway from sponges to eumetazoans is the *most enigmatic* [my italics] of any evolutionary transition in metazoans" (p. 324). One can continue to multiply quotes such as these. Conway Morris, in a recent review, states, "My main conclusion is that the Cambrian 'explosion' is a real event."[26] Is this event, occurring over an interval of twenty-five or more million years, opaque to our efforts to discern normal causal processes operating in the past? Conway Morris, a few paragraphs following the quote above, concludes, "Does this course of events create a problem for Darwinism, even for evolution? I do not think so."[27]

How *do* we interpret God's active providence in the affairs of the world of the past? As Christians, we understand that God is good and that his creation reflects that. But in the human world, we think that we can (or must) discriminate between God's decretive will and his permissive will. Does God worry about which color shirt I put on this morning? I sometimes think our pondering over the direction of life is something like that. I believe God directed the course of life, but I am not sure whether he worries about putting together every bit of (just-right) pigment on the back of a dragonfly, or even about which particular flower that honeybee is going to pollinate, and so forth. Maybe he likes to watch how his creatures behave, just as he enjoys hearing us pray to him voluntarily. I am not sure that it is in our place to know. If that is so, perhaps our efforts to obtain certainty in seeing his design will end in frustration.

I do know that the life of the past praised its Creator, just as giraffes and oysters and prickly pear cacti do today. I think we are *blessed* to get glimpses of these ancient creatures, and also blessed to intelligently ferret out what was going on, even if this ferreting-out leads us up some dead ends from time to time. ★

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Notes

1C. Darwin, *On the Origin of Species* (1859; reprint, Cambridge, MA: Harvard University Press, 1964), 307.

2S. J. Gould, *Wonderful Life: The Burgess Shale and the Nature of History* (New York: W. W. Norton and Company, 1989).

3S. Conway Morris, *The Crucible of Creation: The Burgess Shale and the Rise of Animals* (Oxford: Oxford University Press, 1998).

4Cf. J. G. Ogg, G. Ogg, and F. M. Gradstein, *The Concise Geologic Time Scale* (Cambridge: Cambridge University Press, 2008). Dates in this article and in figure 1 conform to those of the International Commission on Stratigraphy: see www.stratigraphy.org for further information.

5Ibid.

6J. W. Schopf, *Cradle of Life: The Discovery of Earth's Earliest Fossils* (Princeton, NJ: Princeton University Press, 1999); and B. T. De Gregorio et al., "Biogenic Origin for Earth's Oldest Putative Microfossils," *Geology* 37 (2009): 631–4.

7De Gregorio et al., "Biogenic Origin for Earth's Oldest Putative Microfossils;" and A. H. Knoll and S. Xiao, "Precambrian Lagerstaetten," in *Palaeobiology II*, ed. D. E. G. Briggs and P. R. Crowther (London: Blackwell Publishers, 2003), 332–7.

8E. A. Sperling, D. Pisani, and K. J. Peterson, "Poriferan Paraphyly and Its Implications for Precambrian Palaeobiology," *Geological Society of London Special Publications* 286 (2007): 355–68; and E. A. Sperling, K. J. Peterson, and M. LaFlamme, "Rangeomorphs, *Thectardis* (Porifera?) and Dissolved Organic Carbon in the Ediacaran Oceans," *Geobiology* 9 (2011): 24–33.

9A. H. Knoll, M. R. Walter, G. M. Narbonne, and N. Christie-Blick, "The Ediacaran Period: A New Addition to the Geologic Time Scale," *Lethaia* 39 (2006): 13–30.

10Knoll and Xiao, "Precambrian Lagerstaetten."

11B. R. Pratt, B. R. Spincer, R. A. Wood, and A. Yu. Zhuravlev, "Ecology and Evolution of Cambrian Reefs," in *The Ecology of the Cambrian Radiation*, ed. A. Yu. Zhuravlev and R. Riding (New York: Columbia University Press, 2001), 254–74.

12A. C. Maloof et al., "The Earliest Cambrian Record of Animals and Ocean Geochemical Change," *Geological Society of America Bulletin* 122 (2010): 1731–74.

13G. M. Narbonne, "Modular Construction of Early Ediacaran Complex Life Forms," *Science* 305 (2004): 1141–4.

14Cf. M. A. S. McMenamin and D. L. S. McMenamin, *The Emergence of Animals: The Cambrian Breakthrough* (New York: Columbia University Press, 1990); and Sperling, Peterson, and LaFlamme, "Rangeomorphs, *Thectardis* (Porifera?) and Dissolved Organic Carbon in the Ediacaran Oceans."

[15]D. H. Erwin and S. Tweedt, "Ecological Drivers of the Ediacaran-Cambrian Diversification of Metazoa," *Evolutionary Ecology* 26 (2012): 417–33.

[16]J. W. Valentine, *On the Origin of Phyla* (Chicago, IL: University of Chicago Press, 2004).

[17]R. K. Bambach, A. M. Bush, and D. H. Erwin, "Autecology and the Filling of Ecospace: Key Metazoan Radiations," *Palaeontology* 50 (2007): Pt. 1:1–22.

[18]E. H. Davidson and D. H. Erwin, "Gene Regulatory Networks and the Evolution of Animal Body Plans," *Science* 311 (2006): 796–800; and E. H. Davidson, "Emerging Properties of Animal Gene Regulatory Networks," *Nature* 468 (2010): 911–20.

[19]S. A. Bowring, J. P. Grotzinger, C. E. Isaachsen, A. H. Knoll, S. M. Pelechaty, and P. Kolosov, "Calibrating Rates of Early Cambrian Evolution," *Science* 261 (1993): 1293–8; and D. H. Erwin, M. Laflamme, S. M. Tweedt, E. A. Sperling, D. Pisani, and K. J. Peterson, "The Cambrian Conundrum: Early Divergence and Later Ecological Success in the Early History of Animals," *Science* 334 (2011): 1091–7.

[20]Erwin, Laflamme, Tweedt, Sperling, Pisani, and Peterson, "The Cambrian Conundrum: Early Divergence and Later Ecological Success in the Early History of Animals." The full quote, which is partially extracted in this review, is the following:

> A recompilation (SOM text 1 and table S1) of the first occurrences of all metazoan phyla, classes, and stem-classes (extinct clades) of equivalent morphological disparity (fig. 2, D and E) shows their first occurrences in the latest Ediacaran (by 555 MA), with a dramatic rise over about 25 million years in the first several stages of the Cambrian, and continuing into the Ordovician (figs. 1 and 3 and table S3). (p. 1091)

[21]D. Prothero, "Stephen Meyer's Fumbling Bumbling Cambrian Amateur Follies: Review of *Darwin's Doubt*," 2013, http://www.amazon.com/review/R2HNOHERF138DU/ref=cm_cr_pr_viewpnt#R2HNOHERF138DU.

[22]Cf. Valentine, *On the Origin of Phyla*; and Douglas H. Erwin and James W. Valentine, *The Cambrian Explosion: The Construction of Animal Biodiversity* (Greenwood Village, CO: Roberts and Company, 2013).

[23]Davidson and Erwin, "Gene Regulatory Networks and the Evolution of Animal Body Plans;" and Davidson, "Emerging Properties of Animal Gene Regulatory Networks."

[24]M. Roberts, "Intelligent Design: Some Geological, Historical, and Theological Questions," in *Debating Design: from Darwin to DNA*, ed. W. A. Dembski and M. Ruse (Cambridge: Cambridge University Press, 2004), 275–93.

[25]J.-Y. Chen, "The Sudden Appearance of Diverse Animal Body Plans during the Cambrian Explosion," *International Journal of Developmental Biology* 53 (2009): 737.

[26]S. Conway Morris, "Darwin's Dilemma: The Realities of the Cambrian 'Explosion,'" *Philosophical Transactions of the Royal Society* B 361 (2006): 1077.

[27]Ibid., 1078.

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Environment

DUSTY EARTHLINGS: Living as Eco-Physical Beings in God's Eco-Physical World by John Mustol. Eugene, OR: Cascade, 2012. 280 pages. Paperback; $33.00. ISBN: 9781620321171.

Author John Mustol deserves credit on many fronts with this interestingly titled book, his first. *Dusty Earthlings* explores environmental ethics from a Christian standpoint, doing justice along the way to the conceptual and theoretical challenges of thinking about nature as well as grounding his work in the nitty-gritty dust and dirt of this world.

There is a certain expansive approach to the topic that in a different author might be interpreted as facileness. Of necessity, given the breadth of its subject, the book moves quickly across an array of theological, philosophical and scientific arguments and conclusions, almost any of which would be suitable for book-length treatment on its own. One has the feeling of quickly hopping from stone to stone across a fast running stream, hoping that each stone is properly anchored. If not, one's feet will get wet or worse.

Fortunately, the stones are solidly placed, in large part due to the situatedness of the author. Mustol is a come-late-to-writing author who packs a lifetime of significant reading, thinking, and reflecting into a single volume. A physician by training and career, Mustol retired from the medical profession to pursue a theological PhD late in life and now teaches at Bethel Seminary in San Diego. Mustol's medical experience and scientific background illumine his approach to the subject. He has obviously been engaging these questions for some time, and this book constitutes his considered conclusions.

The second half of Mustol's title is transparent: Humans are physical entities enmeshed in ecological webs within God's world. This is the way God created both us and the world. Much of the book is devoted to drawing out the implications of this eco-physical enmeshment.

The first part of the title is more complex. We are, of course, created from the dust of Earth—hence, "dusty earthlings." But Mustol is indebted to Fuller Seminary theologian Nancey Murphy's notion of nonreductive physicalism. We are inescapably physical entities, although not in a reductionistic sense. Knowing that Murphy's position on philosophical anthropology is controversial, Mustol wisely refuses to hang his entire argument on it. Instead he argues that nonreductive physicalism is sufficient, but not necessary, to ground his argument that Christians must heed the ecological realities of life in this world. So long as readers accept that humans are inescapably physical, and therefore need to be reconciled to rather than alienated from the physical world, Mustol's argument should resonate.

What audience would benefit most from Mustol's writing? *Dusty Earthlings* would well serve as a basic text in a survey course on Christian environmental stewardship. Mustol's copious quotations from a wide variety of Christian writers, as well as his referencing of select environmental issues as examples, create rabbit trails of potentiality for further investigation.

Dusty Earthlings's most pointed arguments function primarily as an *apologia* toward Christians who dismiss environmental concerns as beneath the dignity of theological attention. They also serve a secondary purpose, that of countering arguments from non-Christians who claim that Christianity is inescapably other worldly in its concerns.

For readers already familiar with the basic outline of Christian environmental thought and who need little convincing of our connectedness to creation, two sections of the book will generate the most interest. One will satisfy; the other will most likely disappoint.

Mustol is particularly helpful when summarizing the available data and arguments on human uniqueness as they relate to and inform the concept of the *imago Dei*. His medical and scientific expertise is particularly evident when he reviews the evidence on human capacities in relationship to the rest of the animal world. This is comfortable ground for him, and he does his work thoroughly. This comfort level carries over into his theological conclusions as he eschews a singular meaning to the *imago Dei* and opts for a multi-faceted interpretation that emphasizes our representation of God on this earth through our various functions and abilities.

Less satisfying is Mustol's invocation of Murphy's nonreductive physicalism. For many readers, this will be the most novel idea in the book. Mustol's inclination to hedge his bets, however, prevents him from fully exploring the concept. Mustol spends insufficient time on the concept of nonreductive physicalism to give the reader—especially one for whom the concept is new—an opportunity to explore the implications of a monist understanding of human beings. Nor does he fully engage some of the primary New Testament texts that slant toward a dualism of body and soul. Mustol repeats the canard that Hebrew notions of creation and anthropology must be kept free of the taint of Hellenism (despite the presence of Hellenistic vocabulary and concepts in the New Testament, however, they may be shaped Hebraically). Those intrigued by non-reductive physicalism will wish for a fuller treatment, while those skeptical will wish that judicious use of Occam's razor would leave a cleaner look and smoother complexion to Mustol's overall intent.

Reviewed by Rolf Bouma, Pastor for Academic Ministries at the Campus Chapel and Adjunct Faculty, Program in the Environment, University of Michigan, Ann Arbor, MI 48104.

General Sciences

IF TRUTH BE KNOWN by Clarence Menninga. Published by Clarence Menninga, 2012. 286 pages. Paperback. ISBN: 9780985882310.

Though few under the age of fifty may realize it, Clarence Menninga was one of the early voices among Christian geologists to raise concerns over the treatment of science by young-earth creationists. Menninga was hired by Calvin College in 1967 to start a geology program, where he eventually joined with fellow Calvin faculty members Howard Van Till and Davis Young to author the classic work *Science Held Hostage: What's Wrong with Creation Science AND Evolutionism* in 1988. A quarter century later, Menninga has produced a solo-authored work, *If Truth Be Known*, on a similar topic.

The book is written, as related in the foreword, for "those who attend Christian churches … who have legitimate questions about conflicting stories from science and Christian faith, but have had little or no training in science …" His concern for this target audience stems from his own experience and frustration of being told as a child that dinosaurs were "just the wild imaginings of godless scientists who are trying to lead Christians astray," only to discover later that dinosaurs were, in fact, quite real. The stated intention of the work is to address arguments related to the age of the earth, not evolution, but the book does touch on the subject of increasing complexity of life in discussions on the second law of thermodynamics in chapters 13 and 14.

The title of the book derives from a popular expression that often follows the telling of a story in which details are either left out or misrepresented, resulting in a mischaracterization of the actual events. But—"if truth be known"—when missing details of the story are related, or when correctly represented, the story takes on an entirely different meaning. Each chapter of this book relates a common partial or inaccurate story used to defend a young earth, followed by a detailed and well-documented account of the parts of the story that were either left out or communicated incorrectly, to show how the full story does not support a young earth. Though unabashedly critical of young-earth arguments that misrepresent scientific evidence, Menninga repeatedly states that there is no dishonor in believing that the earth is young, but one should not base such belief on misrepresented or inaccurate scientific data.

Chapter 1 opens with a review of what science is, and what its limitations are. Science is possible because the physical universe is ordered, allowing us to investigate and understand how it works. The presence of order neither presupposes nor denies the existence of a Creator, and is thus practiced by Christians and non-Christians alike. While science is subject to human interpretation and thus is fallible, Menninga reminds readers that theology (our understanding of the Bible) is also subject to human interpretation and is likewise fallible. To minimize human error in the reporting of scientific studies, Menninga provides four guidelines: (1) report the data and observations accurately (honestly); (2) report all the data without omissions (completeness); (3) make the methods, data, and observations freely available (openness); and (4) mention of others' work should be accurate and representative (faithfulness). All of the young-earth arguments discussed in the subsequent chapters violate one or more of these guidelines, resulting in a mistaken appearance of supporting a young earth.

No attempt was made by the author to group chapters by the type of violation, and readers are not always explicitly told that chapter *X* is an example of violating a particular guideline *Y*. Nonetheless, Menninga does an excellent job of documenting what was left out, misquoted, misrepresented, or misunderstood for a diverse collection of arguments, addressing fossils (dinosaurs, whales, frozen mammoths, petrified trees, fish, and birds), hoaxes (Piltdown Man and Java Man), rock layers (Green River varves, Mount St. Helens ash, Columbia Basin lava), principles and terminology (uniformitarianism, thermodynamics), and radioactive decay (decay rates, dating methods, isochrones, uncertainties, sample selection, neutrinos, inconsistent results, radiocarbon).

Menninga will likely take some criticism from young-earth advocates for "not keeping up with current young-earth literature," because of his frequent references to Henry Morris's *Scientific Creationism*. However, Menninga accurately notes that *Scientific Creationism* continues in recent printings to be touted as "authoritative and thoroughly documented," and the young-earth arguments described either are still being circulated or are excellent examples of how stories have been historically misrepresented. A particular strength of this book is Menninga's attention to original source material, particularly in his chapters on frozen mammoths and "brontosaurus" fossils. The juxtaposition of the young-earth renderings of history with the actual words of the original explorers and researchers is quite enlightening.

The final three chapters of the book are devoted to general observations on science and the conflict with young-earth claims, including why it is appropriate to bar creation science from public education (because the claims have been tested and found false), why changes in scientific paradigms do not mean that science cannot be trusted, and why Menninga believes we have reached a point at which we can say, "Enough! There is no scientific support for that [young earth] viewpoint."

Perhaps the most significant shortcoming of the book is a general lack of illustrations (ignoring the cartoons in chapter 1, there are only four). Many places in the book would have benefitted, both aesthetically and educationally, from sketches or images of the described subject material. Menninga's closing thoughts also include his opinion that scientific explanations should never be described as fact. Though this is a popular sentiment among many scientists, it is an oversimplification that often clouds the appreciation of scientific advances. There are many scientific discoveries that should, indeed, be considered fact. No one, for example, will continue to question whether the air we breathe is made up of physical atoms or not. The exact nature of the subatomic particles making up those atoms may still be tentative, but as science advances, so does our certainty in various respects.

Minor criticisms aside, *If Truth Be Known* is a worthwhile read. It is well written, respectful in its tone, and describes the problems with each young-earth argument in a manner that is clear, easy to follow, and thoroughly documented. It is a great resource for understanding exactly why many common young-earth arguments fall short of truth.

Reviewed by Gregg Davidson, Professor and Chair, Geology & Geological Engineering, University of Mississippi, MS 38677.

Health and Medicine

DEMENTIA: Living in the Memories of God by John Swinton. Grand Rapids, MI: Eerdmans, 2012. 308 pages, index. Paperback; $25.00. ISBN: 978-0802867162.

John Swinton is professor of Practical Theology and Pastoral Care at the University of Aberdeen, Scotland. He writes from the conviction that the church should approach "dementia" (his preferred general term over Alzheimer's) from a theological point of view rather than a neurological or biological one. Thus, the central religious questions should be "WHO is the person?" and "Where is GOD?"

Swinton states his position very early: "At a very basic level, well-being within Christianity is not gauged by the presence or absence of illness or distress" (p. 7), and Christians should seek to understand "what it means to be a person with dementia living in God's creation" (p. 9).

Unfortunately, from Swinton's vantage point, there has been an almost universal tendency to approach dementia from a *negative sociobiological* starting position that focuses on behavior deficiencies rooted in internal biological changes. Thus, we talk of confusion and loss of memory, identity, orientation, and interactive skills as symptoms of neurological changes. We think of demented persons as having a disease, e.g., Alzheimer's. We label them with a biological diagnosis that explains their condition and depicts "who" they no longer are or "who" they have become. Very often the demented individual is treated as no longer a person but as an embodied diagnostic disease category. Christians, like much of the rest of society, have gone along with this tendency.

This analysis stirred memories of two incidents that occurred in my predoctoral internship in clinical psychology at Topeka State Hospital, where diagnostic conferences for new patients were led by psychiatric residents who were being trained by Topeka's Menninger Foundation. The residents had to fit their patients into one of the categories listed in the DSM (*Diagnostic and Statistical Manual of Mental Disorders*) in order for their treatment to be paid by insurance companies. The head of the Foundation, Karl Menninger, had disaffection for such diagnoses similar to Swinton's dislike of neurobiological diagnoses for demented persons. The psychiatric residents were caught in a bind between the insurance companies and Menninger who preferred that the residents learn how to describe their patients uniquely. He did not want them reduced to DSM categories. Menninger would make surprise visits to the diagnostic conferences, and the residents often felt his wrath.

The second memory involves chaplain interns at the hospital who tended to present reports full of psychiatric jargon. Paul Pruyser, the Menninger Foundation chief psychologist who was also a serious Presbyterian layman, became disturbed over this tendency. He asked why chaplains should use such modern jargon in their evaluations of patients when they had at hand a two-thousand-year-old religious tradition that provided them a model to use in describing human beings. He encouraged them to use their Christian faith in their reports. This is similar to the theological point made by Swinton in this volume.

Swinton voices a strong apologetic appeal to Christians to understand persons as having selfhood and identity as a gift from God, not based on their success in interpersonal communication (the quality that is so often disrupted in dementia). He grounds this contention in Gen. 2:7, where God creates humans and breathes into them so that they become living souls. He cautions against any presumption that humans have a body *and* a spirit (or soul). They do not have a soul; they are souls. Their integrity and value are established and do not only come into being as they acquire abilities, relationships, or language. Such persons were present at the outset of creation and exist within the memories of God, as the title of the book attests. Swinton does not claim to know the form God's memory takes but strongly asserts that human life is God's business and that its value does not rise and fall with either the adequacy or the loss of certain interpersonal skills of the body or the mind.

Swinton considers a number of ways in which the physical, behavioral, or social sciences have defined personhood. He notes how dependent human life is on social functioning at both the intimate and interpersonal levels. Memory and role functioning are essential to the everyday value humans automatically place on one another. While he acknowledges the importance of these interpersonal skills, he has an especially negative view of what he calls "negative sociology," in which persons become devalued and isolated when they lose some ability in these areas. He suggests that this routinely leads to depersonalization and pulling back of human contact and interaction. Demented individuals become more confused when relationships are withdrawn. Granted, caring for such individuals can become very difficult. People speak of the demented as "not themselves any longer." He strongly contends that, from a theological point of view, they can never lose their selfhood or identity as long as there is a God (Ps. 139:7 ff; Rom. 8:35 ff).

Readers of *PSCF* will find reading this volume very enlightening, if somewhat disturbing. They will experience a sense of courage in trying to apply their Christian faith to personal situations involving dementia. It will take courage to think within a theological framework when loved ones cease to respond adequately and normally. They will feel refreshed in their efforts to affirm the essential personhood that is God given and treasured for all time within God's memory.

However, *PSCF* readers may be disturbed by the possibility that nothing of essential worth can be learned from science, in the face of Swinton's insistence that their research might not be the starting place for Christians to begin their thinking. Certainly biological and neurological scientists among us may wonder whether Swinton would affirm their efforts to find alleviation, if not a cure of dementia's symptoms.

I think any negative reaction to Swinton's perspective might be eliminated if two things were kept in mind. First, it should be remembered that he is writing primarily to Christian pastoral caregivers who have been neglectful of the treasure of their theological training. Second, he is essentially calling for a both/and rather than an either/or approach to dementia. This encourages mutual respect and genuine appreciation.

Further, it should not be overlooked that we are fortunate to be able to read such a highly literate, readable, informed, and erudite set of reflections on one of the major health conditions of our time. Personally, as a clinical psychologist and ordained minister, I found his book to be a most perceptive and informed analysis.

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EXPOSED SCIENCE: Genes, the Environment, and the Politics of Population Health by Sara Shostak. Berkeley, CA: University of California Press, 2013. 312 pages. Paperback; $26.95. ISBN: 9780520275188.

It is difficult to determine whether I found *Exposed Science: Genes, the Environment, and the Politics of Population Health* a helpful book or not. It is obvious that Sara Shostak has done much research and preparation for this book, including extensive scientist interviews and a fairly clear explanation of genetic techniques. The book is based on "fields theory," in which the development of a field of study is explored over time (in this case, the field of environmental health). The book starts by discussing the history of United States government agencies that deal with environmental health issues, such as the National Institute of Environmental Health Sciences (NIEHS), the National Toxicology Program (NTP), and the Environmental Protection Agency (EPA). Subsequently, Shostak brings to the fore one of the main issues that she is trying to get across in the book: that, namely, there are a large number of environmental chemicals for which we have little data on human exposure and for which rodent models may not be the best way to determine toxicity or oncologic potential. As a result, Shostak indicates that human genetic studies dealing with environmental health may be a helpful and forward-thinking strategy.

Several advantages are given for human genetic testing, such as the superiority of molecular genetic studies over classic toxicology testing techniques, the high throughput and lower cost of such techniques, and the expansion of these techniques into the ever-expanding field of environmental health. Shostak does a good job of describing how scientists have been interested in using genetic testing to determine disease susceptibility as well as to determine chemical differences between individuals. The idea of "inborn errors of metabolism" is used as an example of chemical differences, although it is not clear how this term is truly defined in the book, as inborn errors of metabolism are typically associated with specific enzyme deficiencies (such as tyrosinemia or galactosemia) that often can be improved by dietary elimination, medications, or removal of the organ with the missing enzyme component (as in liver transplantation). Nor is it entirely clear how this term could be related to environmental studies at all times, and I am hopeful that further editions of this book will expand on this issue.

One weakness of this book is that it includes only one expanded case study of environmental health and its genetic and political consequences. In particular, the author explores the case of Midway Village in the San Francisco, California, area in which soil contaminated with oil refuse was potentially associated with "chromosomal aberrations and irregularities," which are only briefly listed. For a lay person, this chapter will be difficult to understand. It would have been helpful if a listing of potential cancers associated with the exposure had been included. Also, it is not clear how "learning disabilities" (listed as a potential consequence) were associated with the exposure. There is minimal information about the 1997 court ruling that no exposure link could be made in Midway Village,[1] and there is no significant discussion as to why the EPA has stated that the current exposure to toxic agents in that neighborhood "probably [does] not constitute a significant health risk to the residents."[2] In other words, the case study is not balanced in its data presentation, which significantly reduces the quality of this book section.

The book ends with a lengthy, but quite good, explanation of how government agencies have expanded their testing arsenal with such techniques as microarray analysis and the development of large databases (such as the Chemical Effects in Biological Systems database). A history of the often tense relationship between the environmental justice movement and scientists who perform molecular genetic testing is also explored.

The book has some very good aspects, such as an explanation of the various agencies involved in environmental science, as well as a thorough history of the environmental justice in the setting of social disparity. However, I think the book is significantly weakened by using the one example of Midway Village. A review of the NIEHS web site (www.niehs.nih.gov) revealed quite interesting research, including air pollution and United States life expectancy, the economic benefits of prevention of methylmercury exposure in Europe, and *in utero* tobacco exposure and plasma lipid levels in adult women (just to name a few topics). I think the book would have benefited greatly from a discussion of similar research projects sponsored by governmental agencies, such as the NIEHS. The lack of case studies in this book considerably weakens an otherwise interesting topic.

Notes

[1]San Francisco Chronicle, http://www.sfgate.com/health/article/Daly-City-housing-complex-haunted-by-toxic-past-3170203.php#page-1.

[2]California Environmental Protection Agency, http://www.calepa.ca.gov/envjustice/Documents/2007/MidwyVillage.pdf.

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History of Science

REREADING THE FOSSIL RECORD: The Growth of Paleobiology as an Evolutionary Discipline by David Sepkoski. Chicago, IL: University of Chicago

Press, 2012. 432 pages; includes list of references cited and index. Hardcover; $55.00. ISBN: 9780226748559.

In his jacket recommendation, Niles Eldredge comments, "I give his description and analysis of the history of paleobiology a five-star rating; to my mind, this actually was the way it was." And for good reason. David Sepkoski, a historian of science, is the son of the late University of Chicago quantitative paleobiologist Jack Sepkoski (1948–1999). The elder Sepkoski is largely credited with sparking the use of computerized databases to analyze long-term trends in biodiversity during Earth's history. David's perch within the social and intellectual circle of his father grants him an empathic understanding to several of the leading actors in the transformation of paleontology which occurred between the late 1960s and today. And, thanks to his timeliness, he was able to interview many of the major protagonists as well. For those potential readers interested in the history of the diversification of life on Earth and/or those biologists interested in the impact of such paleontologically derived concepts such as punctuated equilibrium, mass extinctions, or species selection, this book is extremely important.

Paleontology straddles the standard disciplinary boundaries of geology and biology, and its practitioners must be evenly trained in both. However, academic paleontology typically has been housed in university departments of geology due to two factors: a historic close association of paleontology with stratigraphy (i.e., biostratigraphy); and the long reliance for employment of most trained paleontologists in the fossil hydrocarbon industry. Sepkoski devotes the first two chapters of his book to explaining how paleontology became more and more distanced from academic biology during the early twentieth century, terming this situation "paleontology's identity crisis" (p. 52). The prominent student of fossil mammals George Gaylord Simpson and the invertebrate paleontologist Norman Newell are given credit for bucking this trend; notably both were museum scientists, associated with the American Museum of Natural History.

Chapters 3, "The Rise of Quantitative Paleobiology," and 4, "From Paleoecology to Paleobiology," describe two highly significant mid-twentieth-century inputs to paleontology that would trigger a metamorphosis of that science. Chapter 3 narrates several developments: the adoption of statistical techniques (collateral with the shift to population rather than typological taxic definitions) by workers such as G. G. Simpson, Everett C. Olson, and John Imbrie to understand evolutionary trends; the influence of D'Arcy Thompson's mathematical study of form on what would be termed "theoretical morphology"; and the signal role played by David Raup (then at the University of Rochester) during the 1960s to pioneer morphometric studies of molluscan groups (gastropods, cephalopods) utilizing early computers. In 1971, Raup would author, with Steven Stanley, the influential textbook, *Principles of Paleontology*, which promoted more quantitative and biological approaches to the treatment of fossils.

Chapter 4 lays out the profound influence of ecological thinking on approaches to the fossil record during the 1960s and beyond, particularly following the publication of Robert MacArthur and E. O. Wilson's *The Theory of Island Biogeography* (1967) and MacArthur's *Geographical Ecology* (1972). Sepkoski describes the personal impact that the paleontologist Lee McAlester and the polymath ecologist G. E. Hutchinson had on a large clique of graduate students in paleontology at Yale University during this interval. Many of these Yale products, including the aforementioned Steven Stanley, Jeremy Jackson, Richard Bambach, Jeffrey Levinton, Geerat Vermeij, and others, would become pioneers of new ecological and morphological approaches to fossils conducted from the 1970s to the present. Sepkoski also nicely details the early personal history of James Valentine (eventually housed at the University of California, Berkeley) and his writing of the seminal volume *Evolutionary Paleoecology of the Marine Biosphere* (1973). Beginning with fundamental concepts of organismal ecology, Valentine erected an interpretative scheme for the history of biological communities over time, addressing such important topics as the significance of mass extinctions in the history of life (which Norman Newell had notably drawn attention to during the early 1960s), and adaptive models for increasing organismal complexity.

Here I register one major gap in Sepkoski's history of the paleobiological movement. Ecological interpretation, in fact, had been a prominent exercise for many sedimentary geologists and paleontologists following World War II, as evidenced, for example, by the massive two-volume *Treatise on Marine Ecology and Paleoecology*, collectively Memoir 67 of the Geological Society of America, published in 1957. Each of these volumes is over 1,000 pages long; an introductory essay outlines the tradition, extending back to the mid-nineteenth century, of linking studies of sea-floor ecology to interpretations of the sedimentary record and the reconstruction of ancient communities. And the study of marine paleoecology had many influential practitioners in Europe during the 1950s and 1960s, including Adolf Seilacher, Derek

Ager, Anthony Hallam, and Wilhelm Schäfer, among others, who are largely ignored in this volume. Dolf Seilacher, certainly one of the most influential paleontologists of the twentieth century, is only mentioned in passing. Schäfer is not mentioned; his *Ecology and Palaeoecology of Marine Environments* was published in German in 1962 and then translated into English in 1972, and was widely read. In my opinion, *Rereading the Fossil Record* could have been greatly enriched by the addition of one long chapter to accommodate an overview of this significant history. Against this larger backdrop, Valentine's masterful review can more properly be seen as a timely and comprehensive summation of decades of prior research. Sadly, major syntheses following Valentine's lead for the marine biota, such as Vermeij's *Evolution and Escalation* (1987) and Levinton's *Genetics, Paleontology and Macroevolution* (2001), as well as paleobotanical counterparts such as Karl Niklas's *The Evolutionary Biology of Plants* (1997), are not mentioned.

Chapters 5 through 10 detail the blossoming of paleobiology, beginning during the 1970s and continuing up until about 1990. Conceptual momentum begins to grow, and the stream of paleobiological analyses begins to flood in multiple anastomosing channels.

Chapter 5 details the history of the "punc eek" controversy following the publication of the paper "Punctuated Equilibria: An Alternative to Phyletic Gradualism" by Niles Eldredge and Stephen Gould, as a chapter in the volume *Models in Paleobiology* (1972), edited by Thomas J. M. Schopf. Both Gould and Eldredge had been doctoral students of Norman Newell in New York, Gould going to Harvard and Eldredge remaining at the American Museum of Natural History. The intricacies of the Gould-Eldredge interaction, their efforts to address their critics, and the relationship of their proposals concerning speciation models and in particular concerning Ernst Mayr's allopatric speciation model are thoroughly and fairly explicated. This chapter is a fascinating read and by itself justifies the reason for this book's creation.

Chapter 6 recounts the founding and early history of the journal *Paleobiology* (first issue published March 1975) under the guidance of Tom Schopf and Ralph Gordon Johnson. Schopf, after an early career at Lehigh University, had joined Johnson at the University of Chicago in 1969, and would remain there until his death in 1984. Schopf, although somewhat skeptical of the punctuated equilibrium hypothesis, encouraged publication of papers defending it by Gould; perhaps the strongest was Gould's 1980 resume, "Is a New and General Theory of Evolution Emerging?" Herein, Gould's confidence that new data and concepts from the study of the fossil record would revolutionize evolutionary theory is notoriously contained in his claim "if Mayr's characterization of the synthetic theory is accurate … then that theory, as a general proposition, is effectively dead, despite its persistence as textbook orthodoxy" (p. 201). Wow!

Chapters 7 and 8 describe the hard but exciting task of developing mathematically representative models of the diversification of life through time and the corresponding collating of enormous databases of fossil taxa distributions in space and in the stratigraphic record. These two prongs of a quantitative approach to "big picture" dynamic interpretations of life's history are yet under refinement today.

Chapter 7, the longest of the book, details the history during the 1970s of what became known as the "MBL group" (the acronym being that of the Marine Biological Laboratory at Woods Hole, where the group periodically met to hash out alternative methods and interpretations). The group consisted of Gould, Schopf, Raup, and the young ecologist Daniel Simberloff. Using computer programs largely developed by Raup, the group modeled the diversification through time of theoretical clades (evolutionary units) of organisms, permitting these to branch or go extinct through randomized (Markov) processes. These idealized random diversification pictures, forming a series of "null models," could then be compared to samples of real clades of organisms to gain hints as to the significance of extinction or the filling of available ecospace. Equilibrium models analogized from MacArthur and Wilson's basic island biogeography, plus Leigh Van Valen's "Red Queen" picture of evolution and the risk of extinction, provided a theoretical basis for the development of the "null model" approach.

Near the end of its existence as a working entity, the MBL group entertained Gould's graduate student Jack Sepkoski to hear him explain how their models might be refined. Sepkoski, nominally producing a standard dissertation on Cambrian biostratigraphy, was immersing himself in studies of computer science and statistics. After completing his PhD in 1974, he joined Raup at Rochester. In 1978 he would relocate to the University of Chicago. Eventually, Raup himself joined the University of Chicago group, after a stint at the Field Museum, placing the University of Chicago on the map as the geographical focal point for the new quantitative paleobiology.

The events of chapter 8, "A Natural History of Data," parallel those of chapter 7, also taking place during the 1970s. The story begins with a sparring match during the early 1970s between Raup and Valentine on what the biostratigraphic occurrences of taxa were empirically telling us regarding the overall diversification of life. For Valentine, the available fossil data clearly demonstrated an overall upward trend in diversification from the earliest Paleozoic until the present. This could be interpreted as greater partitioning of potential ecospace over time (despite occasional setbacks due to extinctions). Raup countered with a model in which biotic diversity blossomed during the early Paleozoic but then had only marginally increased, if at all, from the mid-Paleozoic onward; Valentine's increased diversity was thought to be an artifact of the record. Others such as Richard Bambach and Karl Flessa offered yet other viewpoints. Eventually, with the addition of trace fossil data and advice from Seilacher, and Jack Sepkoski's computer skills and his expanding database, a consensus model was achieved (Sepkoski, Bambach, Raup and Valentine, "Phanerozoic Marine Diversity and the Fossil Record" in *Nature* 293 [1981]: 435–7). In retrospect, a major cottage industry within paleontology had been birthed. Newly minted icons of this industry include Sepkoski's "spindle diagrams" of taxic diversity, in which clade diversity is depicted as the width of the spindle while the long axis is time—many such spindles being set side by side so as to see which ones expand while others thin and wane; and Sepkoski's famous diversity curve for the Phanerozoic broken into his "three evolutionary faunas" (Cambrian, Paleozoic, Modern).

Chapter 9 provides a wonderful resume of the realization during the 1980s of the significance of large-scale mass extinctions for the history of life. Early biostratigraphers, such as Cuvier, Omallius, Sedgwick, and Phillips (typically labeled "catastrophists"), had great appreciation for the role of extinction; but paleontologists in the later nineteenth and early twentieth centuries had tended to downplay major extinctions, convinced that the severity of mass extinctions was an artifact of an imperfect record. However, this situation was to change. Norman Newell and notably Derek Ager, in his classic *The Nature of the Stratigraphical Record* (1973, 1981), had provocatively urged that paleontologists needed to go back to their roots and realize the empirical reality of mass extinction. (However, British paleoecologist Ager is absent from Sepkoski's volume.) This became unavoidable when Walter Alvarez and colleagues published the outrageous proposal in 1980 that a large impact with an extraterrestrial body was responsible for the major loss of taxa at the end of the Cretaceous. That story in itself took decades to play out and is, in fact, not perfectly understood, but that a very large impact occurred at the end of the Cretaceous period and that it had a severe effect on the planetary biota is now unquestioned. As a graduate student during the 1980s, I experienced the furor that this notion caused and the near violent disagreements over the quality and significance of such data items as shocked quartz fragments in deep-sea sediments.

Coinciding with this controversy was the revelation provided by Sepkoski's growing database demonstrating ever-more-clearly demarcated episodic major losses of taxa. Raup developed the stochastic notion of mass extinctions in several significant scientific papers and in his gem of a popular book, *Extinctions: Bad Genes or Bad Luck?* (Norton, 1991). Read the book if you want to know the answer! By 1990, it is safe to say that the data from the fossil record were indeed forcing neontologists to modify standard approaches to what governed the history of life—and probably engendering more questions than answers. Anthony Barnosky would later (1999) dub the notion that spasmodic changes in abiotic factors (including impacts by extraterrestrial objects) strongly force evolutionary history as the "Court Jester hypothesis." (For fun, see the review article by Michael Benton, "The Red Queen and the Court Jester: Species Diversity and the Role of Biotic and Abiotic Factors through Time," *Science* 323 [2009]: 728–32.)

All histories must find a stopping point. Chapter 10, "Toward a New Macroevolutionary Synthesis," runs out the clock by tackling other ways in which standard gradualistic Neo-Darwinian evolution was challenged (or was imagined to be challenged, depending on one's point of view) by new paleobiological perspectives. The author begins by explicating the role assumed by Gould as the spokesperson for the new paleobiology. In articles such as "Is a New and General Theory of Evolution Emerging" (see above) and his book *Wonderful Life* (Norton, 1990), Gould argued that multiple levels of selection, the phenomenon of mass extinction, and early diversification of major phyletic groups followed by culling, all undermined the heretofore simplistic and gradualistic standard Neo-Darwinian story. And in articles such as "The Hardening of the Modern Synthesis" (in *Dimensions of Darwinism*, edited by Marjorie Grene, Cambridge University Press, 1983), he attempted to explain just how the main architects of the New Synthesis of the 1930s and 1940s, including G. G. Simpson, oversimplified their own positions for ideologic reasons. (Joe Cain diagnosed this aspect of Gould's writing as "ritual patricide," in "Ritual Patricide: Why Stephen Jay Gould Assassinated George Gaylord Simpson," in *The Paleobiological Revolution*, ed. Sepkoski and Ruse, described below.)

Chapter 10 continues and concludes its story of the further development of paleobiology's promise by examining the development and promulgation of a more hierarchical theory of evolution, championed again by Gould, with colleagues Richard Lewontin, Elizabeth Vrba, and Steven Stanley. Along the way, simplistic views of adaptation come in for some bashing with Gould and Lewontin's now-standard "The Spandrels of San Marco and the Panglossian Paradigm," a critique of an over-reliance on the concept of adaptation as a shortcut to understanding all of biology. Stanley's concept of "species selection" was initially expressed in a short paper in 1975, but then greatly expanded in his *Macroevolution: Pattern and Process* (1979). Simplified, the notion is that some taxa leave many more descendant taxa, not because they are better adapted to their environment(s), but rather because there are aspects to their biologies which tend to promote speciation.

A short conclusion, "Paleontology at the High Table?" argues that the events described between 1960 and 1990 contributed to an evolution of sorts within evolutionary theory itself. The Darwinian framework is held to be robust enough to accommodate these additional insights.

> Paleobiology is no more a repudiation of Darwinism than is molecular genetics, or evo-devo, or any of the other countless developments in evolutionary biology that have come about since 1859. (p. 394)

I would have to agree, but certainly the paleobiological revolution has opened our eyes to a diversity of explanation in the history of life. Just as quantum theory has shown us that in physics nature does not demonstrate a rigid Laplacian determinism, so too the history of life appears to be more dynamic and full of messy particulars than a rigid application of Mendelian particle genetics can explicate.

Of course, all this did not come to a halt after the early 1990s. Throughout the twenty-plus years since, a flood of articles and a new edited compilation every other year with titles such as *Biodiversity Dynamics* or *Macroevolution: Diversity, Disparity, Contingency* have been generated. But tackling this newer round of forcing information from the record would take yet another volume.

Overall, the book is a great read. For those with an interest in getting the details of the history of evolutionary thought right, this is a must-read. I should add that an excellent supplement exists in the form of the earlier volume edited by Sepkoski and Michael Ruse, *The Paleobiological Revolution: Essays on the Growth of Modern Paleontology* (University of Chicago Press, 2009). This volume includes retrospective essays by Valentine, Bambach, Art Boucot, Anthony Hallam, and several others; and an interview with Raup.

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DARWIN DELETED: Imagining a World without Darwin by Peter J. Bowler. Chicago, IL: University of Chicago Press, 2013. 328 pages. Hardcover; $30.00. ISBN: 9780226068671.

According to the well-known Harvard biologist Ernst Mayr, Charles Darwin's theory of evolution actually consists of five separate theories. Darwin's own, distinctive contribution to Mayr's list is well known: natural selection. Darwin's name is irrevocably linked to "selectionism" and this view has shaped evolutionary theory to a remarkable extent. What would biology have been like without Darwin's *On The Origin of Species*? Or to use Peter Bowler's scenario, what if the young Charles Darwin had been swept off the deck of the *Beagle* in a storm? This "counterfactual history" is the focus of Peter Bowler's latest book, *Darwin Deleted.*

In the opening pages of his book, Bowler defends the idea that a counterfactual history can shed light on the contributions of a historical figure and rejects the view that Darwin's theory of selectionism was "in the air" and would have emerged regardless. No, Darwin was in a unique position to influence public and scientific opinion, given his contacts with animal breeders and farmers, his knowledge of the ideas of Thomas Malthus, his ability to secure the publication of a book, and his membership in the Victorian upper class with its commitment to economic competition. Alfred Russel Wallace, on the other hand, posited similar ideas—the story of their simultaneous publication is so well known it does not bear repeating—but was not in a position to make a similar impact. In a world without Darwin, Bowler states, "Evolutionism would eventually have flourished—but it would have been an evolutionism based on non-Darwinian ideas, not on natural selection" (p. 70).

What ideas would have shaped evolutionary theory in Bowler's counterfactual world? Purpose in evolution would have received more attention, with, perhaps, more emphasis on orthogenesis (an innate drive for linear complexification). For some European thinkers, internal forces would direct evolution in a purposeful direction. Others supported formalism, another nonselectionist approach, in which "law-like processes governed the development of living structures" (p. 141). However, for Bowler, the chief candidate in a non-Darwinian world is Lamarckism.

Peter Bowler is a respected author of the history of biology, *Darwin Deleted* being his fifteenth (or so) book. In many of his writings, Bowler has emphasized the influence of Lamarckism. Jean-Baptiste Lamarck (1744–1829), from whom Lamarckism draws its name, suggested that there are two trends in nature: an upward, unidirectional trend of complexification (orthogenesis), and the inheritance of acquired characteristics ("use and disuse" for Darwin) that would explain an organism's adaptation to environmental conditions. In his books, *The Eclipse of Darwinism* (1983) and *The Non-Darwinian Revolution* (1988), both published by The Johns Hopkins University Press, Bowler describes how Darwin's theory of evolution was accepted by many thinkers of his time, particularly theologians. However, they did not necessarily accept his selectionism; some preferred to "Lamarckianize" Darwin's theories, inserting tendencies of direction and purpose into evolutionary theory. In *Darwin Deleted*, Bowler suggests that, in the absence of Darwin, it is this kind of thinking that would have greatly influenced evolutionary thought.[1]

Bowler submits that in a world without Darwin, evolutionary theory would nevertheless have been established, thanks to fossil and morphological evidence. Selectionism would not have been absent, but rather would have become part of an existing evolutionary paradigm. It would have played a more moderate role. As a consequence, the idea of natural selection might have been less disruptive to the relationship between science and religion, and acrimonious debates would have occurred less often. One has the impression that Bowler supports the idea of natural selection, but not its all-encompassing role. In my view, this sheds an interesting light on the topic of natural selection, a topic that is receiving renewed attention.[2]

The names of Herbert Spencer and Charles Darwin have often been linked to negative social practices and views, such as racism, militarism, and eugenics. The label "social Darwinism," although often used, is somewhat of a misnomer because Spencer wrote before Darwin, and Darwin did not espouse these objectionable views. Spencer, whose faith was placed in progress and Lamarckism, was influential at the time Darwin wrote. If Darwin had not have written *On The Origin of Species,* Bowler suggests, the negative social views mentioned would nevertheless have become prevalent, because they are based on views that were prevalent at the time.

Darwin Deleted is a dense, detailed book; it may be intimidating to some readers. However, Bowler has worthwhile contributions to make. It may be helpful to start with some of his previous books mentioned above. *Darwin Deleted* is of interest because it puts the mechanisms that drive evolution, particularly natural selection, under the microscope. Furthermore, it is a commendable contribution to the religion-science debate. Finally, it points out to us that theory shapes scientific concepts to an extent that is often not recognized. I recommend the book and, in fact, all of Bowler's books to *PSCF* readers.

Notes

[1]See also Harry Cook and Hank D. Bestman, "A Persistent View: Lamarckian Thought in Early Evolutionary Theories and in Modern Biology," *Perspectives on Science and Christian Faith* 52, no. 2 (2000): 86–96.

[2]See, for example, Conor Cunningham, *Darwin's Pious Idea: Why the Ultra-Darwinists and Creationists Both Get It Wrong* (Grand Rapids, MI: Wm. B. Eerdmans Publishing, 2010), chap. 3.

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Origins & Cosmology

LIFE'S RATCHET: How Molecular Machines Extract Order from Chaos by Peter M. Hoffmann. New York: Basic Books, 2012. 278 pages, notes, index. Hardcover; $27.99. ISBN: 9780465022533.

Peter Hoffmann takes the educated reader on an amazing journey, interweaving physics, chemistry, biology, history, and philosophy to explain how the molecular storm and molecular machines, driven by chance and necessity, define life and living. The questions posed by the author have been discussed throughout history in various forms: "What creates 'purposeful motion' in living beings? … How do we go from assemblies of mere atoms to the organized complex motions in a cell?" (p. 5). His argument is that chaos (the molecular storm, otherwise known as the immense number of random collisions of molecules to each other and energy transfers between each) is the life force harnessed by molecular machines (proteins) to do work within each cell. He also argues that this molecular chaos, mixed with chance and necessity (or mutation and natural selection), is able to transform DNA and alter the overall structure and function of the molecular machines that do work in the cell.

The book is divided into four parts, each part building on the earlier chapters. In part 1 (chaps. 1–2), the author describes the agonizing struggle to define life by philosophers, theologians, and scientists throughout history. In chapter 1, he introduces the evolution of various philosophies of life in Western civilizations, especially with regard to the turmoil between religion and science. In chapter 2, he describes the introduction of statistics and chance in the mid-1800s through the 1900s, and the impact that chance and randomness had on defining life. In part 2 (chaps. 3–4), he introduces the reader to basic concepts in physics, molecular biophysics, and nanoscience, which are the author's areas of expertise. In chapter 3, he uses a remarkable analogy of a robber taking and spending money to redefine (for biologists!) entropy and the second law of thermodynamics. This chapter is the foundation for understanding his arguments about the molecular storm and molecular machines, as well as refuting one of the commonly used arguments in favor of intelligent design. In part 3 (chaps. 5–7), he very carefully explains the development of the concept of molecular machines from macroscopic machines through "thought experiments," scientific experiments, and detailed examples of well-studied molecular machines (i.e., kinesin, myosin, helicase, ATP synthetase). In part 4 (chaps. 8–9, epilogue), he tackles head on the arguments for intelligent design and creationism, in particular how molecular machines actually use the chaos of the molecular storm to allow mutations, which are then selected out of necessity. His conclusion is that the life force that has been vigorously debated and scientifically examined over human history is the random force of atoms, and "… the molecular machines of our bodies tame the molecular storm and turn it into the dance of life" (p. 243).

What makes this argument more successful than the arguments of others who have tried to answer this question is Hoffmann's expertise in molecular biophysics and nanoscience. He is a professor of physics and materials science, and the founder and director of Biomedical Physics at Wayne State University in Detroit, Michigan. Instead of using biology to argue for the underlying life force, he clearly and succinctly explains how physics, in particular energy, is a crucial part of defining life and making strong, logical arguments against an intelligent designer. For example, molecular machines harness the chaos of the molecular storm through physical laws using a bottom-up process that engages the chaos, in contrast with our macroscopic machines (i.e., cars, computers) that are designed to resist chaos. Science has also suggested that the chaos from the Big Bang predates the first molecules, so a logical deduction is that these first molecules would need to harness the chaos and be able to be molded by it in order to arrive at the versions of macromolecules that are studied by scientists today. His numerous detailed examples show the application of these concepts to specific molecular machines, especially kinesins, and how different kinesins have been altered for different functions in the cell.

His explanations and arguments are the first time that someone has clearly explained to me why learning physics is required for understanding biology, and as such should be required reading for anyone interested in biology. Hoffmann goes to great lengths to explain physics to an educated reader by incorporating easily understood analogies and examples, such as how chance and necessity have a role in snowflake formation. Another strength of this author is that he does not water-down the science, but states in the introduction that this book is written for a more educated (college-level) audience. I particularly appreciated this after reading numerous nonfiction science texts for less educated readers in the past year, which usually left me (and my undergraduate students) wanting more.

A weakness of this book is that it was very challenging to be engaged in the early chapters. The first chapter is essentially a laundry list of different philosophies of life, which I appreciate in hindsight, but struggled to get through as I started reading the book. It takes approximately half the book to start discussing biology, which made reading the first half seem long and laborious since my interest is biology. He seems to anticipate this by trying to use more simplified language, analogies, and diagrams, to spur the reader on to continue reading, but at times it is challenging to continue. A physicist may feel the same way in reverse, and find the second half of the book little more than a list of different machines. However, the application of the basic concepts is important to his argument and to the reader's learning of molecular machines.

In conclusion, I recommend this book to undergraduate students as well as scientists who wish to gain a better understanding of the role of physics in understanding life and biology. Overall, *Life's Ratchet* was well written for individuals without a strong background in physics, helped me to integrate physics into my teaching of molecular biology, and further developed my own thoughts on evolution.

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Philosophy & Theology

GOD AND THE WORLD OF SIGNS: Trinity, Evolution, and the Metaphysical Semiotics of C. S. Peirce by Andrew Robinson. Boston, MA: Brill, 2010. xiii + 381 pages. Hardcover; $168.00. ISBN: 978-9004187993.

Andrew Robinson spent a decade plus in the field of medicine before turning to theology. So although this volume is a revision of a 2003 PhD dissertation, it reflects a level of mature thinking not usually found in the "first book" category. Its ideas were initially developed under the tutelage of Exeter advisor Christopher Southgate (an established scholar at the interface of science and religion), and further honed over the last eight years, in part through a series of substantial grants jointly to author and mentor from the John Templeton Foundation. In short, *God and the World of Signs* is a substantial contribution to the theology and science conversation.

The central thesis unfolded over the first four chapters (two-thirds of the book) is that the semiotic philosophy of Charles Sanders Peirce (1839–1914) not only illuminates perennially difficult theological topics (the doctrines of the Trinity, incarnation, and theological anthropology are discussed) but also contributes to contemporary discussions in evolutionary biology (in particular, biosemiotics and origins-of-life research) and philosophy of mind (including the arena of teleosemiotics). This leads, in the fifth chapter, to a trinitarian theology of nature wherein it is argued that the contingency, naturalism, and continuity of evolutionary processes are not merely analogies (which remain at the epistemological level) but actual vestiges of the trinitarian God imprinted in the world (thus having ontological purchase) through the very activity of divine creation. The last three chapters (about a fifth of the book) turn to epistemological matters (defending both metaphysical and theological reflection), argue that the proposed semiotic model of the Trinity is more adequate than classical psychological or social models, and provide a creative retelling of the fourth-century debates about the Trinity in semiotic perspective.

Those familiar with the philosophy of Peirce will appreciate the various moves made herein. Space constraints prohibit any extended summary, so I will focus my explication in two directions, one theological and the other scientific. Theologically, Peirce's fundamental triadic categories of Firstness (possibility), Secondness (actuality), and Thirdness (mediation) are suggested as providing a semiotic model for the classical Christian understanding of the Trinitarian perichoresis. Others, including this author (in Yong, *Spirit-Word-Community: Theological Hermeneutics in Trinitarian Perspective*, Ashgate, 2002, part I), have made suggestions along similar lines. What is new is Robinson's extension of this semiotic model into both the immanent and economic Trinity. With regard to the incarnation and the mission of Jesus, for instance, Peirce's semiotic taxonomy clarifies how various aspects of Jesus's ministry can be understood as sign embodiments. The last supper in this Peircean schema is an *iconic legisign*, which signifies through the fellowship around the table (hence iconically) by virtue of being a token or type produced according to a rule, in this case of eating together (what Peirce meant by *legisign*). By way of contrast, the cleansing of the temple is an *iconic sinsign*, which signifies in this singular instance (what Peirce meant by *sinsign*) through the overturning of the tables (hence iconically presaging the destruction of Jerusalem, according to many biblical scholars). More comprehensively, the life and ministry of Jesus as a whole, which included these two major sign-events, can be understood as an *iconic qualisign*, an embodiment of the very quality of the Father. Thus is Jesus the qualitative representation of the image, presence, and the very being of Israel's God in the flesh.

Robinson goes on to argue—successfully, I believe—for the superiority of his semiotic interpretation of the incarnation over current proposals on offer, in particular, Rahner's "real-symbolic" understanding of Jesus as revelatory of God. The latter is metaphysically robust in terms of its neo-Thomistic ontology, but its minimalist theory of symbolic interpretation results in the inability of humans to refer to Christ in any other than a conventional manner. By contrast, a Peircean-inspired semiotic theology of the incarnation advances beyond neo-Thomistic models—and even existential and Whiteheadian ones, I might add—not only by overcoming the binary and mostly dyadic formulation of how symbols connect with reality, but also by showing how semiosis or interpretive mediation is part of how reality is constituted and signifies.

On the anthropological side, Robinson's discussion includes the evolution of human semiosis (from competence with *legisigns* through to conventional symbols) and shows how the "gift of abduction" enables human sign-interpreters to infer, discern, and engage, however fallibly, the revelatory signs of God's presence and activity in the world. Intriguingly, an expansion of such considerations into the field of evolutionary biology invites viewing all dynamic and living processes semiotically and teleologically. To be sure, evolutionary biologists are extremely reticent to suggest that either evolution itself (considered as a whole) is purposeful or even that its processes can be understood interpretively. Yet natural selection itself presumes that nature selects, through its various codes, signals, and information-rich interactions, that which has reproductive and adaptive advantage; hence much energy has been expended on how such processes are goal-directed but not necessarily agential. Peircean semiosis comes to the rescue here, Robinson suggests—and not outlandishly, I think—in terms of showing how Thirdness manifests itself not only in terms of mediation but also in interpretation, and how nature's selection for general outcomes neither implies vitalism nor risks undermining the integrity of nature's processes. Applied to origins-of-life research, then, such an approach invites considerations of how protobiotic systems and environments might have facilitated both interpretive and misinterpretive processes (the capacity to make mistaken inferences) being central to semiosis, resulting not only in metabolism and localization but also in reproduction. Both empirical and theoretical ramifications are specified; it remains to be seen whether these suggestions can generate new research projects or complement existing inquiries in these arenas.

Robinson acknowledges that he has not been formally trained as a Peirce scholar, and he relies heavily on T. L. Short's magisterial *Peirce's Theory of Signs* (Cambridge University Press, 2007). While I also do not consider myself a Peirce specialist, I did not notice any obvious misinterpretations or misapplications of Peirce's ideas. I do have one minor quibble with Robinson's eschatology, recognizing that this pertains only to an extension of his ideas and does not touch on its central elements. His speculative proposal is that even upon the passing away of the space-time universe, human beings "will subsist as eternal centres of Firstness [qualities] in the presence of God's glory" (p. 336). This leaves unsaid, though, that such eternal qualitative realities would be dynamically constituted in relationship to others and especially to God. Such interrelational constitution suggests that creaturely Firstness does not leave behind Secondness or Thirdness. This should not be surprising since the divinity of the triune God also is triadically constituted by Father, Son, and Spirit. If that is the case, then Robinson's vestiges of the Trinity in creation are eternal, remaining even after the passing away of the space-time universe.

As a philosophical theologian, I view *God and the World of Signs* as a theology of nature (not a natural theology) that makes a significant contribution to the twenty-first century quest for a "grand unified theory" that includes rather than ignores metaphysics. In Robinson's hands, this view of the whole is best unraveled semiotically, and in that sense, it can be read as an update on what Peirce a century ago called a "guess at the riddle." Philosophers interested in theological metaphysics, those engaged in the theology and science conversation, and theologians who have some familiarity either with Peirce or with semiotic theories in general are in the best position to benefit from this book. Yet, because of the vast amount of ground that is covered, most readers will have to work through the volume patiently and carefully. Those persisting through it will be rewarded with a trinitarian and semiotic philosophy that may in due course prove to have explanatory power superior to other metaphysical systems for which Christian faith has sought.

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MIND AND COSMOS: Why the Materialist Neo-Darwinian Conception of Nature Is Almost Certainly False by Thomas Nagel. New York: Oxford University Press, 2012. 144 pages. Hardcover; $24.95. ISBN: 9780199919758.

Though brief, this book is profound and provocative. Nagel's thesis is that the reigning materialist version of neo-Darwinism has come up empty in its quest to explain the rise of life, consciousness, cognition, and value in terms of physics and chemistry. This is a particularly interesting thesis given that Nagel is neither a creationist nor ID advocate but an atheist. And while he claims that it is not his purpose to "propose a solution" (p. 15) to the inadequacy of a reductionist Darwinian framework, he favors a non-intentional Aristotelian natural teleology (p. 91).

First, Nagel wishes to propose that mind is not an accidental side consequence of material forces but is a basic aspect of nature (p. 16). Nagel derives this position from the procedures and successes of science itself. The world studied by science is intelligible and that fact stands in need of explanation; its intelligibility cannot be waved away with the statement, "this is just how things are" (p. 20). Materialist science simply assumes the existence of the laws that govern inorganic and organic life, but Nagel wishes to know "why the laws that do hold hold" (p. 20). Though Nagel proposes that mind is a fundamental part of nature, he rejects the notion that there is a Mind or Intention behind the universe. This option is unavailable because theism does not furnish an explanation of the intelligibility of the world but only "pushes the quest for intelligibility outside the world" (p. 26). We shall consider Nagel's revived natural teleology later.

Consciousness, claims Nagel, cannot be explained by the neo-Darwinian account of nature. This account ignores the first-person perspective of the conscious subject. Evolutionary process has produced "subjective individual points of view" (p. 44), and while any number of physical correlations can be produced by science to identify the effect termed "consciousness," there is little, if any, understanding concerning "why the cause produces the effect" (p. 45). In her book, *Science and Poetry*, British philosopher Mary Midgley has argued cogently that overly literal use of atomistic metaphors has eclipsed the first-person perspective and distorted our understanding of the human person.

Having rejected reductive accounts of mind, Nagel considers emergence and panpsychism as explanatory frameworks for the historical rise of consciousness. He favors emergence with a teleological twist and argues that natural selection will favor those physical characteristics that give rise to consciousness. Thus, though for Nagel the evolutionary process is not guided by God, there is a certain directedness built into the natural order orienting it to the production of conscious beings (pp. 60–1, 66–7). Here, we see his appreciative nod toward Aristotle's concept of nature.

Next, Nagel claims that a materialist evolutionary account cannot explain human cognitive capacities. As a realist, Nagel has something at stake regarding evolutionary explanations of reason since he claims that, transcending the sensory world of biological routines, we make contact with "the timeless domains of logic and mathematics" as well as the realm of value (p. 72). The antirealist is not as upset with materialist explanations of reason because truth, for her, is a human construction with no "judgment-independent" status (p. 75).

Nagel claims that the neo-Darwinian's argument that reason is reliable "because it is consistent with its having an evolutionary explanation" is circular and self-refuting. It is circular because we presuppose reason's validity in appealing to it for the making of that very judgment.

> It is not enough to be able to think that *if* there are logical truths, natural selection might very well have given me the capacity to recognize them. That cannot be my ground for trusting my reason, because even that thought implicitly relies on reason in a prior way. (p. 81)

The materialist version of evolution, if correct, would undermine our trust in reason's ability to have true beliefs about the world because natural selection does not track for truth, only for survival. But we do have true beliefs and can transcend our own biological routines, because "[s]omething has happened that has gotten our minds into immediate contact with the rational order of the world …" (p. 83). Perception may be a "truth-preserving algorithm" and for that we have natural selection to thank, but reason is "a mechanism that can see that the algorithm it follows is truth-preserving." This critical distance we have from our own algorithm, he says, "is a kind of freedom …" and that, says Nagel, cannot be explained by evolutionary naturalism (p. 82).

Human consciousness is a part of the history of the emergence of consciousness in general, "of the universe gradually waking up and becoming aware of itself" (p. 85). The historical rise of consciousness, says Nagel, is best explained through an "Aristotelian idea of teleology without intention," in which nature's evolutionary unfolding is (quoting Roger White's lovely phrase) "biased toward the marvelous." Such a bias, according to Nagel, "would probably have to involve some conception of an increase in value," since "not just any outcome could qualify as a *telos*" (p. 92). Nagel's conception of nature has interesting parallels with Canadian philosopher/theologian Bernard Lonergan's notions of finality and emergent probability as applied to natural processes.

Nagel agrees with the influential article by Sharon Street that the realist account of value is incompatible with Darwinian naturalism. Natural selection may be able to track for reproductive fitness, but it cannot "detect any mind-independent moral or evaluative truth," since that has no survival value (p. 107). However, whereas Street holds that moral realism is false, Nagel thinks there is something "missing from Darwinism" (p. 111). The realist account of value is true, claims Nagel, for we can be motivated by reason to pursue what is good for its own sake and avoid what is bad because it is bad: "We are the subjects of judgment-sensitive attitudes, in Scanlon's phrase, and those judgments have a subject matter beyond themselves" (p. 114). Value, Nagel claims, is internal to life itself and the rise of life must include some account of the genesis of value. Again, Nagel appeals to a natural teleology to account for the historical rise of value. Thus, natural selection "would have a propensity to give rise to beings of the kind that have a good—beings for which things can be good or bad," because it is in this way that the evolving process could introduce value to the world (p. 121).

Nagel has graced us with a deep and engaging work, a rich source of reflection—and controversy. Highly recommended.

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Religion & Science

GOD AND THE ATOM. From Democritus to the Higgs Boson: The Story of a Triumphant Idea by Victor J. Stenger. Amherst, NY: Prometheus Books, 2013. 332 pages including index. Hardcover; $25.00. ISBN: 9781616147532.

The success of atomic theory, and science in general, is presented as evidence for materialism, reductionism, and atheism. According to Stenger, atomic theory is incompatible with a belief in God: "everything is simply atoms and the void, with no divine creation or purpose …" (p. 12). Stenger declares, "Atomism is atheism" (p. 13). This book is consistent with Stenger's earlier books, *God and the Folly of Faith* and *God: The Failed Hypothesis*.

Victor J. Stenger has degrees in engineering and physics. He is an emeritus professor of physics at the University of Hawaii. He is well known for his work in high energy physics and writing general audience articles on topics of religion and science.

Stenger defines atomism as the idea that there are small particles, molecules, atoms, or subatomic particles, of which all things are made. To discuss these particles, he arranged the book into a preface and thirteen chapters. Twelve of the thirteen chapters are a narration of the evolution of atomic theory, though he also includes discussions of thermodynamics and electromagnetism. The early chapters focus on ancient philosopher-scientists and the concept of atomism, while the later chapters discuss more recent theories involving subatomic particles such as the Higgs boson. The philosophical basis for the declaration that atomism is atheism is discussed primarily in the preface and the last chapter.

Ancient atomist philosophers such as Epicurus (see Acts 17:18), Lucretius (whose poem Stenger devotes considerable attention to), Leucippus, and Democritus are discussed with respect to both their science and their religious worldviews. These atomistic philosophers are contrasted with Aristotle, the Stoics, and the Neo-Platonists whose philosophies were adopted by the Christian church. Stenger claims the early atomists were materialists, who felt that "matter and natural forces are all there is to observable reality" (p. 22).

Stenger also denies the concept of emergence, citing the concept of wetness, which appears to emerge only when there is a bulk amount of molecules. Though wetness is a bulk property, it is only possible due to the properties of individual molecules, and so can be reduced to the smallest indivisible molecule.

Conflicts between church fathers such as Augustine, and atomists such as Epicurus, are also discussed. Augustine is quoted as opposing the idea of "infinitely small objects that can neither be divided nor perceived" (p. 47). This debate is about philosophies of the eternal, purposeless world of the atomist and the Christian view of a world created by an immanent God. Stenger claims that the church's resistance to atomism was due to a rejection of reductionism and materialism, philosophies which logically follow from the atomistic models. Though Stenger paints an overall negative picture of Christianity he does praise one theist and scientist, Pierre Gassendi, who lived in the latter part of the seventeenth century.

The remaining chapters of the book, except for the summary, make less reference to religion. These chapters narrate the scientific revolution from Newton to the discovery of the Higgs boson, providing historical context to scientists such as Newton, Boltzmann, Gibbs, and others. In addition to discussions of atomic theory, these chapters also look at discoveries in electromagnetism and thermodynamics.

The strength and value of the book are in the later chapters devoted to historical narratives of the scientific revolution. Stenger is an excellent storyteller and offers wonderful explanations of thermodynamics and high energy physics. He also includes many historical insights into the personal philosophy and lives of scientists.

The weakness of the book lies in Stenger's hypothesis that atomism is atheism; his argument is not well developed. The argument may work well in denying the superstitions of volcano gods and may be used to refute claims of fiat creation by intelligent design advocates, but it does not go any deeper.

Though the book does not present a strong thesis for atheism, it may be of value to those who have an interest in science history and recent developments in modern particle physics. For those who are teaching in the sciences, portions of the book may be good sources for qualitative explanations of quantum mechanics, thermodynamics, and modern physics.

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EINSTEIN'S JEWISH SCIENCE: Physics at the Intersection of Politics and Religion by Steven Gimbel. Baltimore, MD: Johns Hopkins University Press, 2012. viii + 245 pages. Hardcover; $24.95. ISBN: 9781421405544.

Just two days before Albert Einstein spoke to the French Philosophical Society on April 6, 1922, one of his fiercest German opponents, Johannes Stark, a Nobel Prize physicist, lamented the fact that "since the end of the war the French have suppressed the German people in the most brutal manner … And just at this very time, Herr Einstein travels to Paris to deliver lectures." The tension in the air was rife and Einstein was fully cognizant of the sustained efforts of his detractors, such as the Nobel laureate Philipp Lenard, an early architect of the *Deutsche Physik* movement, who questioned the viability of Einstein's theory of relativity derogatively calling it "Jewish physics," a work of fiction "which never was intended to be true." Einstein's somewhat cynical comment in his Paris lecture succinctly captures the cultural situation:

> If my theory of relativity is proven successful, Germany will claim me as a German and France will declare that I am a citizen of the world. Should my theory prove untrue, France will say that I am a German and Germany will declare that I am a Jew. (p. 1)

The opposition to Einstein's "Jewish physics" reached fever pitch once his work (on the general theory of relativity) was confirmed and described as "one of the greatest—perhaps *the* greatest of achievements in the history of human thought" by J. J. Thomson, the English Nobel Prize winner in 1906 for his discovery of cathode rays. Almost overnight Einstein became a celebrated international hero—the scientific genius, intellectual rebel, *enfant terrible*, untainted by the war and of dubious nationality. He had revolutionized our conception of the universe by offering new interpretations of time and space, and had done so in a style that only a handful of scientists could understand. Not only had old conservative and militaristic heroes been bypassed after the war in the government of Weimar Germany, but experimental scientists, such as Lenard and Stark, were being challenged by new quantum approaches in physics. The intellectual pressure to change was a bridge too far to cross for many conservative scientists; they sought to privilege the experimenter rather than the theoretician, who was seen as a mere "loner" sitting in an office with pen and paper.

In this stimulating and provocative book, Steven Gimbel, the chairman of the philosophy department at Gettysburg College, recreates the historical, scientific, and political contexts in Einstein's Germany. In *Einstein's Jewish Science: Physics at the Intersection of Politics and Religion*, Gimbel provocatively argues that the Nazis, in their support of a *Deutsche Physik* and denigration of Einstein's "Jewish science," may have been on to something. This book is an exploration of the diverse ways in which Einstein's physics may have reflected Jewish characteristics. Perhaps, Gimbel argues, there is more to the epithet "Jewish science" then we have ever assumed or expected to uncover. Was Einstein's science "Jewish"? If one could get past the anti-Semitism, Gimbel suggests, one could make an argument for a "Jewish science." But Gimbel's answer is both a qualified yes and no; as he says, a typical Jewish response. Not Jewish in the sense that the Nazis would argue *ad nauseam*, namely, that this style of thinking influenced the content of relativity theory or that its style maliciously tainted the theory. Rather, Jewish as a style of thinking analogous to the argumentation and approach of Talmudic scholars. "While there is certainly no direct link between Einstein's work and the rabbinic tradition, there is an interesting resemblance between their approaches to problems" (p. 86). The resemblance is one of analogy rather than a causal link.

> The heart of the Talmudic view is that there is an absolute truth, but this truth is not directly and completely available to us. We can only see it through our experience, which is limited to a context. In our search for deeper meaning, we must try to understand how the limited view of the truth fits together with seemingly contrasting views of the truth from other perspectives and contexts. It turns out that exactly the same style of thinking occurs in the relativity theory and in some of Einstein's other research in the period. (p. 96)

Scholars do weigh the "absolute" but in a manner that does not claim final, complete, or comprehensive knowledge. Such weighing always involves a path of tentative steps, of feeling one's way.

Gimbel compares this Jewish approach to what he calls "Christian" approaches, which exemplify a "single sort of rationality." He calls to mind the "single absolute truth" approach of René Descartes (top-down Catholic style, hierarchical, the pope as CEO and epistemological officer) with deductive truth flowing downhill, giving us certainty. By contrast, Isaac Newton's "Protestant bottoms-up inductive style," also fitted with certain absolute pretensions (think of Newton's notion of absolute space and time). There is much in this historical analysis that one could, and perhaps should, question, but the contrast Gimbel sketches, in some detail, is a revealing one.

What are we to make of this perceived Jewish style of inquiry? Is it simply a disguised postmodern method of inquiry, replete with a relativistic strand, coupled to an inherent loss of objectivity? Gimbel appeals to feminist philosopher Sandra Harding to argue that her standpoint theory provides a way of maintaining a strong sense of objectivity, which is required in science, while still recognizing the role different approaches and perspectives play (pp. 215–7). Clearly, this suggestion of a Jewish style in science raises similar issues for readers of *PSCF*. Does it make any sense, at all, to speak of a "religious" science? Not in the sense that religion and science are compatible (which often leaves one feeling shortchanged), but rather do religious ways, styles, sensibilities, commitments shape one's approach in science? Would we dare speak of a "Christian" science? Is there a "Christian" style of doing science, or a Christian scientific practice? Gimbel's book provides a viewpoint readers cannot dismiss easily; it calls for deeper reflection and more far-reaching considerations on our part.

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WALKING WITH GOSSE: Natural History, Creation and Religious Conflicts by Roger S. Wotton. Southhampton, UK: Clio Publishing, 2012. 214 pages. Paperback; $19.00. ISBN: 9780955698392.

Roger Wotton is an Emeritus Professor of Biology at University College London (England). The main focus of his teaching and research has been in zoology and aquatic biology, interests he has in common with those of Philip Henry Gosse. He states in the preface of this book that his interest in Henry Gosse was kindled by the biography, *Glimpses of the Wonderful: The Life of Philip Henry Gosse* by Ann Thwaite (2002). Thwaite's book introduced him to "the man behind the Natural History; his profound belief in the literal truth of the Bible, and the complex and difficult relationship he had with his son, Edmund." All three of these topics are revisited in Wotton's more recent book *Walking with Gosse*.

Henry Gosse was a self-taught English nineteenth-century writer and lecturer who popularized natural history. Stephen Jay Gould described him as the nineteenth-century's answer to Sir David Attenborough! Much of his work was focused on the aquatic life of the south Devon coast where Gosse lived for a number of years. He is regarded as one of the inventors of the modern aquarium and his experiments with aeration enabled marine organisms to survive in captivity for long periods of time. His book, *The Aquarium: An Unveiling of the Wonders of the Deep Sea*, published in 1854, provided the general public with the information needed to set up an aquarium in one's home. He also popularized the use of the microscope, which became an instrument of entertainment in many wealthy Victorian households. His book, *Evenings at the Microscope; or, Researches among the Minuter Organs and Forms of Animal Life*, published in 1859, remained in print for some forty-six years. In addition to describing and illustrating various aspects of the natural world for the general public, he published numerous books and articles in journals for the scientific community. He also attended meetings of various scientific societies until the late 1850s and was made a Fellow of the Royal Society in 1856, despite the fact that he had no formal university training.

Gosse's contact with the scientific establishment changed dramatically in 1857 after the death of his first wife and the publishing of his most controversial book, *Omphalos: An Attempt to Untie the Geological Knot*. This book was an attempt to reconcile his belief in the literal biblical account of creation with the geological and fossil evidence, which supported an evolutionary process that took place over a very long period of time. His solution to the problem was to make a distinction between organisms that have had an actual existence (diachronic) and those that only appear to have existed prior to the act of creation (prochronic). Prochronic organisms, which may be represented at any point in the circle of their life cycle, were created at the same time as all the living diachronic creatures during the week of creation described in the book of Genesis. While Gosse thought his explanation perfectly understandable, hardly anyone else did. The scientific community of his day thought that his argument was absurd, and the Christian community disliked the implication that God was a deceiver if he created the earth in a way that only appeared to be very old. The twentieth-century English novelist John Fowles described Gosse's hypothesis as "the most incomprehensible cover-up operation ever attributed to divinity by man."

Gosse's dogmatic religious beliefs led not only to his being cut off from the scientific community and from the wider Christian community; they also had a negative effect on Edmund, his only child. Wotton devotes a large section of his book to this relationship between father and son. While Edmund always respected his father's reputation as a naturalist and illustrator, he could not accept his rigid brand of Christianity. Edmund eventually became a famous literary figure and was knighted for his contribution to the arts. His best known work, *Father and Son: A Study of Two Temperaments*, describes the major differences between himself and his father. The book ends with a powerful attack on his father's position, and his description of Henry as a religious oppressor is one of its dominant themes. *Father and Son* was recognized as a literary masterpiece when it was first published, and it continues to have that status today.

While *Walking with Gosse* is primarily about Henry's life as a naturalist and evangelical Christian, Roger Wotton has also included a fair amount of autobiography. The first chapter documents his own upbringing in a church setting similar to the one that Edmund Gosse experienced. Like Edmund, he also has rejected the Christian faith, so he obviously can identify and empathize with Edmund's struggles. Although he admits that he is an atheist and an evolutionist (p. 194), he still holds Henry Gosse in high esteem as a writer and illustrator of natural history. While his religious views are similar to those of Edmund, his interest in zoology and aquatic biology provides a deep connection with Henry. He even grew up exploring the same south Devon shores that Henry had investigated years before. It is this unique combination of connections that makes Wotton's book such an interesting read.

Anyone interested in natural history, the history of science, or the relationship between science and Christian faith should consider reading this book. Included in the book are many pictures, copies of Henry Gosse's own illustrations, and a bibliography of his publications. While Wotton does not share Gosse's religious beliefs, he does not resort to ridiculing them either. The book ends with a plea for tolerance of opposing views about the origins of life on earth. The overall tone of the book is well summarized when Wotton writes,

> Some suggest all talk of creation should be squashed, based as it is on the supernatural, but I want to be inclusive. We can marvel at Natural History, whatever our explanations for the existence of living things, and this is a view that has been reinforced by studying Henry Gosse, one of the great Natural Historians. Paradoxically, Henry was not capable of such apparent tolerance. (p. 194)

Reviewed by J. David Holland, Associate Professor of Biology, Benedictine University at Springfield, Springfield, IL 62702. ★

Book Notice

THE TEMPLETON SCIENCE AND RELIGION READER by J. Wentzel van Huyssteen and Khalil Chamcham, eds. West Conshohocken, PA: Templeton Press, 2012. v + 243 pages, index. Paperback; $19.95. ISBN: 9781599473932.

This reader comprises a play on the number nine: a collection of nine essays (plus an introduction written by the editors) from nine different fields representing selected chapters from the nine volumes in the Templeton Science and Religion Series, published from 2008 to 2011. Contributors and their topics (in the successive nine chapters) are Joseph Silk (cosmology), Ian Tattersall (paleontology), R. J. Berry (environmental science), Malcolm Jeeves and Warren S. Brown (neuroscience and psychology), Denis R. Alexander (genetics), Justin L. Barrett (cognitive science), Javier Leach (mathematics), Noreen Herzfeld (technology), and Harold G. Koenig (medicine). Four of the original volumes by Berry, Jeeves and Brown, Leach, and Tattersall have been reviewed in previous issues of *PSCF*.

This single edited volume offers one a good understanding of scientific developments in a wide range of fields. No scientific background is presupposed. The editors provide a rationale for the readings in their introduction. The selected readings give evidence of "a 'complementary' approach to science and religion, which implies that each has territories with limits, much as human knowledge will have limits" (p. 7). The book should give the general reader a springboard for participating in broader philosophical and theological discussions.

Reviewed by Arie Leegwater, Calvin College, Grand Rapids, MI 49546. ★

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Canadian Scientific and Christian Affiliation, PO Box 63082, University Plaza, Dundas, ON L9H 4H0. Website: www.csca.ca.

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