The Creation Narrative of Science

by
David C. Bossard

> "Tiger got to hunt, bird got to fly;
> Man got to sit and wonder 'why, why, why?'
> Tiger got to sleep, bird got to land;
> Man got to tell himself he understand."[1]
>
> Curt Vonnegut, *Cat's Cradle*

The Creation Narrative of Science (CNS) is the current scientific consensus regarding cosmology, an elaboration of the Standard Model, on how the universe and our earth came to be as we see it today. It is relatively recent, having come together since the mid-20th Century as the result of major struggles in understanding the implications of quantum physics and general relativity, some of which invalidate prior philosophical views in science.[2]

The creation narrative concerns the beginnings, not just of the earth and of life on earth, but of the universe itself and of the elements themselves.

One of the most basic philosophical views is that every effect must have a cause. The discovery that science implies a beginning to the universe, means, philosophically, that something else must be eternal. In the past, many scientists assumed that our universe is eternal, setting up a fundamental clash with the Bible's assertion that it was created by God in the finite past, that there was a time before it existed, and that only God is eternal, the final cause.[3]

But by the 1950s it became evident that the physical universe had a beginning from which it expanded at about the speed of light from that beginning to the present, thus (to an extent) confirming the Bible's ancient assertion that there was a beginning in the finite past.

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[1] Philosophers got to philosophize; scientists (and theologians) got to explain.

[2] Prior to the early 1900s, cosmology and cosmologists were considered outside the proper domain of science. Today, cosmology is a well-established experimentally-based objective scientific discipline. The surprise is how the objective facts have demolished many "assured" results of philosophy.

[3] Aristotle (and later the Church) identified four causes. For many scientists it is preferable to take the philosophical view that the final cause is eternal (but not necessarily God). This was the view of Fred Hoyle (one of my favorites scientists) who held to Steady State Cosmology in opposition to Big Bang Cosmology until his opposition collapsed by the weight of contrary evidence. See *Big Bang of Steady State: Creation of the Elements*. Summarizing the near-universal acceptance of the Big Bang cosmology, George Gamow quipped "I am glad to say that it isn't necessary any more to pour Hoyle on the troubled waters of cosmogony." Until the mid-20th century many scientists assumed that the universe is itself eternal.

To preserve the cause-effect relationship, many scientists today take the multiverse view: that our universe came out of an indefinitely large (possibly infinite[4]) multiverse, and that there are perhaps an infinity of universes spawned in that multiverse from the present and back to the indefinite past. All of this is, of course, untestable and properly beyond the scope of science because all empirical science is trapped within our own universe. Nonetheless it is remarkable and unexpected that the age of our universe can be fixed to about 13.8 billion years.[5]

I. Creation of the physical world.

The CNS asserts the following, based on empirical investigations.

- **Physics in the universe has a particular small number of laws and physical constants that are the same throughout the universe.**[6] These laws and constants are part of the standard model.

It appears that the laws and constants must be finely-tuned to an incredible degree in any universe that can support life of any sort (not just the life that we experience).[7] This is one motivation for the multiverse idea: an infinite number of universes, each with a random selection of physical laws and constants, it is thought, will compensate for the apparent fine-tuning necessary for life to exist. Our own universe just lucked out; after all we would not be here otherwise. This is the weak form of the so-called Anthropic Principle.[8]

- **The universe itself, including space and time, had a definite beginning.**

The CNB also has an abrupt beginning on Day One. The CNS suggests that Day One applies not just to the earth, but to the whole universe and includes all of space as well. The Bible

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[4] Ironically, philosophers argue that if something physical is *finite* then it has boundaries, or possibly wraps around itself (such as the surface of a sphere—but observation of deep space does not support this view), and so the question arises: what is on the other side? It is difficult to say "nothing" so one comes back to the conclusion that *something* is infinite. This gets very abstruse and well beyond our practical interests!

[5] The current value (2017) is 13.799±0.021 billion years based on WMAP measurement of the cosmic microwave background ("The echo of the Big Bang")—a project of NASA COBE and the European Planck space missions.

[6] This conclusion is the result of extensive empirical observation. See Symmertry Magazine on the subject.

[7] For a recent book on this theme, see Geraint F. Lewis and Luke A. Barnes, *A Fortunate Universe: Life in a Finely Tuned Cosmos* (2017). We will mention or allude to some features of this fine-tuning in the following discussion.

[8] Cf. Barrow and Tipler, *The Anthropic Cosmological Principle* (1986), p.4. The book's prolog points out that many of the features of the universe that would seem to point to man's insignificance are in fact essential for life to exist at all. Thus the dismissive attacks against belief in man's uniqueness based on such observations are totally specious; they are fundamentally invalid.

definitely teaches that the universe had a beginning, but many Bible scholars did not view Day One as a reference to this beginning.[9]

In the new CNS cosmology the universe doesn't expand into existing empty space, because space itself is part of the universe and is part of the Big Bang beginning. Our own universe is all that we can investigate in science. What is beyond the universe? The Bible says that God is eternally existent and more specifically he existed before the earth was formed[10], and so clearly he exists beyond the limitations of the universe—after all, he was there before the universe began. But there is no objective way for science to say—except to speculate. Does nothingness surround the universe? Who can say? And what would nothingness look like?[11]

But we do know that the universe we occupy, began about 13.8 billion years ago (in the so-called Big Bang), and that this universe has a radius of something a bit less than 13.8 billion light years.[12]

- **All of the energy of the universe was created at the Big Bang instant.**

The physics law of energy conservation states that energy cannot be created or destroyed: it only changes its form. This is the most fundamental of the dozen or so conservation laws of physics.[13]

Note regarding the Genesis Creation Account: If Creation Day One corresponds to the Big Bang, then the light of the actual, physical Day One was not sunlight because the Sun did not yet exist! It was pure light energy vastly brighter and much more intense than anything that would ever exist on the Sun and Earth. This is very interesting, because it resolves a puzzle that existed for Bible scholars for well over 3,000 years: what was the light of Day One?[14]

- **No matter existed at the very beginning—only light-energy.**[15]

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[9] An example is the footnotes on Genesis 1 in the Scofield Reference Bible, which lists a number of possible views, none of which take Day One as the beginning of the universe. I do not know of a single prominent Bible scholar who has or had the view that Day One is the beginning of the *universe* of space and time.

[10] References: Ps. 90:2, Eph. 1:4, John 17:24, Titus 1:2

[11] The Hindu *Rig Veda* creation myth, "*Nasadiya Sukta*", hints, rather elliptically, at this nothingness, and yet hedges by implying that (perhaps) there is something there. Genesis 1:2 also hints at this, as St. Augustine observed. See remarks on Genesis 1:2 in the CNB.

[12] The gravitational pull of the mass of the whole universe retards the expansion somewhat.

[13] Moskowitz, *Scientific American*, Aug. 5, 2014, *Fact or Fiction?: Energy Can Neither Be Created Nor Destroyed*? (Author's answer: fact!)

[14] See the Creation Narrative of the Bible (CNB).

[15] More precisely, masses could form momentarily but then they immediately returned to light energy because at these high temperatures there was a perfect symmetry of formation and dissolution between mass and light-energy. See Leon M. Lederman and Christopher T. Hill, *Symmetry and the Beautiful Universe*, (2004). Mass could not exist for any length of time until the temperature of the universe dropped sufficiently to break the symmetry of formation/dissolution. That happened at about 1 second after the Big Bang, when primordial

It was the inverse of what St. Peter said about the cataclysmic end of the world: "The elements shall melt with fervent heat, the earth also ... shall be burned up."[16]. The temperature at the very beginning of the universe was so high that no matter could hold together—no physical force could bind it—so everything was radiation: that is, light.

As the universe expanded and cooled in the first few minutes, the primordial elements formed—the nuclei of hydrogen and helium. These would eventually fuse in star interiors to form the other elements. Essentially all of the fuel that fires the stars in the entire universe formed in the first few minutes after the Big Bang, primarily hydrogen and helium.[17]

- **The early universe had no darkness: that came about when proper atoms could form about 380 thousand years after the Big Bang.[18]**

- **The Milky Way galaxy formed about a billion years after the Big Bang.**

And much later—8 billion years later—the sun would form and light up after several generations of star formation and dissolution in supernovas.

- **The earth began as a molten body which cooled to be covered with a global ocean.**

CNS asserts that the solar system condensed out of a vast cloud of debris, the product of supernova explosions of earlier stars. The sun and planets formed, pummeled with this debris that surrounded the sun. The primitive earth melted (perhaps several times) under the impact of this bombardment, and after the debris surrounding the sun finally clarified, the earth cooled from its molten state and formed a fairly smooth crust under a global ocean.[19]

- **Gradually the continents formed to make dry land.**

Hydrogen and Helium formed. There is a great mystery in this: what happened to the antimatter—because matter and antimatter should form in equal amounts? See Cern's article on antimatter: "One of the greatest challenges in physics is to figure out what happened to the antimatter, or why we see an asymmetry between matter and antimatter... Some unknown entity [!dcb] intervening in this process in the early universe could have caused these "oscillating" particles to decay as matter more often than they decayed as antimatter."

[16] II Pet. 3:10.

[17] Several very readable books discuss this brief period of time after the Big Bang. See Steven Weinberg, *The First Three Minutes: A Modern View of the origin of the Universe* (1993) and Martin Rees, *Just Six Numbers: The Deep Forces that Shape the Universe* (2001).

[18] See graphic *History of the Universe* (2014)

[19] The source of the water remains in dispute. Since many icy comets exist today, some speculate that bombardment by icy comets provided water for the global oceans, rather than out-gassing from the planet itself.

The details of this process were generally accepted by science only since the mid-20th century.[20]

- **Immaterial shields built up to surround the earth and divide inner space around the earth from outer space.**

These shields are essential to protect the earth's atmosphere and dry land from life-destroying lethal particles and rays. Apart from these shields, life was possible only in water, which shielded it from this bombardment. Life could not survive in the open air and on dry land.

This describes the material world, and sets the stage for the beginnings of life.

[20] See Brief History of the plate tectonics theory.

Ia. Before the Beginning.

But what is outside of our universe? This is an interesting question, but there is no scientific way to describe the nature of space (let us call it) before the beginning, or what exists (if anything) beyond the universe.

Empirical science cannot say with any authority what occurs outside of our universe, because the observable universe is necessarily within the universe. One possible answer is "nothing" but it is hard to describe such a situation. Presumably the temperature would be 0° Kelvin—a temperature that can be approached but never reached within the universe.

However, the overwhelming evidence of fine-tuning in the universe leads to the idea that our universe is just one of an infinity of universes (called a multiverse) in each of which the laws and constants of physics vary. In this case, our own universe enjoys a selection that is "just right." There appears to be no way to prove that we live in a multiverse.[21] In particular, there is no physical explanation of how random laws and constants could be generated in a multiverse. Such a question is beyond the reach of empirical science.

II. Preparation for biological life.

Just as the physical world requires the laws and physical constants, so the earth had to be prepared to host biological life, and ultimately the advanced, multi-cellular nature of visible life—plants, animals and (of course) humans.[22]

First, there are some physical constraints imposed on any (potentially) habitable planet:

- **The Solar System must be placed in a "quiet" place in the Milky Way galaxy.**

This is one matter discussed in *Fortunate Universe* (*op. cit.*): for one thing, the Solar System should be placed near the galaxy's *co-rotation radius*. At this radius, the Sun will not pass through the dense arms of the galaxy as it orbits the Milky Way's center. There are other requirements discussed, for example in Hugh Ross's *Reasons to Believe* website.

- **The earth must be within the habitable zone of the Sun, and it must stay in that zone for the length of time needed to create a habitat suitable for all living species from the simplest to the most complex (humans).**

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[21] See P.C.W. Davies, *The Goldiocks Enigma: Why Is the Universe Just Right for Life?* (2008). See also Lewis & Barnes, *op. cit.* and the Wikipedia article on a fine-tuned Universe.

[22] Multi-celled species of life required many remarkable innovations, involving inter-cellular signaling and other detailed, technical accomplishments. For an example of very primitive multi-cellular behavior of *single-celled* life, see life cycle of slime molds.

The habitable zone is defined as the zone in which the sun heats up the planet to have liquid water on its surface. This zone is roughly between Saturn and Mars.

One problem with the habitable zone is that its proximity to the Sun causes it to be subject to a high flux of lethal solar rays and particles[23] ejected from the Sun. This requires the erection of shields around the earth to protect life on its surface and in the air.

From the geological record, it is evident that earth must remain within this habitable zone continuously for several billion years.[24] This implies an extremely stable orbit for the earth, well beyond the current capability of physical science to predict for any planetary system consisting of several major planets.[25]

The time is largely dictated by the lengthy time needed for primitive forms of life to prepare food for advanced species which cannot prepare such food for themselves.[26] This preparation

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[23] Called Coronal Mass Ejection (CME) and lethal to life.

[24] This is not just an observation of fact, it is a necessity, as discussed in CNOB and notes below.

[25] The difficulty is the "Many-body problem". Systems of more than two objects (such as the sun and multiple orbiting planets) are inherently unstable, because minor influences—even the small errors in measurements of the physical constants—can cause unpredictable long-term effects, popularly called the "butterfly effect". Isaac Newton noted this stability problem and concluded that God had to "tweak" the orbits from time to time. See Scott Tremaine, *Is the Solar System Stable?*, Princeton Institute for Advanced Study (2011), "The stability of the solar system is one of the oldest problems in theoretical physics, dating back to Isaac Newton...The puzzle posed by Newton is whether the net effect of these periodic forces on the planetary orbits averages to zero over long times, so that the planets continue to follow orbits similar to the ones they have today, or whether these small mutual interactions gradually degrade the regular arrangement of the orbits in the solar system." Tremaine includes a quotation about this from Newton's treatise *Principia Mathematica*, "The Planets move one and the same way in Orbs concentrick, some inconsiderable Irregularities excepted, which may have arisen from the mutual Actions of Comets and Planets upon one another, and which will be apt to increase, till this System wants a Reformation." Tremaine continues, "Evidently Newton believed that the solar system was unstable, and that occasional divine intervention was required to restore the well-spaced, nearly circular planetary orbits that we observe today." ¶A century later the mathematician LaPlace claimed to prove the stability of the earth's orbit, in his famous (and erroneous) remark "I have no need for that hypothesis," referring to the necessity for God's stabilizing the earth's orbit. However LaPlace was in error, as is acknowledged by later mathematicians. Modern computations cannot predict stability of the earth's orbit beyond about 100 million years, much less than the required billions of years, resulting from the roundoff errors in the measurement of the physical parameters.

[26] Note that this need for billions of years is aside from the supposed need for natural evolution to occur. The fossil record implies that new advances in life appear as soon as the conditions of the environment are able to support them. In my view the concept of natural evolution only confuses the issue because there doesn't appear to be enough time for major random changes to take place—from the nearly instantaneous first evidence of life as soon as the earth cooled, through to the explosion of body plans in the "Cambrian explosion" and on to the present day. Several scientists have remarked on this failure to find plausible mechanisms for evolution on such a vast scale. See, for example, Michael Denton, *Evolution: A Theory in Crisis* (1986); *Evolution: Still a Theory in Crisis* (2016); *Nature's Destiny: How the Laws of Biology Reveal Purpose in the Universe* (1998); and Michael Behe,, *In Search for the Limits of Darwinism* (2007).

time appears to be on the scale of billions of years, and is the driving factor behind the need for the Earth's orbital stability for such a long period of time.[27]

• **The earth must maintain an ambient surface temperature that allows biological processes to proceed.** This temperature, particularly for advanced species, is roughly bounded by freezing (0°C) to the lower limits of pasteurization (60°C). The fossil record indicates that the earth cooled from a molten state to this temperature range around 3.9 billion years ago. No life on earth, of any conceivable form, was possible earlier than this.[28]

• **Advanced life[29] requires the preparation of nutrients available worldwide that include (at minimum) fixed Carbon and Fixed Nitrogen.**

These nutrients are actually the waste products of past living and dead bacterial[30] species. The fossil record indicates that this preparation took billions of years (and of course is still ongoing). There are reasons to believe that this is a minimal preparation time. On earth the Phanerozoic era (the era of visible plants and animals) began about 600 million years ago, after over 3 billion years of build-up of these nutrients.

The difficulty here, and the reason for the large amount of time to prepare the habitat is that the preparation of useable forms of carbon and nitrogen require the work of exceedingly complex enzymes (RuBisCO and Nitrogenase). In each case, only one way is known to do this work at ambient temperature and pressure.

Nitrogen-fixing is particularly problematic: it takes large amounts of energy and a carefully-controlled environment. It requires over a second to convert a single molecule of nitrogen gas to ammonia.[31] No plant or animal can fix nitrogen: the assistance of specialized bacteria is

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[27] Frequent announcements of potentially "habitable" planets orbiting nearby stars should be tempered by the fact that it is not possible at present to predict the long-term stability of such planets. This is not because of a need for evolution to do its random work—the universe is too young for the needed complex random results to come about. It is needed to build up the nutrients to support plants and animals.

[28] For this reason, some scientists suggest that life came to the Earth from space. See, for example, Fred Hoyle, *Evolution From Space* (1984). But this does not answer the issues, it just moves them to a different portion of space.

[29] The term "advanced life" usually means multi-cellular life, visible to the unaided eye. All such life is eukaryotic (cells that include a nucleus and many other structural features). The first eukaryotes appear in the fossil record around 2 billion years ago. See Meinesz, *Three Geneses* cited below.

[30] Bacteria and eukaryotes are the two main divisions of living species, eukaryotes being vastly more complex than bacterial. Evidence for bacterial life goes back to 3.9 billion years ago. Eukaryotes appear in the fossil record around 1.9 billion years ago, after the earth has developed an oxygen atmosphere and the earth had sufficient food in place to support these advanced forms.

[31] See David W. Wolfe, *Tales from the Underground* (2001) and G. J. Leigh, *The World's Greatest Fix* (2004). Wolfe, p. 78, ""The entire world's supply of nitrogenase could fit into a single large beaker or bucket! Lose this and life on Earth as we know it would come to a screeching halt."

essential to carry it out. This is a primary reason why billions of years of preparation were needed before the earth could host advanced plants and animals.

• Earth's oxygen atmosphere is almost entirely a byproduct of photosynthesis.

It took almost 2 billion years for the Earth to develop a stable oxygen-based atmosphere that was built, slowly, from photosynthetic cyanobacteria. All animal species are dependent on an oxygen-based atmosphere.[32]

All of this preparation was needed in order for the Earth to host advanced life.

III. Life Itself.

The CNS does not explain how life began, but it shows its presence and progression in the geological record from very early times. This records when life began on earth, and how it developed over time. It is entirely due to the remarkable details contained in the geological formations and fossils that this record is available.[33]

A. General Features of Life.

The general features of life are remarkably open to careful scientific query.

• Life is cellular. All forms of life are cellular; that is, the bodily form involves a cell wall that provides a protective shield surrounding a controlled interior environment in which the various activities of living cells take place.

Bacteria perform all of the cellular functions in a single undifferentiated cell interior; there is no separate microclimate set aside and partitioned off to facilitate certain functions.

Eukaryotes, on the other hand isolate many of the cell's actions in controlled microclimates, the organelles, enclosed in the cell, and each with its own specialized function, microclimate, and a wall with controlled-access portals. The organelles are connected with a microskeleton that provides structure and a transportation network between the organelles and the cell wall. The transport itself involves some remarkable motor molecules.

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[32] Marine animals require dissolved oxygen in the upper ocean layers which comes from the oxygen atmosphere. The organic food in the floor and lower parts of the ocean "rain down" from the upper levels.

[33] This is the theme of 19thpsalm.org. The geologic/fossil record is part of the "silent voice" of Psalm 19:3-4 that declares God's handiwork and glory.

• **Life is digital.** The metabolism[34] of every life species, however simple or complex, uses the same digital schema, and the same digital language, to define, build and execute its activities. This universal schema is called the Central Dogma[35], and includes the following components:

- All cellular functions are determined by genes (digital instructions) arranged in the specie's DNA. A gene is a chain of instructions which dictate the design of a particular protein to carry out that gene's intended functions. The instructions in the gene are arranged as rungs of a ladder in a double spiral helix. Each rung is one of four nucleotides, generally designated G (Guanine), C (Cytosine), A (Adenine) and T (Thymine). Each species of life has its own unique set of genes, but all of the genes of all species use this same coding method in the DNA.[36] [37]

- Each triplet of nucleotides in the gene's DNA chain defines a particular amino acid in a unique protein that carries out the gene's action, or marks the gene's beginning or end. The genes code for 20 amino acids, the building-blocks of the proteins. The same[38] triplet coding scheme is used to define all genes and proteins for all living species, however simple or complex.

- The gene's digital instructions define proteins which are chains of amino acids (20 varieties). The specific sequence of the amino acids determines the shape and function of the particular protein. The gene itself is a chain of nucleotides, four in number, arranged as rungs of a ladder in a spiral helix.

- The way decoding of a gene occurs is this: A "reader" molecule goes along the gene, copying the code into a "messenger RNA" (mRNA) molecule. When the copying is done, the mRNA uses a *ribosome* (a complex molecular machine) to form an amino acid chain by associating coding triples with a tRNA molecule that carries the needed amino acid on its tail. The amino acid is detached from the tRNA by the ribosome and then used to form an amino acid chain which defines a particular protein.

This coding/decoding scheme is the Central Dogma. It is essentially the same across all species from the simplest to most complex. It includes many contingencies[39], which virtually all

[34] Metabolism is the chemical processes that go on in a living species of life to carry out all of the needed activities to maintain life.
[35] The term technically refers to only part of the universal schema, but here the term is applies to the whole schema, including all aspects that are listed here.
[36] RNA is a variation, in which T is replaced by U (Uracil). The overall coding scheme is the same.
[37] Four nucleotides in triplets allow for 4x4x4 = 64 possible combinations, which is more than sufficient for defining 20 amino acids. There is some duplication.
[38] Technical point: throughout this discussion, the "same" allows for a few variations that occur in certain species. I believe there are a few other amino acids that occur rarely.
[39] That is, features that appear to be arbitrarily chosen, in that other random selections would appear to work just as well, but are not found in nature.

scientists take to mean that the dogma was defined only once in the entire history of life on earth. All life forms carry this genetic information within a regulatory apparatus that is itself determined by these same genes. If that sounds a bit circular, well ... it is.

• **Cells come in two varieties:**

- Prokaryote or bacterial cells. Prokaryotes have no elaborate internal structure, and rely largely on diffusion to distribute nutrients throughout the cell. This limits the prokaryote to only three basic balloon-like shapes (spherical, rod-shaped or spiral), determined by internal osmotic pressure, without specific structural framework. The prokaryotes are necessarily small (generally under 50 microns) because of the dependence on diffusion for internal transfer.

Bacterial cells have a kind of microstructure and signaling methodology that is still under extensive investigation. It has been suggested that the "simple" structure compared with Eukaryotes, is in fact much more elaborate than appears at present.[40]

- Eukaryote or "proper" cells. Generally eukaryotes are recognized by the presence of a nucleus, but this is only one of many differences. A eukaryote has internal structure, the cytoskeleton, and can take on a broad range of shapes and sizes, some visible to the naked eye.

All eukaryotes require oxygen for metabolism. Plants (eukaryotes that conduct photosynthesis) require CO_2 but the previously "waste" oxygen of photosynthesis is used as part of the plant metabolism. This is why eukaryotes, especially animals, had to wait for oxygen in the atmosphere to build up.

• **Life is exceedingly complex.**

In 1998 there was a colloquium of the National Academy of Sciences that tried to define the features of the simplest possible living cell—of any sort, not just the kind found on earth. The conclusion was that the simplest possible cell is exceedingly complex.[41]

It's fair to ask, "How can something like the central dogma be 'established' before a single living cell exists?" I can't answer that for a secular interpretation of CNS, but for

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[40] See, for example, Ronald D. Vale, *The Molecular Motor Toolbox* (2003), "While the existence of a bacterial cytoskeleton is now beyond dispute, the manner in which these filaments perform their duties remains unclear." However, "In eukaryotes, the cytoskeleton assumed many new roles in addition to cell shape determination and DNA segregation." [emphases added.]

[41] Space Studies Board, National Research Council, *Size Limits of Very Small Microorganisms,* Proceedings of a Workshop of the National Academy of Sciences (1999) (available as a PDF download).

CNB it is easy: God did it. That's not a cop out, because scientists are invited, even encouraged to answer the question—and many have attempted, resulting in many interesting insights, but no fundamental success in answering the basic question—so far!

B. The Geological timeline for Life. A brief synopsis of how life developed on earth is the following. As is true of all conclusions of science, this synopsis is always subject to change, and you may of course quibble about some details, but I believe this is a very likely sequence laid out in the geological records. Subject of course to further discoveries and developments in geology and in science in general. We'll say something about each step.

• Life began on Earth almost as soon as the temperature cooled to habitable temperature.

• Bacteria were the first living cells.

Their primary task was to prepare the earth for eukaryotes, a task that required over 2 billion years. The geological record shows that the first living species were bacteria, or bacteria-like. Their basic task in life was to reproduce themselves and die. You might think this is a pointless objective for life, but it is not, because the carcasses of these early cells provide food for more advanced cells in the form of molecules that contain fixed carbon, nitrogen and other nutrients.

The first bacteria were able to utilize inorganic food as well as recycle the wastes of other bacteria. Over time this led to many specialized forms of bacteria.

- The first bacteria were cyanobacteria-like and used photosynthesis to energize the cellular processes. Photosynthesis is a very complex process, yet it appears to have been used by the earliest living cells.

Life's most urgent task on the early earth was to fix carbon and nitrogen to build the molecules that carry out the cell's tasks. Carbon must be released from its natural oxidized state, CO_2, and made part of a simple sugar; nitrogen must be converted from its natural binary state, the nitrogen gas N_2 (di-nitrogen), to form nitrates or other single-N molecules. Once "fixed", then C and N can go on to participate in the many molecular chains that carry out the cellular functions. All of the genetic molecules include fixed nitrogen, so it is needed by the millions in even the simplest living cell.

These early bacteria had many inventions, including

- the universal energy-storage battery molecules ATP and ADP. These molecules occur only within living cells. They are not formed naturally outside the cell.

- carbon fixing with RuBisCO, a complex molecule used as part of sugar production in photosynthesis.
- Sugar making for storage of sugars
- Nitrogen-fixing with nitrogenase, requiring specialized cells to isolate the process from the oxygen wastes of photosynthesis
- Oxygen production as a waste product of photosynthesis.

• The waste products (oxygen for the atmosphere and food for future species) were distributed worldwide throughout the global ocean.

A waste product of carbon fixing is oxygen, produced when oxygen is stripped off from the C atom. This will be essential later in the metabolism of more advanced cells. But for these early cells it is an unwanted waste product.

And of course these conversions must occur under natural ambient conditions of temperature and pressure. That's the catch. At present, there appears to be only one natural way known to science, to fix carbon (the RuBisCO molecule) and one way to fix nitrogen (Nitrogenase) under normal ambient conditions. These molecules are exceedingly complex, and—one would think—very unlikely to come together by chance. And the exact way that they work is still not completely known, a matter of active research.

Nitrogen-fixing is particularly hard to do because of the energy needed to split apart the nitrogen gas molecule. Perhaps because of that the production rate is very slow: it takes about 1.2 seconds to fix each N atom.

The nitrogenase molecule that does this is also poisoned by oxygen, so its operation requires special cells that have to be elaborately isolated to concentrate on that one task. These specialized cells have to get their food from other nearby cells because they can't make it themselves.

• After about 2 billion years, atmospheric oxygen built up to a steady abundance of about 25%.

• At this point (after 2 billion years) eukaryotes appeared.

All in all, the eukaryote is a vast jump from the bacterial cell[42]. I won't say that a eukaryote is to a bacterium as a bacterium is to a rock, but that's not far off. The eukaryote is so complex compared to bacteria that it almost (not quite!) amounts to a new creation of life. Not quite,

[42] In the excellent book, Alexandre Meinesz, *How Life Began: Evolution's Three Geneses*, he calls the formation of eukaryotes "the second genesis" (p 92, 203).

because many of the individual activities that make up the eukaryotic cell can be found in certain bacteria. The central dogma is the same, just a bit more elaborate.

Along with the increased capability of eukaryotic cells come some limitations. For example, neither plants nor animals can fix nitrogen and animals require oxygen for respiration. These must be available in their habitat. Unlike the simple cells which appear as soon as the earth had cooled enough that they could survive the heat, the geological record shows a 2 billion year gap between the first simple life and the first advanced cells. During this time, the simple cells were busy preparing the earth with food (their own dead bodies!) and atmospheric oxygen, both of which must be in place before advanced cells can thrive. The food consisted of fixed carbon, fixed nitrogen and atmospheric oxygen. Other nutrients of course, but principally these.

Eukaryotes are much more complex than bacteria, and have the structure to form multi-cellular species of plants and animals. On the other hand, eukaryotes cannot live on inorganic food. They breathe oxygen and feed on the organic wastes of bacteria and other eukaryotes.

One outstanding feature of the eukaryotes is that they incorporate organelles which are specialized to carry out many cellular functions. They also have a cytoskeleton to provide structure to the cell and use that cytoskeleton to transport food and wastes between the organelles and the cell wall.

This transport involves specially designed motor molecules (kinesin, for example)[43]

The cell functions require hundreds of specialized molecules, structures and enzymes, all of which are specified in the cell's genetic code. Special genes and coding also control reproduction, by a variety of mechanisms including, in some species, the invention of sexual reproduction.

- **After another billion years, the eukaryotes formed multi-celled species.**

This occurred in the "Cambrian explosion" and the nearby geologic layers, around 540 Million years ago. The Cambrian explosion occurred in an ocean environment. Virtually all of the modern body plans (phyla) of animal life appear in the fossil record during the Cambrian age. Plant phyla first appear during the various geologic strata after moving to dry land in the late Silurian/Devonian age, culminating in the angiosperms which first appear in the Cretaceous age about 125 million years ago.

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[43] There are a number of cartoon animations that show how this transport works. See for example YouTube videos on the kinesin and dynein molecule. See in particular the series by Dr. Ronald D. Vale on molecular motor molecules available on Youtube.com.

Life could multiply in the ocean because the ocean water can protect marine species from the damaging rays coming from the sun and outer space. Meanwhile tectonic plate movement caused dry land to emerge from the oceans, forming the future continents.

- **About 400 million years ago, the ozone shield and other shields that separate inner from outer space built up so that life could live in the air and on dry land.**

Flying insects, and some land animals (amphibians and reptiles) utilized the land. Gradually these plants and animals proliferated and the familiar land plants and animals appear in the fossil record.

- **Humans appear in the record as the most advanced life, just a geological instant ago (30-50,000 years).**

Last but not least came the humans. Again with a marked advance over all other animals. They are correctly called the crown of creation (and some other things too).

This is how life began and flourished. The story is mostly told in the geological and fossil record.