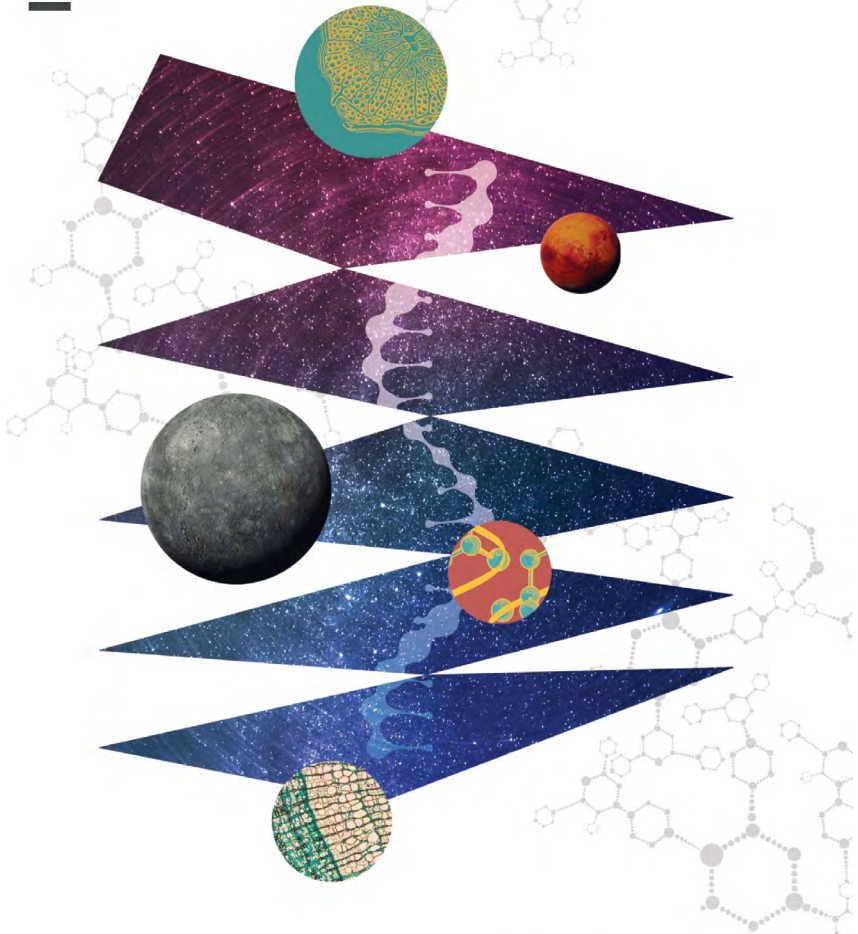


# God and Molecules

Chemical Evolution and  
Divine Providence



W. Ross Hastings



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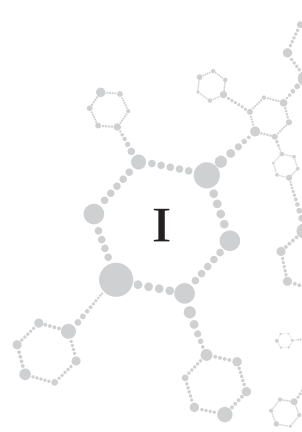
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# The Science

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## Aspects of Chemical Evolution—from Primary Elements to Compounds

### The Cosmic History of Earth's Chemicals

Epistemological caution is definitely appropriate when it comes to scientific knowledge of how the elements were formed in the early universe, and how the elements then came to Earth and became compounds, that is, how the atoms bonded to form the prebiotic molecules, which then reacted and bonded together to form life's molecules. The narrative of Big Bang theory in brief is that the Big Bang (13.8 billion years ago) created a rapidly expanding universe consisting of three simple elements: hydrogen (atomic number 1, meaning that H atoms have one proton [positively charged +1] in the nucleus, and one electron [negatively charged -1] in their orbitals), helium (atomic number 2), and a small amount of lithium (atomic number 3). After the period of initial rapid expansion, cosmic material began to aggregate, creating dense regions of very high temperature and pressure that we know as stars. In this environment stellar nucleosynthesis began to occur by nuclear fusion, so that more complex elements were made—elements such as carbon, nitrogen, and oxygen. For example, if three helium nuclei fused together, each containing two protons and two neutrons, a carbon atom consisting of six protons



and six neutrons might conceivably have been formed. Similarly, two helium atoms and one hydrogen atom may have fused to form nitrogen, or four helium atoms may have formed one oxygen atom, and so on. These are chosen as examples because ultimately it was necessary for these particular elements to become part of planet Earth and form the necessary molecules for the synthesis of more complex molecules required for the evolution of life.

In more detail, the actual proposed sequence of this synthesis of the elements is described as “timed natural selection” by R. J. P. Williams and J. J. R. Fraústo da Silva.<sup>1</sup> It should be emphasized prior to this section that the use of the term *natural selection* with reference to primeval elemental chemistry by these authors is certainly a non-standard definition of the concept. Natural selection in biological evolution involves highly accurate self-replication, and an obvious genotypical and phenotypical mechanism. Some scientists therefore rule out the use of the term for abiotic processes. Having said that, Williams and da Silva, without any stated theological commitments, seem to assume a driving force that influenced the direction of the prebiotic chemistry ultimately toward life. Their view of a timed selection is expressed in the following way.

1. Just after the Big Bang (the time scale is infinitesimal, and is known as “Planck time”), the state of matter was “homogeneous and at equilibrium,” that is, it was in a steady “uniform thermalised state.” During this time, “the formation of light nuclei from neutrons and protons occurred in the initial ‘gas.’” The *nuclei* of hydrogen, deuterium (an isotope of hydrogen with two neutrons), and helium were thereby synthesized in a state of near equilibrium and at temperatures in the  $10^8\text{K}$  range.<sup>2</sup>

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<sup>1</sup>R. J. P. Williams and J. J. R. Fraústo da Silva, *The Natural Selection of the Chemical Elements: The Environment and Life's Chemistry* (Clarendon, 1996), 222. See also Williams and da Silva, *The Biological Chemistry of the Elements: The Inorganic Chemistry of Life* (Oxford University Press, 2001).

<sup>2</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 222, 291.

2. The cosmos then began to expand and cool with time in “immediate steps . . . which involved rapid (even down to  $10^{-43}$  sec) processes of immense, uniformly changing temperature and pressure,” leading next to the beginning of the “formation of light elements” like hydrogen and helium, and their isotopes, with the kinetics (speed or rates of reaction) of this formation also taking place in extremely short periods, so much so that these “light nuclei formed in equilibrium with radiation and the bare neutrons and protons well within one minute so that the universe remained homogeneous.”<sup>3</sup>
3. An estimated  $10^5$  to  $10^6$  years after this, it is postulated that this homogeneity was broken up by the “decoupling of matter and radiation (photons)” as well as subsequent fluctuations, leading to the formation of “galaxies, nebulae and stars.”<sup>4</sup>
4. Following that time, the formation and evolution of other slightly larger nuclei like carbon, nitrogen, and oxygen occurred in these stars, especially isolated giant stars (in which they are still being made), in circumstances that provided “*local* kinetic limitations” that governed the particular evolution of the particular elements. At this point, space becomes relatively homogeneous again.
5. The explosions of these stars and further cooling as the universe unfolded then facilitated “formation, locally and disproportionately, of larger nuclei and then in turn elements, gaseous compounds and finally co-operative condensed systems including the earth.”<sup>5</sup> The authors draw on the work of Burbidge et al. to map out the formation of the elements, which include carbon, nitrogen, oxygen, sodium, magnesium, chlorine, sulfur, and

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<sup>3</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 222.

<sup>4</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 222.

<sup>5</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 222.

- iron, from both hydrogen- and helium-burning reactions, as well as various nuclear reactions.<sup>6</sup>
6. The development of planets in the midst of this inhomogeneity was, according to the authors, “caused by local fluctuations.”<sup>7</sup>
  7. In this whole process, all of the stages except the first were “out of equilibrium . . . and forever falling into kinetic traps . . . from many of which it is difficult to escape.”<sup>8</sup> That is, the lifetime of atoms and molecules and therefore their capacity to react and form atoms and molecules of larger elements is determined by the chemical and physical circumstances in which they are trapped. The kinetics (the rates of reactions) are affected by both chemical and physical features such as temperature and phases of the element.
  8. The consequences of these developments are then worked out by a study of the natural selection of elements in the local conditions on earth as it evolved as a planet  $10^{10}$  years after the Big Bang. The process from the Big Bang depicted by Williams and da Silva involved the initial absence of kinetic control in the formation of hydrogen and helium, followed progressively by the emerging of the larger elements, then molecules, then organic molecules (under the influence of heat and light), in each case selected out by the overcoming of kinetic barriers, meaning factors related to reaction rates that favored some pathways to these compounds more so than others.<sup>9</sup>

Stepping back from the details of this process, some high-level observations are appropriate. The first comment is that the pattern of

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<sup>6</sup>E. M. Burbidge et al., “Synthesis of the Elements in Stars,” *Reviews of Modern Physics* 29 (1957): 547, <https://doi.org/10.1103/RevModPhys.29.547>; Williams and da Silva, *Natural Selection of the Chemical Elements*, figure 7.3, 223.

<sup>7</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 222-23.

<sup>8</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 223.

<sup>9</sup>This putative process is depicted in figure 7.4 in Williams and da Silva, *Natural Selection of the Chemical Elements*, 223.

this process of the formation of elements is certainly one of complexification—the most simple atoms of simple elements coming together to form more complex atoms, and the atoms coming together to form simple molecules, which in turn become complex molecules like proteins, lipids, carbohydrates, and self-replicating nucleotides. This same pattern of complexification would then be reflected in the process of biological evolution, which moved, seemingly ineluctably, from simple to increasingly complex life forms. The increase in brain size in primates and hominids is just one of many examples. In general, life forms became larger, more complex, more energetically intensive, and more taxonomically diverse.<sup>10</sup> This strong directional element in elemental, chemical, and biological evolution seems to point to some kind of a purpose or aim, that is a telos.

The question of whether there is an “immanent directionality” within the cosmos will be discussed in more detail below under “Theological Reflection.”<sup>11</sup> Suffice it to say that the reality that Earth somehow ends up with an element such as carbon, that is, carbon atoms and then carbon compounds, is one possible example of fine-tuning and the anthropic principle, indeed of immanent directionality.

We do not know that Earth is unique in the cosmos, but we do know that its inorganic chemistry differs significantly from all other planets in the solar system, and from the moon, for example. We assume that the chemical and physical conditions, including the temperature on earth, must have been conducive to the synthesis of sophisticated organic molecules that in turn gave rise to the molecules that were preexisting for life. But how did the earth obtain its inorganic and then organic chemistry? And what were the driving forces behind this “happy” set of chemicals and environmental circumstances? I will also discuss this below.

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<sup>10</sup>Alister E. McGrath, *Darwinism and the Divine: Evolutionary Thought and Natural Theology* (Wiley-Blackwell, 2011), 188.

<sup>11</sup>McGrath, *Darwinism and the Divine*, 188.

A second comment is that although we cannot detect signs of divine intervention in this long process, there is nevertheless a sense of the divine at work all along, through laws and through the directionality of the process. The role of the stars, which in their internal nuclear furnaces produced elements necessary for life, that is carbon, nitrogen, oxygen, and twenty or so others, was crucial to the presence of these elements on earth. These elements reached Earth as stars burned up and spread their stardust across the universe. “We are all creatures of stardust, formed from the ashes of dead stars,” said physicist-priest John Polkinghorne.<sup>12</sup> He speaks of Fred Hoyle, the English astronomer who formulated the theory of stellar nucleosynthesis, and was one of the authors of the work (the influential B<sup>2</sup>FH paper) that led to the diagram on the formation of the elements in the history of the universe.<sup>13</sup> As one of the scientists who “unravelling the delicate and beautiful chain of stellar nuclear reactions by which these elements were made,” upon noticing that the nuclear forces had to be just what they were for the reactions to develop in this way, is reported to have said, “The universe is a put-up job.”<sup>14</sup> Though not himself a believer, he seemed to be hinting at the possibility of an intelligence and a telos behind what he was observing. Fine-tuning seemed obvious, though no doubt he believed that the universe had its own freedom to be and to act according to what it is. How this freedom is defined in relation to the freedom and sovereignty of God, its Creator, is a matter for consideration in due course. As indicated above, once the evolutionary process is acknowledged to be teleological, there is the possibility of divine action *always* and *within* the evolutionary process, yet without detection of this divine action, or design. McGrath suggests that this evolutionary teleology is an a

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<sup>12</sup>John Polkinghorne, *Science and the Trinity: The Christian Encounter with Reality* (Yale University Press, 2004), 69.

<sup>13</sup>Burbidge et al., “Synthesis of the Elements in Stars,” 547-650.

<sup>14</sup>Polkinghorne, *Science and the Trinity*, 69.

posteriori rather than an a priori concept.<sup>15</sup> The following comments from Michael Ruse are cogent to this matter:

In recent years, a number of philosophically minded thinkers have raised the possibility that the nature of the physical world is such as to demand understanding in terms of teleology and deity. Enthusiasts for the so-called anthropic principle argue for a spectrum of claims, from the relatively innocuous observation that any world that supports life must be a world capable of supporting life to the much stronger conclusion that the world in which we live—a world that supports life—is so unlikely that its existence can be no mere coincidence and hence must be evidence of powers beyond nature.<sup>16</sup>

Further reflection on questions of teleology will arise also toward the end of the discussion of the evolution of the elements.

### The Driving Forces Behind Earth's Fortuitous Chemistry

The work of Williams and da Silva, *The Natural Selection of the Chemical Elements*, is still the classical treatment of the evolution of the elements. This section will again rely heavily on this work.

The chemical composition of the earth and its primeval soup (on earth, or in hydrothermal vents) and the chemical composition of its atmosphere that became conducive to the formation of preexisting life molecules are thought to have been “selected” by three mechanisms. *First*, they were selected by certain affinities. In the subatomic particles that came together to form primitive nuclei, in the cooling period after the Big Bang, affinities existed according to preexisting natural laws—a matter of interest for a theologian, of course, as is the discrete structure and ordering of the elements! These nuclear affinities were important in the formation of chemical elements. Once formed, the atoms of elements formed bonds with the atoms of other

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<sup>15</sup>McGrath, *Darwinism and the Divine*, 187, 190.

<sup>16</sup>Michael Ruse, *Darwin and Design: Does Evolution Have a Purpose* (Harvard University Press, 2003), x.

elements. This bonding was governed by “principles of chemical affinity related to the electronic configuration of the atoms” of each element. The *second* mechanism of the natural selection of elements also has to do with bonding, but with a particular orientation toward energy states within their three possible phases of matter: solid, liquid, and gas. Within these physical phases, whether bonding occurs or not is determined by two main influences. The first is thermodynamic stability, which is expressed in a state of equilibrium. The second is that of kinetic stability, when combinations of elements are held together in certain physical phases for a long time, even though they are thermodynamically unstable. This may involve, for example, a crystalline state that “does not require a constant supply of energy or material to maintain them.”<sup>17</sup>

A *third* mode of the selection of elements, which employs both of the driving principles of the second, is the selection of an element for its “functional value to an organization such as a living system.”<sup>18</sup> As the authors indicate,

this selection mode is not so obviously restricted by factors such as strength of elementary bonding, molecular structure or physical phase equilibria, although all are involved, nor is it based on kinetically trapped stability alone, even though kinetics is important for organized systems of chemicals. The new feature, so apparent in living systems, which are organized rather than ordered, is the drive for *survival* of the system based on continuous turnover or flow of both chemicals and energy. This is a steady state, not a stationary condition.<sup>19</sup>

Living cells, whole plants, or whole animals fit this category, but also nonliving entities like “the flow of water in geophysical features such as rivers, the movement of planets around the sun.” Whether living or nonliving, these systems are all natural in the sense that they

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<sup>17</sup>See Williams and da Silva, *Natural Selection of the Chemical Elements*, vii.

<sup>18</sup>See Williams and da Silva, *Natural Selection of the Chemical Elements*, viii.

<sup>19</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, viii.

“all arose spontaneously from the *underlying laws of nature* based on the properties of atoms.”<sup>20</sup> Crucially, this book seeks to show that this natural selection of elements is “related to the Darwinian selection of species, although the reasons for survival may differ.” The authors by their choice of the title “the natural selection of the chemical elements” thus express the desire “to encompass all the existing activities in the classes of chemical systems” they mention.<sup>21</sup> In so doing they give credence to the notion that chemistry is the most centrally important science, given that all systems are chemical in their nature.

These authors do not attempt to suggest where the “underlying laws of nature” come from, but their acknowledgment of them is interesting.<sup>22</sup> Theologian-scientist Alister McGrath comments similarly on the preexistent laws of nature: “The universe can be considered to have come into existence with certain fundamental constants and laws embedded within it, governing its future development.” He then comments on these laws in this manner: “The universe came into being already possessing the laws that would govern its subsequent development. That development is shaped by the laws and fundamental constants of nature, which turn out to be ‘fine-tuned’ to values conducive to the emergence of life.” “This fine-tuning,” he suggests, “does not really represent a proof of Christian belief in God; nevertheless, it is consonant with the Christian vision of God, which is believed to be true on other grounds, in that it offers a significant degree of intellectual resonance at points of importance.”<sup>23</sup>

To engage in preliminary theological reflection, commenting on the existence of laws that preexist all matter is one thing. This is well accounted for by a theistic and trinitarian theology of creation. However, to stop there is tantamount to a form of deism. More is

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<sup>20</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, viii. Emphasis added.

<sup>21</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, viii.

<sup>22</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, viii.

<sup>23</sup>McGrath, *Darwinism and the Divine*, 229-30.

required than laws created by God. Those laws must be shown to be in keeping with a transcendent purpose and an immanent directionality that both preserves the distinction between God and creation and thus also permits creation, including atoms and molecules, to have their own contingent existence and freedom to act. That is, divine agency and creatorial agency must be concurrent. For a theology of divine providence that corresponds to the sentiments of Holy Scripture it is incumbent on us to give evidence theologically and scientifically that the triune God is also always engaged constantly with his creation in ways that transcend mere lawgiving. It needs to be shown that this God also actively governs while still preserving the distinctness of his creation and its divinely given powers and embedded laws.

Williams and da Silva recognize also that the laws of nature determine *order* in the world, and specifically in chemical systems, with respect to elements and their systems. These include commonplace aspects of chemistry such as rules that guide chemical bonding, which include atomic dimensions and the physical properties of elements, their electronic structures, their ionization potentials, the empirical covalent and van der Waal's radii, their electronegativities, their electron affinities, and their binding energies. These qualities serve to guide how atoms of elements can bond with each other or with atoms of other elements in molecules through various types of bonding: covalent bonding, in which electrons are shared in a directional manner; ionic bonding, involving the nondirectional attraction of positive and negative ions; metallic bonding, which is the nondirectional attraction between positive ions and delocalized valence electrons; and hydrogen bonding, which occurs when hydrogen is bonded to a very electronegative atom like fluorine, oxygen, or nitrogen, thus enabling the hydrogen atom to bridge with other molecules. This type of bonding is "a determining factor for the structure of condensed states of, for example, water, ammonia and hydrogen fluoride." It

plays a crucial role in the existence and appearance of liquid water on Earth. It explains why liquid water is more dense than ice. In liquid water “the molecules associate forming statistically permanent aggregates and in the solid, ice, the aggregates consolidate and extend into an open crystal structure” and “the openness of this structure explains why ice is less dense than water.” Williams and da Silva comment that “if ice had been more dense than water it would have accumulated at the bottom of the sea and life would have been very different.” They also comment on the vital importance of hydrogen bonding for proteins and nucleotides in that it “dominates folding” in these molecules.<sup>24</sup> In both cases, might hydrogen bonding point again to evidence of an earth fine-tuned toward life?

The more general point to be made is that elements obey certain laws in their intra- and intermolecular bonding and these laws lead to the selection of certain compounds (or homo-atomic elements such as O<sub>2</sub>) to exist on earth and the elimination of others. In anticipation of the discussion of the evolution of life, I have proposed that there has been a natural selection of elements and compounds that became the molecules of life. The manner in which thermodynamics and kinetic control function within this chemistry and this selection is also discussed at length by Williams and da Silva.

### **Selection of Chemical Elements in Abiotic/ Biotic Systems During Their Evolution**

Building on the chemistry of the elements, and also the thermodynamics and kinetics of their state and reactivity, Williams and da Silva devote a major part of their book to the natural selection of the elements during their evolution on earth. The underlying assumption of the authors is that Earth became a “unique chemical laboratory” around 4.5 billion years ago and that life evolved around 4 billion to

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<sup>24</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 61.

3.5 billion years ago by searching out “optimal selection for survival.” They attempt to show that “the steps that have occurred up to [human] exhibit an almost inevitable progression in the natural selection of the elements given the conditions around and on Earth.”<sup>25</sup> The relative constancy of conditions on Earth—that is, its escape from major fluctuations for  $4.5 \times 10^9$  years, something unusual in the cosmos—was vital to the evolution of life and of humanity. The immediate point is that somewhat stable or homeostatic chemistry plays a large part in this development of life. In turn, the earth’s demonstrated “optimal selection for survival” characterizes biological evolution. Yet again, evidence of fine-tuning seems obvious. Yes, the laws of chemistry given by God at its outset are in evidence, and they work toward his purpose for the earth. Proposing that there is a telos, that of humanity made in God’s image, in all this, seems to make sense. The workings of the chemistry according to his laws are such that creation is at work even as the triune God is at work.

It is impossible to cover all the details of the evolution of the elements that are described in Williams and da Silva. The following are some important highlights related to the development of a relatively stable earth, and then life. The authors speak of three arenas in which there was selective development of chemical elements in compounds and in particular physical states as these occurred on earth: First, the arena of the evolution of Earth with its stable chemistry; then the arena of the evolution of organic compounds, using examples from abiotic or bioorganic chemistry to discuss the early organic compounds found in living systems; and third, the arena of organized biological chemistry, showing how and why life evolved into such complicated organisms. Only the first two will occupy our attention here, given our limitation to be concerned only with prebiotic chemistry, not biotic chemistry.

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<sup>25</sup>See Williams and da Silva, *Natural Selection of the Chemical Elements*, 289-90.

1. The arena of the evolution of Earth with its stable chemistry: This involved first the evolution of the inorganic earth long before “there was dioxygen” in Earth’s atmosphere or before organic chemicals or the first human existed.<sup>26</sup> First, the range of elements present in the universe at large, and therefore available to the earth, is determined by the nuclear synthesis that occurred in the stars and became present to the universe. This is borne out by the reality that the relative abundances of the elements in the universe taken as a whole are *approximately* also those of the earth, though lighter elements in gaseous form such as H, He, C, N, and Xe escaped from the earth, and Fe, along with all siderophiles (iron-loving elements like iridium and gold), is more prominent at the center of the planet.<sup>27</sup> According to these authors, gravity also played “a central role in the evolution of the Earth’s mixture of inorganic chemicals.” This is related to the association of the earth with the sun. Thus it was the “relative *abundance* of elements formed from the nuclei more than  $5 \times 10^9$  years ago and associated with the sun” that determined the “natural selection” of the elements on Earth. The authors claim that the abundances constitute the first step of “natural selection,” and they suggest also that the number of known “natural” elements is “connected to fundamental constants in our universe for which we have no explanation.”<sup>28</sup> These assertions are open to question, but are interesting nevertheless for assertions of teleology.

2. The arena of the evolution of organic compounds using examples from abiotic or bioorganic chemistry to discuss the early organic compounds found in living systems:

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<sup>26</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 291. Oxygen is actually poisonous for prebiotic chemistry, as the work of John D. Sutherland and Paul Rimmer has shown.

<sup>27</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 291. Concerning iridium and gold: This in accordance with the Goldschmidt classification. See Victor Goldschmidt, “The Principles of Distribution of Chemical Elements in Minerals and Rocks: The Seventh Hugo Müller Lecture, Delivered Before the Chemical Society on March 17, 1937,” *Journal of the Chemical Society* (1937): 655-73.

<sup>28</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 291-92.

In this regard, the particularity of Earth in an inhomogeneous universe, despite the broad correspondence with respect to abundances stated earlier, becomes important. As the authors indicate, “since earth was formed by a particular perturbation of a particular star at a given time we must expect that the distribution of elements in it is to some degree fortuitous and not precisely the same as anywhere else in the universe.” They go on to say, “It is worth stressing again that the nuclear numbers do govern abundance generally but *not* chemical stability in compounds; chemistry is governed by combinations of atoms that are controlled by the limitations on how electrons fill space (and time) around nuclei.” These authors observe that chemistry in general, and life chemistry in particular, is a “protected Earth temperature subject.” This is because nuclei can only react together at the high temperatures and pressures of stars, but once they have cooled down when they become present on Earth (or other planets), and once they have formed compounds including organic compounds, their nuclei cannot react (only their electrons interact, though shielding of electrons from the nucleus may play a part in electronegativity and reactivity). Thus the chemistry of compounds on Earth is “confined to a very modest temperature range.”<sup>29</sup>

The compounds that persist in this temperature range are therefore either thermodynamically or kinetically stable. If they are thermodynamically stable, they cannot be transformed into other species without the application of energy. Noble gases and aluminosilicates are examples. If they are kinetically stable, the species in question, in its environment, is capable of change spontaneously, but only very slowly, giving out energy to its environment. An example is the free iron (Fe) in the earth’s core, which “in the presence of dioxygen should give iron oxides but does so only very slowly” because of “kinetic barriers” (this involves high activation energies, for example).

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<sup>29</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 292.

Most interestingly, the same thing applies to the organic chemicals in living systems. These compounds are also “*kinetically* stable due to chemical trapping in our oxidizing environment.”<sup>30</sup> It is acknowledged that all of the planets of our solar system and, as far as we know, most of the planets of the cosmos, do not have the same history and composition and temperature range as that of Earth. Therefore, compounds that are either thermodynamically stable like water, or kinetically stable like the organic compounds of life that exist on Earth, such as the organic compounds in plant and animal cells, were thought for the most part not to be able to exist on those planets.

However, more recent research has shown that, in the case of water, it is present as a liquid beneath ice on several moons: Europa, Enceladus, Titan, and probably others. Water was also almost certainly present transiently on ancient Mars, and may possibly have been on the surface of ancient Venus.<sup>31</sup> In the case of organic compounds, depending on which particular ones, the evidence is both “stronger and less constrained.”<sup>32</sup> The kinetical stability of organic compounds is certainly one fundamental feature of living systems.<sup>33</sup> That is not to say that a different self-replicating life system based on another chemistry does not exist. It is to say that the circumstances of Earth with its kinetically stable organic chemistry is remarkable. To any

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<sup>30</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 292-93. Emphasis original.

<sup>31</sup>Paul Rimmer, email communication, September 8, 2023. For a summary article on this, see Shannon Hall, “Our Solar System Is Overflowing with Liquid Water,” *Scientific American* 314, no. 6 (2015): 14-15. See also “Steep Slopes on Mars Reveal Structure of Buried Ice,” NASA press release, Jet Propulsion Laboratory at the California Institute of Technology, January 11, 2018, [www.jpl.nasa.gov/news/steep-slopes-on-mars-reveal-structure-of-buried-ice/](http://www.jpl.nasa.gov/news/steep-slopes-on-mars-reveal-structure-of-buried-ice/). See also two documents from the US National Academies of Science prepared at NASA’s request: National Research Council, *Vision and Voyages for Planetary Science in the Decade 2013–2022* (National Academies Press, 2001), <https://nap.nationalacademies.org/read/13117/chapter/1>, and National Research Council, *Exploring Organic Environments in the Solar System* (National Academies Press, 2007), <https://nap.nationalacademies.org/read/11860/chapter/1#ii>. See also Karen Meech and Sean N. Raymond, “Origin of Earth’s Water: Sources and Constraints,” December 9, 2019, 1-32, <https://arxiv.org/abs/1912.04361>; James Green and David Draper, “Evolution of Volatiles on the Moon,” *Room: The Space Journal of Asgardia* 4, no. 26 (2020): 80-85, <https://room.eu.com/article/evolution-of-volatiles-on-the-moon>.

<sup>32</sup>Paul Rimmer, email communication, September 8, 2023.

<sup>33</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 293.

fair-minded person, this looks like another put-up job as far as the directionality of evolution and the presence of life on Earth are concerned. The Earth is fine-tuned for life not by occasional divine intervention but by the laws and continuous working of the triune God, which is in concursus with or compatible with the working of the creation itself. Immanent directionality seems clearly in view.

The history and role of *carbon* is a crucial and central piece in the evolution of the kinetically stable organic compounds spoken of, and of life itself. Organic chemistry, which has the connotation of life, is a much bigger field than biological chemistry. It is based on the element carbon in association with the other light elements such as hydrogen, nitrogen, and oxygen. There has also developed carbon chemistry involving compounds, in which carbon is bonded to heavier nonmetals like sulfur, phosphorus, selenium, and the halogens. There is, in addition, a whole relatively new area of chemistry called organometallic chemistry, which is the chemistry of compounds in which carbon in carbon moieties are bonded with metals, especially the transition metals.<sup>34</sup> Organometallic compounds feature in the research of some workers in chemical evolution, especially as catalysts, as will be noted in chapters two through four.

Having noted that organic chemistry is bigger than the molecules of life, it is important to say that it is, however, the very essence of the biological molecules. Amino acids contain carbon, as do the proteins built from amino acids. Carbon is the core element in carbohydrates, in fats, and in the molecules of self-replication like RNA and DNA. As Williams and da Silva indicate, very few of these molecules are thermodynamically stable, yet they are in their cellular systems kinetically stable in ways that are crucial to the existence of life. They

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<sup>34</sup>Although the discovery of organometallic compounds goes back to 1760, organometallic chemistry begins to be a recognized field in the 1960s, and this is signaled by the award in 1973 of the Nobel Prize to Geoffrey Wilkinson and Ernst Otto Fischer for their work on sandwich compounds.

comment that  $\text{CO}_2$  is the only stable organic compound in the presence of  $\text{O}_2$ , and  $\text{CO}_2$  and  $\text{CH}_4$  are the only stable forms of carbon, except for carbon itself, in the presence of water and in the absence of  $\text{O}_2$ .<sup>35</sup> All the other organic compounds, which are kinetically but not thermodynamically stable, and their derivation from carbon as an element on Earth and then as simple compounds, are important in this study.

As already indicated, the presence of carbon in the cosmos is due first to the high temperature fusions of the nuclei of the smaller atoms of hydrogen and helium in the initial phase of the cosmos. The reactions that carbon then underwent when the cosmos underwent cooling were, according to Williams and da Silva, likely based on three features:

1. the stability of the simple oxides,  $\text{CO}$  and  $\text{CO}_2$ , relative to one another and relative to the stability of the oxides of the elements with similar affinity for  $\text{O}_2$
2. the stability of carbon's hydride,  $\text{CH}_4$
3. the stability of carbon itself (including graphite and fullerenes)<sup>36</sup>

A fortuitous feature in the cooling process on Earth is that carbon monoxide is relatively (compared to carbon dioxide) thermodynamically unstable. It seems to have been kinetically stable at some points, but its presence would have been minimized by the high percentage of hydrogen present in the cooling phase. It is thought that in these circumstances, "catalysed reactions of the carbon oxides with  $\text{H}_2$  on the inorganic surfaces could well have resulted in the considerable reduction of carbon to produce C–H compounds." Both of these circumstances mitigated toward the formation of C–H compounds such as methane, some oils, and "small amounts of many organic compounds," which are "still seen in interstellar space." Some of the small

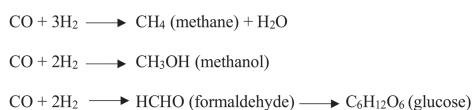
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<sup>35</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 324.

<sup>36</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 325.

organic molecules present in space today include methane ( $\text{CH}_4$ ), methanol ( $\text{CH}_3\text{OH}$ ), methylamine ( $\text{CH}_3\text{NH}_2$ ), hydrogen cyanide (HCN), methylcyanide ( $\text{CH}_3\text{CN}$ ), and many polycyclic aromatic hydrocarbons.<sup>37</sup> Discussion of which of these molecules is presumed also to be on Earth as it cooled down will unfold in the context of discussion of the work of various researchers. Notably, we will discover that one school of thought in chemical evolution has proposed the possibility that HCN was an important precursor because of the presence in this molecule of three elements that are the foundational building blocks for amino acids.

Some of the pathways involving the carbon oxides proposed by Williams and da Silva, which involve the production of products that are thermodynamically unstable but kinetically stable “in trapped energetic states,” are as shown in figure 1.1.<sup>38</sup>



**Figure 1.1.** Pathways involving the carbon oxides

Other pathways may have involved nitrogen, which was present in the early atmosphere of the earth. In reaction with hydrogen and

catalyzed by inorganic compounds, nitrogen, as suggested above, may have given rise to hydrogen cyanide (HCN) and ammonia ( $\text{NH}_3$ ). The authors postulate that the organic chemistry that followed from these simple reactions “evolved on Earth and in interstellar space from a poorly equilibrated mixture of gases which were now quite well retained by gravity, in the presence of liquid water, some  $\text{H}_2\text{S}$  . . . and a variety of catalytic solid surfaces.” They comment also that the catalysts “were essential at the low temperatures of 300 to 350 K if further reactions were to occur in the absence of light.” In a manner that will be

<sup>37</sup>This data is recorded in table 9.1 in Williams and da Silva, *Natural Selection of the Chemical Elements*, 325. The data come from W. W. Duley and David A. Williams, *Interstellar Chemistry* (Academic Press, 1984).

<sup>38</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 326.

borne out in the work of contemporary researchers, “input of energy from the sun or the interior of the Earth . . . was also required for the build-up of an *energized*, that is, even less equilibrated and therefore more unstable, system of relatively unreactive carbon chemicals.”<sup>39</sup> However, they also suggest that this “series of compounds were produced and eventually gave rise to organic (and biological) chemistry,” but that it was “only slowly with time that the sophistication of these compounds developed.” They conclude that “all of [the] organic and bioorganic chemistry is based to this day on synthesis using energy, starting from CH<sub>4</sub>, CO<sub>2</sub>, CO, NH<sub>3</sub> and H<sub>2</sub>O and employing catalysts.”<sup>40</sup> As will be noted in later chapters, current researchers have transcended these conclusions and have suggested different substrates and an emphasis on photochemistry.

Having pointed to the remarkable nature, reactivity, and history of carbon, it must not be forgotten that there are at least twenty essential elements in living systems, and indeed, as Williams and da Silva have indicated, “a set of some 15-20 of these elements is required by *all* known living organisms.” They ask the obvious questions: “To what extent did this drive evolution?” and what were “the functional value of the so-called minor *essential* elements?”<sup>41</sup>

Much more could be said about natural selection of elements but this will serve as a good introduction to the field of their evolution. Before moving on to theological reflection on the evolution of elements, it is plain to see that much has been discovered by science and much remains unknown. The spirit of the scientists is one of epistemological humility.

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<sup>39</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 326. Emphasis original.

<sup>40</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 326-27.

<sup>41</sup>Williams and da Silva, *Natural Selection of the Chemical Elements*, 385.

## Theological Reflection

**Teleology and immanent directionality.** In Thomas Huxley's famous 1887 lecture "On the Reception of the *Origin of Species*," he gave an apologetic against three common criticisms of Darwin's theory of natural selection within biological evolution. He first corrects the notion that Darwin believed that variations and the survival of the fittest had chance as its causation. Darwin did not profess to know what caused things to happen beyond the normal laws of causality. Second, Huxley assures his readers that Darwin's theory did not spell the end of teleology, or "eviscerate the argument from design."<sup>42</sup> As McGrath notes, "Huxley is quite clear that traditional approaches to teleology—such as that adopted by William Paley—face severe challenges from Darwin's account of evolution. Yet the theory of evolution, he argues, bears witness to a 'wider teleology' rooted in a deeper structure of the universe."<sup>43</sup> As Huxley says,

The teleological and the mechanical views of nature are not, necessarily, mutually exclusive. On the contrary, the more purely a mechanist the speculator is, the more firmly does he assume a primordial molecular arrangement of which all the phenomena of the universe are the consequences, and the more completely is he thereby at the mercy of the teleologist, who can always defy him to disprove that this primordial molecular arrangement was not intended to evolve the phenomena of the universe.<sup>44</sup>

The third correction Huxley wished to make was with respect to theism. In Darwin's own words, "The doctrine of Evolution is neither Anti-theistic nor Theistic."<sup>45</sup> No new problems for theism were created by the theory of evolution, as Huxley saw it.

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<sup>42</sup>Francis Darwin, ed., *The Life and Letters of Charles Darwin*, vol. 2 (John Murray, 1887), 201.

<sup>43</sup>McGrath, *Darwinism and the Divine*, 186.

<sup>44</sup>Thomas H. Huxley, "On the Reception of the Origin of Species," in Darwin, *Life and Letters of Charles Darwin*, 201-2.

<sup>45</sup>Darwin, *Life and Letters of Charles Darwin*, 202.

What did Huxley mean by this “wider teleology” that he believed might be grounded in the “primordial molecular arrangement” of the universe that guided its subsequent development? Without interpreting Huxley unequivocally, McGrath expresses the possibility that Huxley’s “suggestive way of speaking certainly resonates strongly with the increasingly influential view that the fundamental constants and laws of the universe were such as to make Darwinian evolution possible.” “In other words,” he adds, “the actuality of biological evolution is ultimately dependent on the fundamental properties of certain elements of the universe, and those properties were established at the beginning of time.” McGrath goes on to discuss in detail the question of whether there can be directionality in evolutionary biology. His concern is first with *observation*, as in, if directionality can be detected, and then second with *interpretation*. That is, if there does appear to be “some kind of immanent directionality within nature,” how might this “be mapped onto various teleological schemes?”<sup>46</sup>

With respect to *observation*, McGrath points first to the “standard cosmological model,” which is “a narrative of increasing complexification from the origins of the universe to the present day.” He asserts, therefore, that this constitutes directionality, an assertion he believes to be fair given that there is “overwhelming evidence” as indicated by a large number of reviews in the literature. On this basis he concludes that the “process of evolution at the physical, chemical, and biological levels shows a marked and essentially irreversible trend toward complexity.”<sup>47</sup>

In *interpretation* of this trend toward complexity, McGrath asks, “Can we move from the descriptive observation of increased complexity in the universe over time to a metaphysical or theological theory of a cosmic purpose? Is directionality functionally equivalent to a teleology—a theory of purpose or goal? In part, the answer given

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<sup>46</sup>McGrath, *Darwinism and the Divine*, 187.

<sup>47</sup>McGrath, *Darwinism and the Divine*, 187-88.

to this question depends on how teleology is defined.” In response, McGrath helpfully clarifies some important notions concerning teleology. In and of itself it does not necessarily imply theism. When Aristotle proposed the idea of telos or goal, and teleology in the process of natural generation, he did not imply “purpose of an external agent” but rather what lies at the end of the process, that is, an “apparent internalized goal.” Aquinas does take this in the direction of a Christian theological interpretation, but it must be noted that teleology was not equated with design in its original intent. McGrath sums this up in a succinct manner: “*Design* is to be understood, as conscious intent, and artifice applied externally to the order of nature, in order to achieve some end or external goal; *teleology* can be interpreted, simply as evidence of function or purpose, within nature, as an expression of natural laws and natural order.”<sup>48</sup> Design understood in this sense seems, as Rimmer has stated, to be “anti-organic. Life is not an artefact.”<sup>49</sup> The lack of the distinction between design and teleology is actually evident in the comparative history of teleology in English natural theology in the seventeenth to the nineteenth century, where teleology did lead to arguments for design (William Paley’s natural theology being a case in point), and the German tradition (Immanuel Kant, for example) where teleology was restricted to the notion of the “internal powers of organization in organisms.”<sup>50</sup>

McGrath concludes that the argument that “rejection of any form of teleology is integral to the evolutionary synthesis” is actually spurious, therefore. The “real (and entirely valid)” concern for natural scientists, he states, is that “a teleology that ultimately rests upon philosophical or theological presuppositions (whether religious or

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<sup>48</sup>McGrath, *Darwinism and the Divine*, 188-89. Emphases added. See Monte Ransome Johnson, *Aristotle on Teleology* (Clarendon, 2005), 159-286, cited in McGrath, *Darwinism and the Divine*, 189.

<sup>49</sup>Paul Rimmer, email communication, September 8, 2023.

<sup>50</sup>McGrath, *Darwinism and the Divine*, 190.

atheist) will be forcibly imposed upon biological processes.” The concern is attempts to “smuggle unverifiable, theological or metaphysical doctrines into supposedly objective scientific accounts of reality.”<sup>51</sup> It is timely to point out at this juncture that is precisely the “unverifiable” or undetectable nature of the constant divine providence of God, who works alongside or in concursus with molecules, allowing their freedom to be and to progress, that makes this theological doctrine compatible with teleology. It is a faith-seeking-understanding proposal based on Holy Scripture, not on verifiable science. The immanent working of the Creator and Sustainer of the cosmos is not verifiable, and it does not “forcibly impose” itself on either chemical or biological processes.

In fact, biologist Francisco Ayala has intervened in this discussion by insisting that teleological language is actually helpful in explaining the “adaptations of organisms” since their existence “can be accounted for in terms of their contributions to the reproductive fitness of the population.” Thus adaptations of “organs, homeostatic mechanisms, or patterns of behavior . . . are observed to have a beneficial impact on the survival or beneficial impact of organisms,” which can be considered therefore to be in line with “the phenomenological goal toward which they tend.”<sup>52</sup> Ernst Mayr, commenting on the pervasive examples of goal-directed behavior in the natural world, insists that the occurrence of such “processes is perhaps the most characteristic feature of the world of living systems.”<sup>53</sup>

McGrath insists that natural selection itself, the most important “source of explanation in biology,” is a teleological process, “in that it is directed to the goal of increasing reproductive efficiency and

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<sup>51</sup>McGrath, *Darwinism and the Divine*, 190. Here McGrath cites Ernst Mayr, *Toward a New Philosophy of Biology: Observations of an Evolutionist* (Belknap, 1988), 38-66.

<sup>52</sup>McGrath, *Darwinism and the Divine*, 190, referring here to Francis Ayala, “Teleological Explanations in Evolutionary Biology,” *Philosophy of Science* 37 (1970): 1-15, and “Teleological Explanations vs. Teleology,” *History and Philosophy of the Life Sciences* 20 (1998): 41-50.

<sup>53</sup>Mayr, *Toward a New Philosophy of Biology*, 44-45.

generates to goal-directed organs and processes required for this.” Indeed, he adds, “such teleological explanations can be considered to be both appropriate and inevitable in biology, yet remain fully compatible with causal accounts. They cannot be reduced to non-teleological explanations without loss of the explanatory content.”<sup>54</sup>

A component in the discussion of teleology is the place that chance plays. Paley thought of chance as “the operation of causes without design,” leading him to believe that complex entities like the human eye could not have arisen by chance, but rather required design. But as McGrath points out, this conclusion “is driven by the undefended controlling presupposition that chance and design are mutually exclusive at every level.” He argues that if something is said to have happened by chance this means “no more than that we do not know enough about its antecedents to predict its outcome with certainty.”<sup>55</sup> Finnish author Rope Kojonen has argued in a similarly nuanced manner.<sup>56</sup> Thomas Aquinas already in the thirteenth century had created a robust intellectual framework in which design and teleology can be found to be compatible with the role of chance in the bringing about of intended outcomes, for, as McGrath notes, “Aquinas is emphatic that the notion of divine providence does *not* exclude luck (*fortuna*) or chance (*accidens*).”<sup>57</sup> For example, in *Contra Gentiles*, Aquinas states, “But it would be contrary to the essential character of divine providence if all things occurred by necessity, as we showed. . . . Therefore, it would also be contrary to the character of divine providence if nothing were to be fortuitous and a matter of chance in things.” But he then goes on say, “Again, it would be contrary to the very meaning of providence if things subject to providence did not act for an end, since it is the function of providence to order all things

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<sup>54</sup>McGrath, *Darwinism and the Divine*, 191.

<sup>55</sup>David J. Bartholomew, *God, Chance and Purpose* (Cambridge University Press, 2008), 18, cited in McGrath, *Darwinism and the Divine*, 191.

<sup>56</sup>E. V. Rope Kojonen, *The Compatibility of Evolution and Design* (Palgrave Macmillan, 2021).

<sup>57</sup>McGrath, *Darwinism and the Divine*, 192.

to their end.”<sup>58</sup> Thus chance, a part of secondary causation, does not for Aquinas work contrary to teleology. This counters the false dichotomy between randomness and teleology held by proponents of Darwinian evolutionism such as French atheist biologist Jacques Monod (1910–1976), who stated that the biological evolutionary process is directed by “pure chance, absolutely free but blind,” and Stephen Jay Gould (1941–2002), who said that “almost every interesting event of life’s history falls into the realm of contingency.”<sup>59</sup>

The question that arises here is, What is contingency? “They just happen to be like that . . . but they did not have to be like that, for they might have been very different,” is the initial answer given by Protestant theologian of science T. F. Torrance. However, he indicates an expansion of its meaning in both science and theology, such that it applies “not only to what things happen to be but the kind of order or pattern they happen to have.” All contingency is grounded in what has always been the Judeo-Christian background to it, namely “that God freely created the universe out of nothing.” In other words, “the universe has been given a distinctive existence of its own, utterly different from God’s.” Torrance goes on to say, “We describe it as contingent for it depends on God entirely for its origin and for what it continues to be in its existence and in its order.” In other words, understood in its Judeo-Christian roots, contingent means *dependent* for its existence on God. In sum, Torrance states, “Since it came into being through the free grace of God, it might not have come into being at all, and now that it has come in to being, it contains no reason in itself why it should be what it is, and why it should continue to exist. Indeed, God was under no necessity to create the universe.”<sup>60</sup>

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<sup>58</sup>Thomas Aquinas, *Contra Gentiles*, trans. Vernon J. Bourke (University of Notre Dame Press, 1975), book 3, cc. 74.

<sup>59</sup>Jacques Monod, *Chance and Necessity: An Essay on the Natural Philosophy of Modern Biology* (A. Knopf, 1971), 112-13; Stephen Jay Gould, *Wonderful Life: The Burgess Shale and the Nature of History* (W. W. Norton, 2006), 101-2.

<sup>60</sup>T. F. Torrance, *Divine and Contingent Order* (Oxford University Press, 1981), vii.

This was certainly the perspective of Duns Scotus (1265/66–1308), Scottish Catholic priest and Franciscan friar who affirmed that “the creation of things proceeds from God, not out of any necessity whether of being or of knowledge, or of will, but out of pure freedom, which is not moved, much less necessitated, by anything outside of itself, so as to be brought into operation.” There is no self-subsistence or inherent stability to the universe and what constitutes it, yet it is “nevertheless endowed with an authentic reality and integrity of its own which must be respected.”<sup>61</sup> Another way to say this is to affirm that there is a “contingent order” in the universe by which is meant that “the universe is not self-sufficient or ultimately self-explaining but is given a rationality and reliability in its own orderliness which depend on and reflect God’s own eternal rationality and reliability.” Torrance then suggests that “modern empirical science owes its existence to the injection of these notions of contingency and contingent order into the basic stock of ideas in our understanding of nature.”<sup>62</sup> This grounding of the created realm in dependence on a God who creates in free and sovereign grace can account both for the contingency of events like elemental nuclear synthesis and the presence on Earth of elements necessary for life, *and* for the teleology that gives evidence of the invisible providence over it. There is a freedom of God and a contingent freedom of the molecule to be itself and to conform to laws embedded by the Creator, that prepares the way for the proposal of concurrence as the mechanism for divine providence.

Complementary to this perspective on contingency arising in Duns Scotus are some elements in Aquinas’s view of providence, which confirm that a notion of *concursus* is already present before Karl Barth’s twentieth century expression of it. As McGrath has stated,

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<sup>61</sup>Duns Scotus, *Quaestiones disputatae de rerum principio*, q. 4, a. 1, n. 3, cited in T. F. Torrance, *Divine and Contingent Order*, vii.

<sup>62</sup>T. F. Torrance, *Divine and Contingent Order*, viii.

“Aquinas’s approach lays a robust conceptual foundation for affirming the providence of God, *without entailing the compromise of the integrity and characteristics of the natural order.*”<sup>63</sup> McGrath backs this up with reference to chaos theory, in which “chance is not inherently anti-teleological.” McGrath also speaks of the compatibility of chance and teleology in evolutionary biology. Chance, he says, may be “the engine of evolutionary development,” but it does not “determine its outcomes.” The work of Cambridge paleobiologist Simon Conway Morris contains evidence of this compatibility. Conway Morris uses “the image of evolution as a search engine, randomly searching biological space for stable outcomes, and hence, allowing ‘islands of stability’ to be identified. The search process may be random, but the destinations are predetermined.”<sup>64</sup> This could equally be said of chemical evolution toward life.

As Conway Morris states, “The view that evolution is open-ended, without predictabilities and indeterminate in terms of outcomes is negated by the ubiquity of evolutionary convergence, [which] . . . points to a deeper structure to life, a metaphorical landscape across which evolution must necessarily navigate.”<sup>65</sup> As noted by McGrath, there is a consonance between Conway Morris’s approach and the earlier work of Joseph Needham (1900–1995), as expressed in his 1935 Terry Lectures at Yale: “The evolutionary process was shown to not be a matter of chance, but inevitable, granting the general principle of biological organization, and the properties of the chemical elements—a conclusion, at least as acceptable to dialectical materialism as to orthodox theology. Vitalism was thus dissolved in universal teleology.”<sup>66</sup>

The “wider teleology” referred to by Huxley included a particular reference to “primordial molecular arrangement” that was so influential

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<sup>63</sup>McGrath, *Darwinism and the Divine*, 192. Emphasis added.

<sup>64</sup>See McGrath, *Darwinism and the Divine*, 192-93.

<sup>65</sup>Simon Conway Morris, “Darwin’s Compass: How Evolution Discovers the Song of Creation,” *Science and Christian Belief* 18 (2006): 5-22, cited in McGrath, *Darwinism and the Divine*, 192.

<sup>66</sup>Joseph Needham, *Order and Life* (Yale University Press, 1936), 15.

in directing the whole evolutionary process. The importance of the chemistry of the cosmos for the shape of its development was recognized early by Harvard chemist Josiah Parsons Cooke (1827–1894): “There is abundant evidence of design in the properties of the chemical elements alone, and hence that the great argument of Natural Theology rests upon a basis which no theories of organic development can shake.”<sup>67</sup> According to later biological chemist Lawrence J. Henderson (1878–1942), the “unique properties of the elements (hydrogen, carbon, nitrogen, oxygen) which were constitutive of the primeval evolutionary synthesis of the molecules of life (later known as RNA, DNA) must be regarded as possessing a teleological character.” This meant for Henderson that “the whole evolutionary process, both cosmic and organic, is one, and the biologist may now rightly regard the universe in its very essence as biocentric.”<sup>68</sup>

In the years since these authors, with the advent of quantum chemistry and physics, the focus has been on the quantum mechanical properties of these elements, and those of catalytic transition metals critical to biochemical processes, properties that were fixed at the origins of the universe in the Big Bang and what followed. For ex-



**Figure 1.2.** Nucleosynthesis of oxygen from reaction of a carbon nucleus and a helium nucleus

ample, the nucleosynthesis of oxygen involved the reaction of a carbon nucleus and a helium nucleus (fig. 1.2).

This process might easily lead to carbon being transmuted completely into oxygen, resulting in too low an amount of carbon in the cosmos for the emergence of life.

In the 1950s cosmologist Fred Hoyle became certain that there must be an aspect to nuclear chemistry not yet known in his time that

<sup>67</sup>Josiah Parsons Cooke, *Religion and Chemistry: A Restatement of an Old Argument* (Scribner, 1864), vii–viii.

<sup>68</sup>Lawrence J. Henderson, *The Fitness of the Environment: An Inquiry into the Significance of the Properties of Matter* (Beacon, 1913), 312.

would cause this reaction to produce equal amounts of carbon and oxygen. It was then discovered that the energy levels of excited states of these nuclei were fixed at a level permitting both carbon and oxygen to be produced in approximately equal amounts. This led Hoyle to make some comments about teleology, calling this evidence of a “second put-up job.” He states, “A common sense interpretation of the facts suggests that a superintellect has monkeyed with physics, as well as with chemistry and biology, and that there are no blind forces worth speaking about in nature.”<sup>69</sup> This and the nucleosynthesis of the other elements present in the first amino acids, fatty acids, proteins, and sugars give evidence that the whole evolutionary process depends on fundamental elemental properties that are known to have been set in the origin of the universe. As McGrath indicates, it “sets the Darwinian mechanism in a wider context, and makes it entirely possible to speak of a ‘wider’ or ‘deeper’ teleology.”<sup>70</sup> The fundamental nature of the chemistry is apparent in all this.

In support of teleology in biology, Seth Hart has cited Francisco Ayala, who as early as 1970 argued, “Teleological explanations are appropriate and indispensable in biology, and . . . are fully compatible with causal accounts, although they cannot be reduced to nonteleological explanations without loss of explanatory content.”<sup>71</sup> He also refers to the “work of Chilean biologists Francisco Varela and Humberto Maturana,” who list “autopoiesis as a clear manifestation of an organism’s teleological unity.” Hart summarizes their argument:

Since the individual systems are dependent on the unity of the network, the investigator must understand each system as operating toward a common end. In a cell, for instance, each system relies on the other systems for the attainment of their goals. Unlike machines, each part

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<sup>69</sup>Fred Hoyle, “The Universe: Past and Present Reflections,” *Annual Review of Astronomy and Astrophysics* 20 (1982): 16.

<sup>70</sup>McGrath, *Darwinism and the Divine*, 197.

<sup>71</sup>Francisco J. Ayala, “Teleological Explanations in Evolutionary Biology,” *Philosophy of Science* 37, no. 1 (1970): 8.

receives its identity only in relation to the whole. Due to these implications, Varela himself has since become a teleological realist.<sup>72</sup>

The similar presence of a common end of dependent individual systems may also apply fittingly to prebiotic chemistry. Hart also refers to the work of Gonzaga philosopher Michael Tkacz, who speaks of “optimality modeling, the most common method of determining adaptations in modern biology,” as providing “particularly clear and evocative examples [of] research programs in which final cause plays an explicit unifying role in explanation.”<sup>73</sup> The work of Robert Koons also supports the idea that biology needs teleology. Speaking of the manner in which teleology has been treated as outdated or as only a heuristic device at best, especially since the rise of evolutionary theory, Koons finds this to be “an untenable position, since biological inquiry exists primarily for the sake of biological knowledge, and biological knowledge is inextricably bound up with teleological concepts, like that of gene or enzyme. Moreover,” he adds, “the very possibility of rational thought and knowledge depends upon a teleological foundation.” He speaks also of how “modern quantum physics points the way to a robust sort of emergence of new causal powers at both the chemical and biological scale, enabling a revivification of scientific teleology, properly understood.”<sup>74</sup> There is no reason to assume that prebiotic chemistry does not work in a similar way, and in fact Koons has wondered whether there might be something special about the origin of life that makes teleology shine.<sup>75</sup> Having reviewed the

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<sup>72</sup>Seth Hart, “The Teleological Menace, Why Biology (Still) Requires God,” *Capturing Christianity*, December 11, 2021, <https://capturingchristianity.com/the-teleological-menace-why-biology-still-requires-god>, with reference to Simon Oliver, “Teleology Revived? Cooperation and the Ends of Nature,” *Studies in Christian Ethics* 26, no. 2 (2013): 164.

<sup>73</sup>Hart, “Teleological Menace”; Michael W. Tkacz, “Thomistic Reflections on Teleology and Contemporary Biological Research,” *New Blackfriars* 94, no. 1054 (2013): 657.

<sup>74</sup>Robert Koons, “Why Biology Still Needs Teleology: A Modern Aristotelian Account of Life, Knowledge, and Health,” RobKoons.net, [https://robkoons.net/uploads/1/3/5/2/135276253/why\\_biology\\_still\\_needs\\_teleology.pdf](https://robkoons.net/uploads/1/3/5/2/135276253/why_biology_still_needs_teleology.pdf).

<sup>75</sup>Dr. Robert Koons, “Why Biology Still Needs Teleology” (lecture, Collegium Institute, University of Pennsylvania, January 14, 2015), [www.youtube.com/watch?v=jnvPvn6rW4](http://www.youtube.com/watch?v=jnvPvn6rW4).

inevitability of teleology in biology, Hart goes as far as to say that “all in all, it remains to be seen if it is even *possible* to account for teleology outside of a theistic foundation.”<sup>76</sup>

**Design.** But does teleology imply design? Within the natural theology of William Paley, the two were almost synonymous. Any sign of contrivance was proof of design. This was, however, challenged significantly in the work of William Whewell (1794–1866), for whom evidences of teleology in natural science were considered to harmonize with the view of the creation, preservation, and government of God.<sup>77</sup> In other words, the belief in a designer of the universe could be shown to be harmonious with what is observed in the world, but design was in fact something inferred, not something observed. Theologian John Henry Newman (1801–1890), who thought of natural theology as helpful in strengthening faith but insufficient for bringing a person to faith, expressed his view on design in a corresponding manner: “I believe in design because I believe in God; not in God because I see design.”<sup>78</sup> As McGrath pointedly asserts, “For Newman, natural theology was a framework for observational accommodation, not for pseudo-scientific proof.”<sup>79</sup>

The positivist idea of proof of God’s existence from mechanisms of biological evolution or the natural sciences in general has since 1850 onward been replaced by an approach that is more in keeping with critical realism. This is an approach that looks for “correspondence, resonance, or consonance between the theoretical framework provided by the Christian faith and our experience of the world around us,” an approach that focuses “on the explanatory capaciousness of the Christian faith to accommodate observation of the world.” In other

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<sup>76</sup>Hart, “Teleological Menace.”

<sup>77</sup>William Whewell, *Astronomy and General Physics Considered with Reference to Natural Theology* (London, 1833), 2.

<sup>78</sup>John Henry Newman to William Robert Brownlow, April 13, 1870, in John Henry Newman, *The Letters and Diaries of John Henry Newman*, ed. Stephen Dessain and Thomas Gornall (Clarendon, 2006), 25:97.

<sup>79</sup>McGrath, *Darwinism and the Divine*, 197.

words, natural theology and observations that look like design are not necessary for proof of the existence of God by inference; “rather,” as McGrath asserts, “it is argued that the vision of nature that is made possible and legitimate by the Christian faith is found to offer satisfactory intellectual resonance with what is actually observed.” This resonates well with the sentiments of Simone Weil, the French philosopher who professed that “faith in God illuminates reality in a far better way than its secular alternatives.” Referring to recent re-statement of traditional teleology arguments in accordance with the philosophy of science’s notion of “inference to the best explanation,” McGrath expresses hope for a new injection of intellectual energy into this area of teleology.<sup>80</sup>

**Augustine and “logical seeds.”** Most interestingly, the creation theology of Augustine involving the idea of creation as containing potential for development, or “logical seeds,” is in keeping with this origin-of-elements proposed pathway, leading to an origin-of-life chemistry.<sup>81</sup> Augustine’s idea that creation was an act that included subsequent processes within it, when certain entities came under certain circumstances, can easily be mapped onto the proposed development of the elements as described above. Whatever the initial particles produced by the Big Bang, *ex nihilo*, they are fecund, that is, they have the capacity to form elements when the temperature and pressure in the early universe decreases. The created first particle, which on a theological account was created *ex nihilo*, has the capacity, even the propensity, to participate in the creation of the initial elements, which in turn participate ultimately in the creation of heavier elements, the elements of life, which in turn participate in the

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<sup>80</sup>McGrath, *Darwinism and the Divine*, 198, 201. This is the methodology consolidated in the philosophy of science in the 1970s, which persists in science. It is a method that “holds that a hypothesis should be accepted because, if it were true, it would explain the phenomena better than any other.” It is the hypothesis that is best by virtue of it having the greatest “epistemic virtue.” See McGrath, *Darwinism and the Divine*, 199.

<sup>81</sup>McGrath, *Fine-Tuned Universe*, 97-102.

formation of simple compounds and then ultimately in the compounds of life. It is hard to avoid the concept of teleology in all this.

To reflect in a provisional way theologically again, on a trinitarian account of providence, this synthesis of the elements toward the telos of life is in keeping with the constant acting of the Son and the Spirit in a noncompetitive and concurrent manner that holds up both the sovereignty of God and the distinct existence of elements that are not God, but are active in God's action. This does not require an interventionist view. It strikes me also that the evolution of the elements is not simple or facile. Labeling certain events "irreducibly complex" neglects the fact that a process by which simple elements emerge from subatomic particles is at that subatomic level already irreducibly complex. So also the formation from these elements of the more complex elements, and then so-called simple compounds, and then complex compounds like carbohydrates and proteins and ribonucleic acid (RNA), and then (deoxyribonucleic acid) DNA. Which level is to be assigned "irreducibly complex"? The electronic level, the atomic level, the molecular level, the macromolecular level? It is all complex, and though on the one hand it appears to happen on its own, a theology of providence suggests that none of it can happen without the two hands of the Trinity being at work, all the time in noncompetitive and undetectable ways.

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