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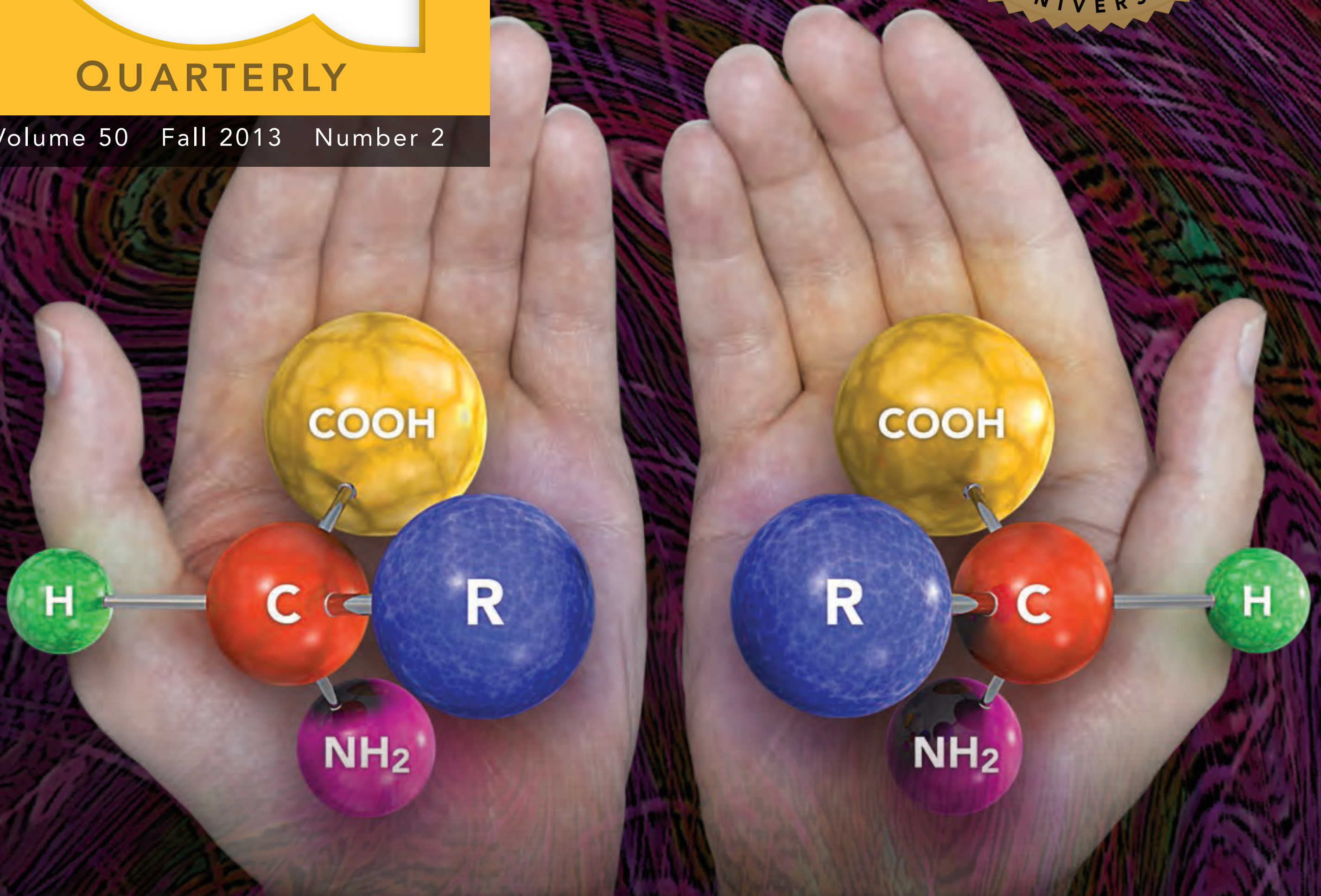

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Haec Credimus

For in six days the Lord made heaven and earth, the sea, and all that in them is, and rested on the seventh.—Exodus 20:11

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The Asteroid Belt—A Computer Simulation

R. F. Mathis*

Abstract

This initial study uses computer simulation to explore the possibility that the asteroid belt observed today resulted from the breakup of a dwarf planet a few thousand years ago. It is assumed that a catastrophic event occurred, and a computer model of the resulting fragmented dwarf planet is developed. The simulation has two parts. First a model of a planet collision is used to provide a starting point. The output file contains the position, velocity, and size of each of more than 16,000 fragments representing an exploded dwarf planet. In the second part of the simulation, each of the fragments is tracked as it propagates under the gravitational influence of the other fragments, the Sun and the planet Jupiter. In this initial study, collisions are not included. The simulation is run out to 15.75 orbit periods of the original dwarf planet or nearly 82 years in 120-second steps. It is shown that a surprising uniformity of the fragments forms around the entire orbit in this short period of time.

Introduction

A current naturalistic explanation for the origin of asteroids claims that asteroids are the debris that did not coalesce into a planet when the solar system was forming about 4.5 billion years ago (4.5 Ga). Modern asteroids are believed to be the result of gravitational accretion, collisions, and the gravitational effects of the planets on the field of debris. This general model forms the basis for most current asteroid studies.

It is interesting that some believe catastrophic collisions are no longer occurring. In a paper by Bottke et al. (2005, p. 111), we read, "Planet formation models suggest the primordial main belt experienced a short but intense period of collisional evolution shortly after the formation of planetary embryos." They go on to describe the main asteroid belt as a "living relic." Of course they are comparing the term "short period" with 4.5 Ga, but this immediately points to the admission that the time to form the asteroid belt is much shorter than its alleged age.

The purpose of this study is to use a computer simulation to explore the possibility that the asteroid belt resulted from the breakup of a planet a few thousand years ago. A natural result of this study ultimately is to gain some insight into the statistics of collisions of the fragments with the planets includ-

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ing the Earth and the Earth's moon. Since the starting planet in this simulation is smaller than the moon, it will be referred to as a dwarf planet.

Typically, the first question that comes up when discussing this topic is, "What caused the breakup?" The possibilities seem to be either a collision or an explosion. For example, could heating due to accelerated nuclear decay have caused a pressure buildup that resulted in an explosion? For planets that are similar to Earth, the answer is apparently no (Baumgardner, 2012, personal communication). The structure of the Earth is such that there would be no internal buildup of pressure that could lead to an explosion. However, we could postulate that this planet was uniquely created in such a way that it would explode with an unusual internal buildup of heat; of course this is pure speculation. It is not the purpose of this paper to explore the cause of the planet's breakup. Rather the purpose is to determine whether such a breakup that occurred a few thousand years ago could result in the asteroid belt we observe today. The analysis will proceed under the assumption that a catastrophic event, probably a collision, occurred.

The simulation consists of two parts. First, a model of a planet collision is used to provide a starting point. The output is a file containing the position, velocity, and size of each of more than 16,000 fragments. In the second part of the simulation, each of the fragments is tracked as it propagates under the gravitational influence of the other fragments, the Sun and the planet Jupiter. In principle, the state of the fragments can be stored and analyzed at any subsequent time.

In this initial study, collisions are not included but will be added in subsequent studies. The ability to track more than 16,000 individual fragments is enabled by the use of an NVIDIA GPU (graphics processing unit) using the CUDA platform.

Dwarf Planet Model

The first part of this study is to simulate a dwarf planet that has already broken up with the fragments separated far enough that any remaining collisions can be ignored. We lean heavily on the results of a recent paper by Jutzi, Michel, Benz, and Richardson (Jutzi et al., 2009). This paper describes a numerical simulation of asteroid breakups resulting from collisions. Although their focus is on comparing the results of porous and nonporous target materials, the simulation results and methods are useful here. The Jutzi model includes both the fragmentation of the parent body and the gravitational interactions between the fragments. The fragment size distributions they obtained agree well with observed and computed asteroid size distributions. Since they focused on smaller target objects, up to 200 km diameter, it is necessary to extrapolate their results to larger objects for use here (up to 1000 km diameter).

A common quantity used to compare different collision models is the catastrophic disruption threshold Q^*_D defined as the specific impact energy leading to a largest fragment containing 50% of the original target's mass (e.g., Jutzi et al., 2009, p. 55). The specific impact energy is defined as $Q = 0.5 m_p v_p^2 / M_t$ where m_p and v_p are the projectile mass and velocity respectively and M_t is the target mass. This provides a useful point of reference when considering energy, velocity, and mass distributions.

Initial Dwarf Planet Size

The simulation results to date suggest the possibility of a much smaller initial size than might be expected: smaller than the Moon. Hence, it is referred to as a dwarf planet. There are several issues that bear on this, such as the current volume of the asteroids and the current size distribution of the asteroids. It also turns out that an estimate of the number of asteroid collisions with Earth and Earth's moon ultimately should provide insight into the size of the dwarf planet and the dynamics of the breakup. Subsequent studies are expected to address this issue in more detail.

If the initial dwarf planet was much larger, several issues emerge. First, the event must be energetic enough to produce the fragment sizes observed today. If a large number of larger fragments were produced, then many secondary collisions between large fragments would be required. A preliminary look at collision statistics indicates that collisions certainly will occur. However, most collisions will include at least one of the numerous smaller fragments. As the fragment size increases, there are significantly fewer of them and the collision probabilities decrease accordingly. Another issue is that as the volume of material increases, it ultimately must end up as a greater volume of smaller fragments. The number and size of the observed larger fragments is fixed. More initial material can only go into a greater volume of ever-smaller pieces.

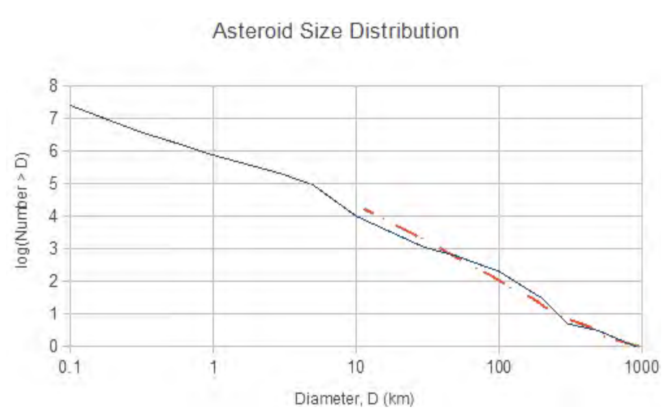


Figure 1. Comparison of simulated asteroid size distribution (dashed line) with published data.

Another issue is the large volume of material from a larger planet. It seems unlikely that a significant fraction of the collision fragments will escape the Sun, or fall into the Sun, even in a much larger, more energetic event. The escape velocity from the Sun at a distance of 3 AU is 24.4 km/s. At 3 AU the dwarf planet is moving at 17.2 km/s and the average fragment velocity is near 3 km/s. The speed distribution is broad enough that some fragments will escape and some will fall into the Sun. However, the smaller fragments tend to have the faster speeds, so the total mass escaping through these means would be relatively small. The average speed increases with dwarf planet size because of the much larger energy required, but this does not appear to be a means for getting rid of a large volume of material.

One interesting possibility for scaling the initial dwarf planet size is that the estimates of numbers of collisions of asteroids with the Earth and the Moon may provide a hook. A particular number density of fragments (fragments per unit volume) intersecting Earth's orbit is directly related to the initial size of the dwarf planet and to the energy of the catastrophic event. In other words the larger the initial dwarf planet, the more fragments will intersect the Earth and Moon.

A lower limit to the size of the original dwarf planet can be obtained using the total mass and average density estimates of the asteroids. In an Asteroid Fact Sheet, NASA estimates the total mass of all of the asteroids as 2.3×10^{21} kg (http://nssdc.gsfc.nasa.gov/planetary/factsheet/asteroidfact.html). There are several references that report asteroid mass estimates. One example is labeled "Recent Asteroid Mass Determinations maintained by Jim Baer last updated 12 December 2010." The most recent value for the mass of Ceres is 9.46×10^{20} kg, which differs from NASA's value of 8.7×10^{20} kg. The values given are accompanied by references. In another paper by Krasinsky et al. (2002), it is claimed that estimates prior to that time were too low. Their estimate for the total mass of all the asteroids is 18×10^{-10} $M_{\odot} \approx 3.6 \times 10^{21}$ kg, which is substantially larger than NASA's value of 2.3×10^{21} kg. Other published values differing from these can be found.

The density of the asteroids varies by the type of material in the asteroid, such as porous, nonporous, rocky core, metallic core, etc. The density used here is 2.1 g/cm^3, which is the average density of Ceres, the largest asteroid. The mass of Ceres, published by NASA is 8.7×10^{20} kg, which is greater than one-third the estimated mass of all the asteroids combined. Therefore, the density of Ceres was used to approximate the density of all the asteroids. This approximation seems reasonable for a starting point. If necessary it can be refined in future simulations. With these values, the estimated diameter of a dwarf planet comprised of all the known asteroids is 1279 km, or less than 40% the diameter of the Moon (≈3476 km). This sets a lower limit to the initial diameter.

Methods

Simulation Fragments

The simulated dwarf planet is assembled using a Monte Carlo approach with a given fragment-size distribution. The resulting equivalent dwarf planet size depends on the number and size of the fragments generated.

The simulation proceeds, first, by assigning a randomly selected radius to each of over 16,000 fragments. There is considerable spread in the published asteroid-size distribution data, but there is a general trend that seems to be common. The data used here (shown in Figure 1) are taken from a paper by Davis et al. (2002). Note that there is a break in the average slope near D = 5 km. The average slope for D > 5km is approximately -2.2, while the slope for D < 5km is approximately -1.4. There is a large range in published distributions, and not all of them include this break in the curve. In their collision simulation, Jutzi et al. (2009) obtained a slope of -2.24 for nonporous material and -2.21 for porous material. This is consistent with asteroid formation resulting from collisions.

The simulation includes more than 16,000 fragments. This number with the given distribution restricts the fragment sizes to be greater than 10 km diameter. The dashed curve in Figure 1 shows the final distribution of the fragment sizes used in the simulation. The slope is approximately -2.2. The largest twelve fragments were not selected randomly but instead correspond to the diameters of the published values of the twelve largest asteroids.

The number 16,000 might seem to be too small a number to provide a realistic simulation since Figure 1 indicates that there are tens of millions of asteroids larger than 100 m diameter. Furthermore, extrapolations to even smaller fragments show even larger numbers. However, most of the mass is in the larger asteroids. Estimates depend on assumptions about the distribution, but within this simulation an extrapolation to much larger numbers showed that more than 90% of the total mass is included in the 16,000 largest fragments. This should be treated only as an indication because of the large variations in distribution estimates. However, it points to this being a reasonable starting point for the simulation. The simulated fragments with the above assumptions can be added to get an initial dwarf planet size. This turns out to be 1288 km, which does not include the large number of smaller fragments that would be present in an actual catastrophic event.

Exploded Dwarf Planet Formation. After determining the fragment sizes, the positions of the fragments are uniformly distributed in a unit radius spherical volume. Then each fragment, beginning with the second largest and working to the smallest, is moved radially outward until it is at least a minimum distance from all other fragments. Finally a velocity is assigned to each fragment. The fragments are modeled as spheres to simplify the code.

The speed distribution of the fragments (Figure 2) is virtually ad hoc with some guidance from papers by Jutzi et al. (2009) and Zappalà et al. (2002). Jutzi et al. (2009) point out that the average, median, and largest ejection speeds scale with target size. They also point out that "smaller fragments tend to have greater ejection speeds than larger ones. However, there is still a wide spread of values for fragments of a given mass, which makes it difficult to define a power-law relationship between fragment masses and speeds" (Jutzi et al., 2009, p. 61). Another constraint in the context of "family-forming events" is discussed by Zappalà et al. (2002). There is a general fit to a model that assumes the maximum kinetic energy is a constant. This results in a power-law trend for the maximum fragment speed as a function of size.

The starting point for determining fragment speeds was an estimate of the size of the original dwarf planet. Then an average speed was obtained by extrapolating the results in Figure 10 of Jutzi et al. (2009). Starting with a modified Rayleigh distribution and adding the maximum speed power-law constraint while maintaining the desired average speed resulted in the distribution shown in Figure 2. The initial direction of each fragment is radially outward from the center of the dwarf planet in the dwarf planet's reference frame.

Energy considerations can be used for an approximate consistency check. Extrapolating the results of Jutzi et al. (2009) for a nonporous dwarf planet with an impact speed and angle of 3 km/sec and 45° respectively, the value of Q^*_D is approximately 2.4×10^{10} erg/gm. Compared with the simulation results, the total fragment energy in the simulation is less than 10% of the initial projectile energy. These numbers are very approximate but provide a consistency check.

Figure 3 shows the exploded dwarf planet used as the starting point for the simulation. The randomly assigned colors help to visualize the fragments. Table 1 summarizes the initial parameters.

Fragment Tracking

The second part of the simulation, in which each fragment is tracked in time and space, requires solving the N-Body problem: the problem of predicting the motion of a group of objects that are connected gravitationally. The problem has no closed analytical solution. Here we use a simulation described as an All-Pairs N-Body Simulation. It generally follows the methods described by Nyland et al. (2007). This approach is brute force and relatively simple but is not generally used because of its $O(N^2)$ computational complexity. The use of a GPU with its massively parallel structure is well matched to this problem and provides substantial acceleration in computing speed.

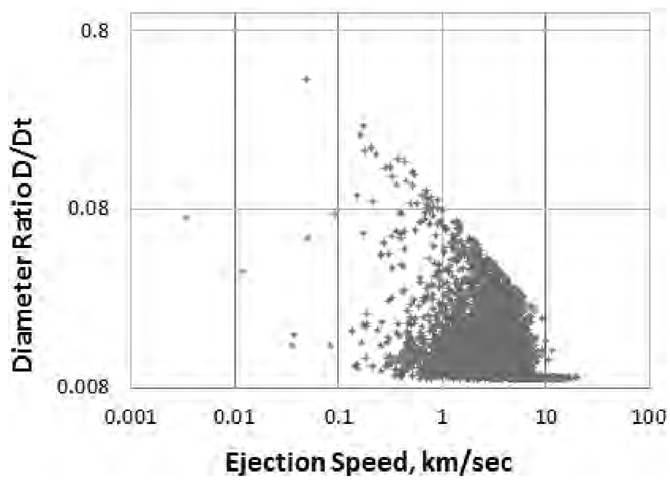


Figure 2. Exploded dwarf planet fragment diameters vs. ejection speed. Dt is initial dwarf planet diameter assuming only these fragments.

The starting point is the array of fragments from the exploded dwarf planet model. Each of the N fragments has three position coordinates, three velocity components, and a fragment radius. As stated above, the fragment densities are assumed constant and equal to the density of the largest asteroid. Therefore each fragment radius can be used to determine each fragment mass. The coordinates and velocities are first transformed from the dwarf planet coordinate system to the solar coordinate system. Then the leapfrog integration method is used to numerically integrate the gravitational differential equations.

Leapfrog integration is a simple, second-order method that conserves energy. The position vector of the i^th^ fragment at time t is given by

$$\overrightarrow{x(t)}_i = \overrightarrow{x(t-\Delta t)}_i + \overrightarrow{v(t-0.5\Delta t)}_i \cdot \Delta t$$

where i = 1, …, N, N is the number of fragments, and Δt is the time step. The corresponding acceleration vector is given by

$$\overrightarrow{a(t)}_i = \sum_{(1 \le j \le N,\, j \ne i)} \frac{G \cdot m_j \cdot \overrightarrow{r(t)}_{ij}}{\left(r(t)_{ij}\right)^3}$$

in which G is the gravitational constant, m_j is the mass of the j^{th} fragment, and

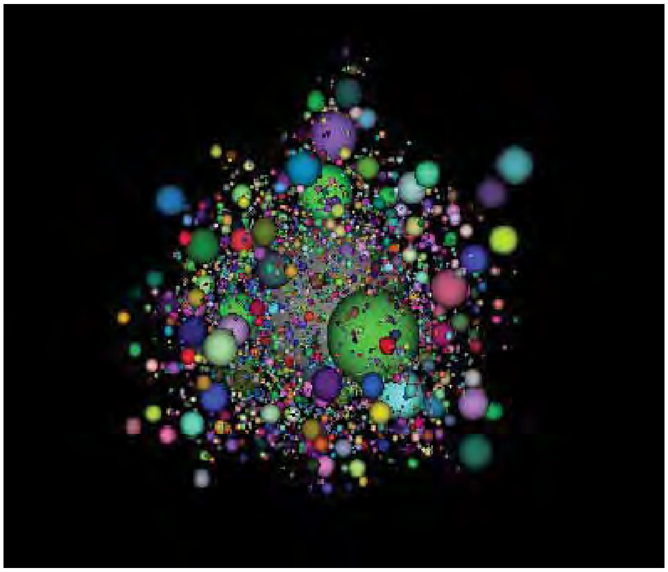


Figure 3. Typical exploded dwarf planet used as a starting point for the simulation. The mean diameter of the swarm of particles shown here is approximately 2,500 km. The randomly assigned colors help to visualize the fragments. Not all fragments are plotted.

$$\overrightarrow{r(t)_{ij}} = \overrightarrow{x(t)_j} - \overrightarrow{x(t)_i}$$

is the vector from fragment i to fragment j. Finally the velocity update of the i^{th} fragment is given by

$$\overrightarrow{v(t + 0.5 \cdot \Delta t)_i} = \overrightarrow{v(t - 0.5 \cdot \Delta t)_i} + \overrightarrow{a(t)_i} \cdot \Delta t$$

Leapfrog integration updates position and velocity at interleaved time points in such a way that they leapfrog over each other. Note that the position and velocity updates require only $O(N)$ computations, while each acceleration update requires N-1 computations resulting in $O(N^2)$ computations overall. The GPU processor is used to perform the acceleration update. The GPU approach generally follows that described by Nyland et al. (2007); however, some simplifications were incorporated. The details of the code are not included here. The use of loop unrolling was implemented to increase efficiency. An independent acceleration computation was also implemented using the CPU (Intel i7 processor) and used to verify that the GPU computations were working correctly. It was found that the use of the GPU increased processing speed by a factor of approximately 300 over the use of a single CPU. A newer GPU (Microway's Tesla GPU accelerated cluster) was made

Table 1. Initial Dwarf Planet Parameters Used in Simulation

Number of fragments in dwarf planet	16,383
Fragment mass density (constant for all fragments)	2.1x10-3 kg/cm3
Total mass of fragments	2.35x1021 kg
Total fragment energy	1.10x1034 erg
Specific fragment energy	4.69x109 erg/g
Average speed of fragments	3.24 km/sec
Equivalent (unexploded) diameter	1288 km
Escape velocity from initial dwarf planet surface	0.70 km/sec
Largest fragment diameter	952 km
Initial minimum distance between fragments	100 km

Table 2. Fragment Tracking Details Used in Simulation

Simulation step size	120 sec.
Dwarf planet solar distance (circular orbit)	3 AU
Dwarf planet speed	17.244 km/sec
Dwarf planet period	5.182 years
Jupiter starting point (Arbitrary angle ahead of dwarf planet)	0.75 pi
Jupiter solar distance (Circular orbit, no inclination)	5.203 AU
Jupiter speed	13.06 km/sec
Jupiter period	11.86 years
Escape velocity from Sun at 3 AU (Ignoring the dwarf planet)	24.4 km/sec

available on a trial basis and used to run the simulation out to 15.75 orbits, corresponding to more than 81 years in 120-second steps. (The accelerated computations were performed on Microway's Tesla GPU accelerated compute cluster. The computing speed was increased by more than a factor of three over the use of the original GPU.)

Simulation key parameters are included in Table 2. The objects in the simulation included the dwarf planet fragments, the Sun, and the planet Jupiter. Jupiter was included because it has the largest planetary influence on the asteroids. The position of Jupiter at the starting point was arbitrarily set at 0.75π ahead of the dwarf planet. No orbital inclination was added. Future simulations may include additional planets.

The step size Δt was set at 120 seconds. There are no requirements for high precision, as in satellite trajectory calculations, and no rapid changes in velocity that would require much smaller step sizes. With an average speed in the solar reference frame of greater than 17 km/sec fragments move about 2000 km between steps. With this step size, the Microway Tesla accelerated computer cluster took more than 52 hours of run time to go from 5 to 15 dwarf planet orbits (5.18 years/orbit).

Results

Tracking

Figures 4a through 4f illustrate the results. Note that in order to see the fragments, the plotted diameters were multiplied by a factor of 20,000. Also the Sun was multiplied by a factor of 12 and Jupiter by a factor of 100. These factors were applied only for visualizing the results of the simulation. Figure 4a illustrates the starting positions. The figure is the x-y plane of a three-dimensional volume. The Sun is at the origin, and the exploding dwarf planet is on the positive x-axis. The planet Jupiter, also shown, is arbitrarily set 0.75π radians ahead of the exploding dwarf planet. The orbits of the inner planets also are indicated, but the planets are not shown.

Initially the fragments spread radially as expected. However, in less than one fourth of an orbit, the pattern of fragments begins to show an elongation (Figure 4b). The elongation is much more evident in Figure 4c. The slower fragments have smaller orbits with shorter periods, while the faster fragments have larger orbits with longer periods. This is further enhanced by the acceleration of the smaller orbit fragments as their radius decreases, while the larger orbit fragments slow as their radius increases. The elongation increases to the point that at the end of a single orbit, there is the appearance of what can be described as filaments (Figure 4d). By the end of 2.5 orbits, the entire orbit of the original dwarf planet is populated with fragments (Figure 4e).

Figure 4f shows the fragments after 15.75 orbits (81.67 years). The differential velocities of the fragments have filled in the distribution of fragments such that it is beginning to approach uniformity around the entire orbit. The obvious exception is the initial collision point to which all fragments return. The only modifying effect included in this simula-

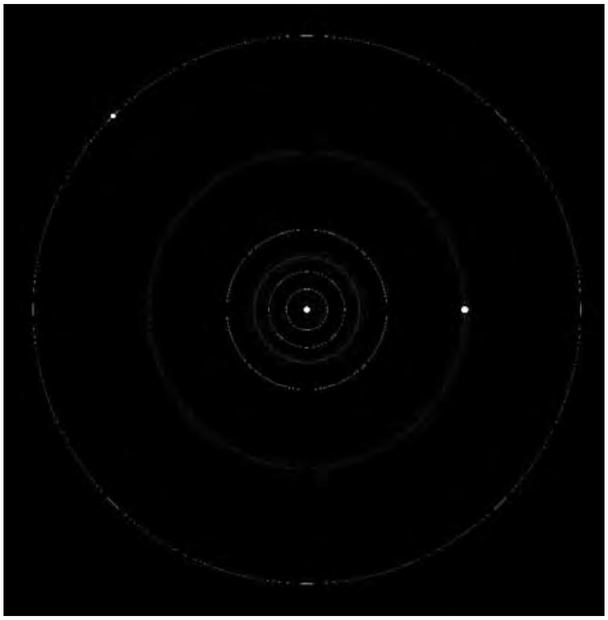


Figure 4a. The figure shows the starting point with the Sun, Jupiter, and the orbits of the inner planets (inner planets are not shown). Visualization is enhanced by artificially increasing the sizes. The Sun's diameter was multiplied by 12; Jupiter's diameter was multiplied by 100, and the asteroid fragment diameters were multiplied by 20,000. Further magnification of the initial dwarf planet would reveal an image similar to Figure 3.

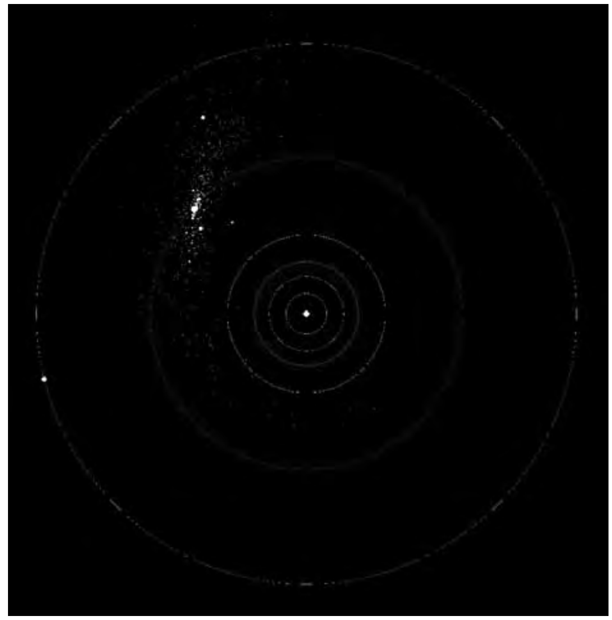


Figure 4c. Asteroid fragments at 0.375 of an orbit of the original dwarf planet (angle is 0.75π radians) corresponding to 1.94 years. The elongation is obvious at this point.

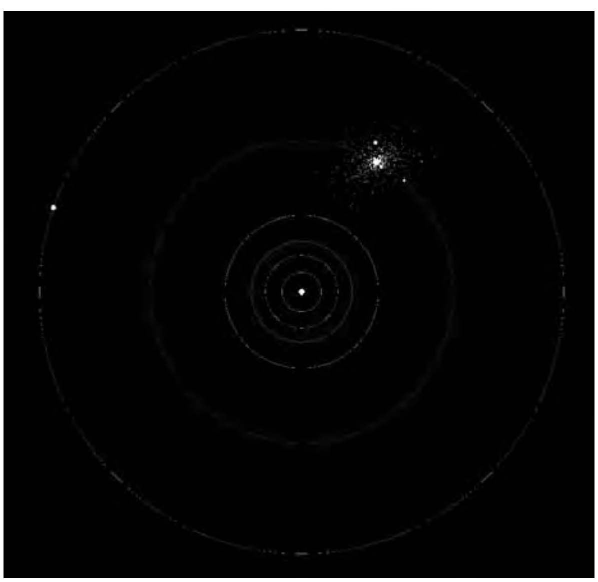


Figure 4b. Asteroid fragments at 0.168 of an orbit of the original dwarf planet (angle is π/3 radians) corresponding to 0.83 years. An elongation of the pattern is beginning to be apparent.

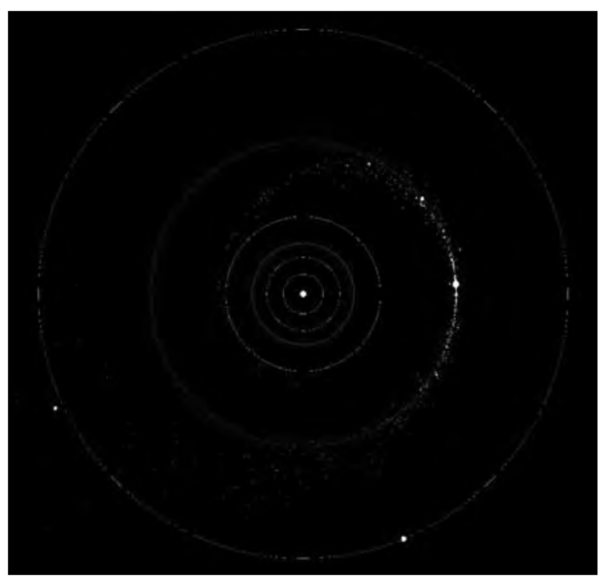


Figure 4d. Asteroid fragments at 1 orbit of the original dwarf planet (angle is 2π radians) corresponding to 5.18 years. Each fragment has an elliptical orbit that returns to the initial collision point. The slower fragments with smaller orbits and shorter periods get ahead of the faster fragments with larger orbits and longer periods, giving the appearance of filaments.

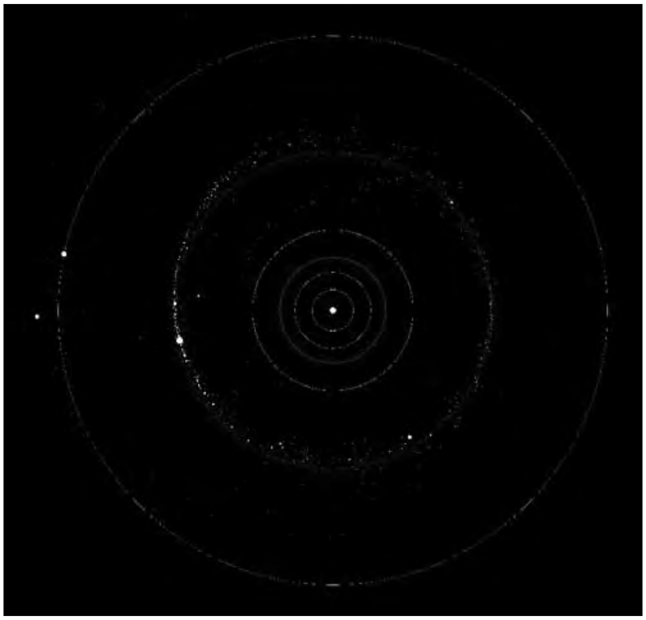


Figure 4e. Asteroid fragments at 2.5 orbits of the original dwarf planet (angle is 5π radians) corresponding to 12.96 years. The remains of the initial filaments are still evident. The entire orbit of the original dwarf planet is populated with fragments. Again all fragments return to the original collision point.

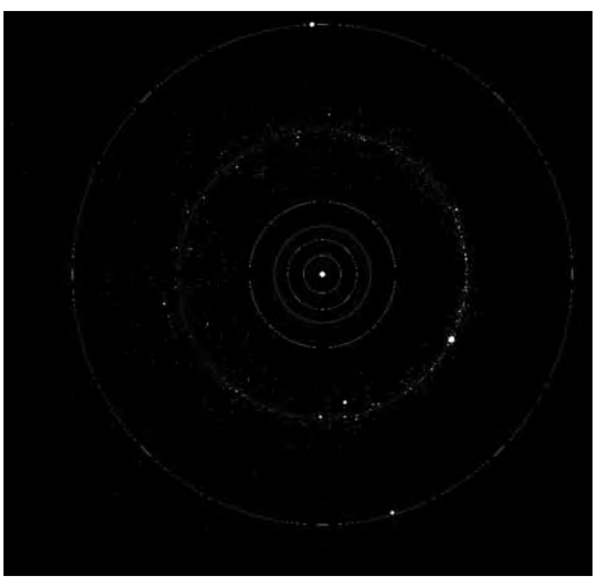


Figure 4f. Asteroid fragments at 15.75 orbits of the original dwarf planet (angle is 31.5π radians) corresponding to 81.67 years. At this point the density of fragments around the entire orbit is becoming more uniform. Clearly, collisions are required to eliminate the return of all orbits to the collision point.

tion is the effect of the planet Jupiter, which can be expected to perturb a few of the fragments. Note that Jupiter orbits only 6.9 times in this initial 81.67 years. The obvious missing effect is that of collisions, which were not included.

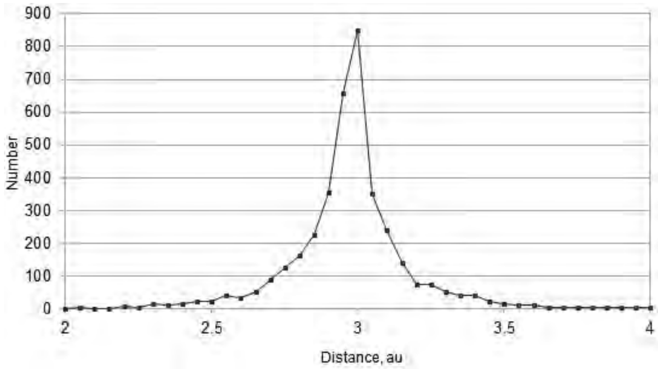
It is remarkable how quickly the fragments are becoming uniformly distributed. This is illustrated in Figures 5a–5d, which plot the density of fragments with distance from the Sun after 15.75 orbits at four different positions, centered at 0°, 90°, 180°, and 270°, including all fragments within ±45° at each position. At 0° the distribution is narrower as expected, since all of the fragments return to the collision point. A combination of collisions and perturbations from the other planets ultimately will spread out this section. The other directions (Figures 5b–5d) show distributions with similar widths and heights. In the position opposite the collision point (Figure 5c), there are peaks that may be remnants of the initial filaments, although they are not seen in the other directions. The number of fragments in each of these directions is also remarkably similar. In order they are 4038 at 0°, 3658 at 90°, 4575 at 180°, and 4112 at 270°. Overall about 10% are at very large distances, with most of the large-distance fragments skewed toward the 180° direction as expected.

Figures 5b–5d do not show any signs of Kirkwood gaps. Kirkwood gaps are gaps in the radial distribution, presumably due to orbital resonances between the fragment periods and the period of the planet Jupiter. The fact that they are not seen is not surprising since 15.75 orbits of the dwarf planet collision point corresponds to only 6.9 orbits of Jupiter as mentioned earlier.

Collisions

A preliminary look at collisions verified that they are virtually certain. As fragments approach the original collision point, they necessarily increase their density and therefore collision probability. Furthermore, different fragments return to this point at different times with different velocities, providing a substantial relative velocity between colliding fragments. Figure 6 illustrates the velocity distribution at the collision point after 1.5 orbits of the collided dwarf planet. Since all unperturbed fragments must return to this point, a relatively broad speed distribution results, which increases the probability of collisions. There are several observations to be made concerning collisions.

1. Collision probabilities will significantly increase with decreasing fragment size. As stated earlier, this simulation includes only the 16,000 largest fragments (diameters of 10 km and larger). There are at least 1000 smaller fragments (100 m diameter or greater) for each fragment in this simulation. The presence of even greater numbers of even smaller fragments is estimated in some studies.
2. The probability of collisions between larger fragments decreases rapidly with increase in size. This implies that it is very unlikely that the starting point is a much larger



Figures 5a–5d. These figures show the distribution of fragments in each of four directions after 15.75 orbits after the collision. Figures 5a through 5d correspond in order to 0°, 90°, 180°, and 270°. Each figure includes the fragments from ±45° around the given direction. The distribution in Figure 5a is narrower than the others because it includes the collision point. It is remarkable that the fragments are this uniform after only 82 years. The orbit of the initial dwarf planet had a radius of 3 AU.

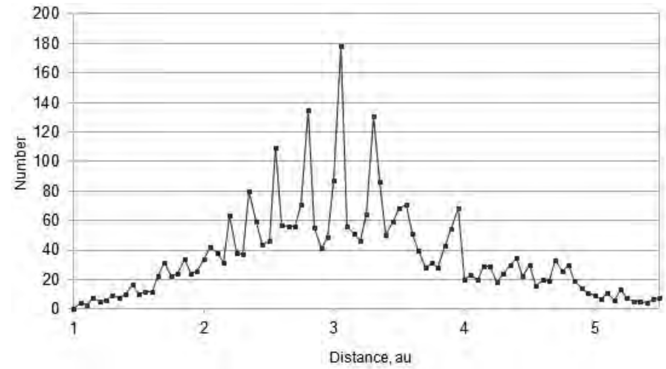


Figure 5c. The distribution at 180° ±45° is broader than the others and has pronounced peaks. The peaks may be the remnants of the filaments seen in Figures 4d and 4e.

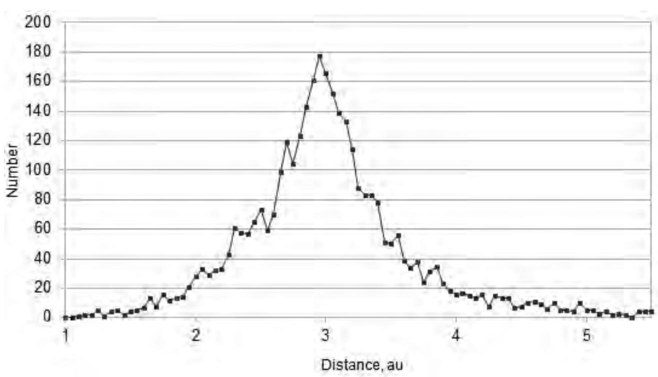


Figure 5b. The distribution of fragments in the 90° ±45° direction.

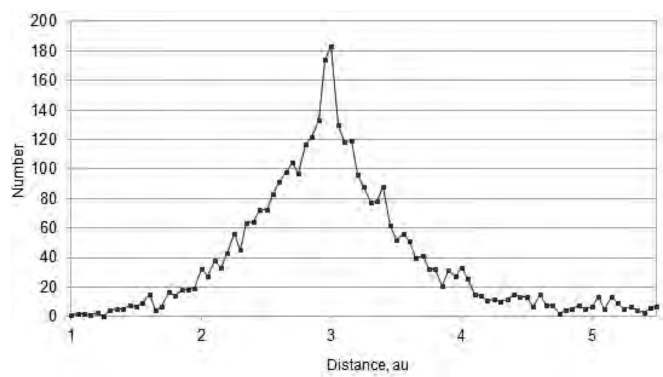


Figure 5d. The distribution of fragments in the 270° ±45° direction.

planet with many large fragments that collide, producing the smaller fragments observed today. Some collisions between the larger fragments can be expected, but they will be much less likely.

3. There are a number of papers on the existence of asteroid families, defined as groups of asteroids with common characteristics that presumably resulted from catastrophic collisions early in the formation of the solar system (cf. Bendjoya and Zappalà, 2002). This provides another motivation for developing a simulation that includes collisions.

Summary

A computer simulation was used to explore the possibility that the asteroid belt could form in a few thousand years as the result of a catastrophic breakup of a dwarf planet. First, a computer model of an exploding dwarf planet was developed based on the results of recent asteroid collision studies. The result was a file containing the position, velocity, and size of each of more than 16,000 explosion fragments. Then each of the fragments was tracked as it propagated under the gravitational influence of the other fragments, the Sun, and the planet Jupiter. An

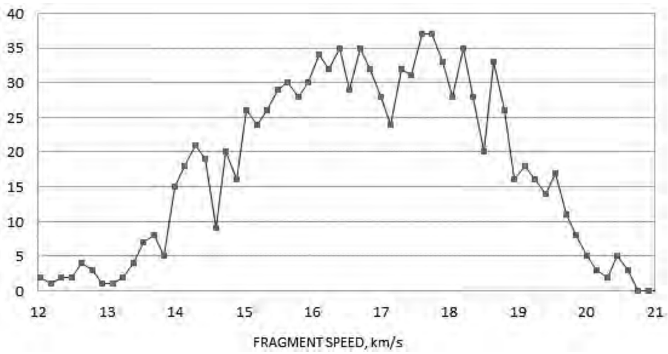


Figure 6. Speed distribution of fragments near collision point after 1.5 orbits of the collided dwarf planet. All unperturbed fragments must return through this point, resulting in large relative velocities.

All-Pairs N-Body Simulation approach is used with a Leapfrog integration algorithm. This brute-force approach was enabled by the use of a GPU using the CUDA platform. The simulation was carried out to 15.75 orbits of the collided dwarf planet, or nearly 82 years in 120-second steps.

These initial results showed that a relatively uniform distribution of fragments formed around the entire orbit of the original dwarf planet in this surprisingly short time. Since each fragment is in essentially a constant elliptic orbit unless perturbed, they almost all return to the collision point. This means that either collisions or perturbations from the other planets are required for complete uniformity. A preliminary analysis showed that collisions are virtually certain, especially during the first few orbits.

The results are consistent with the formation of the observed asteroid belt in a few thousand years. However, the study is certainly not complete. Many questions remain. For example, how long will it take to see the formation of the observed radial distribution including the Kirkwood gaps? And, can a simulation such as this show the formation of Greeks, Trojans, and Hildas, objects assumed to be asteroids orbiting close to the conjugate points of Jupiter? A great deal of work remains.

Acknowledgments

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Understanding the Origin of Homochirality in Amino Acids and Polypeptides

Peter M. Murphy*

Abstract

Origin of Life (OoL) research has produced an amazing amount of scientific experimentation, but no consensus has emerged on any viable naturalistic path from chemical compounds to living, reproducing cells. One example of the accomplishments, optimism, and then futility of OoL research is the search for a prebiotic, naturalistic origin of homochirality in α-amino acids and polypeptides. This review surveys the current research on the significance of homochirality in proteins, the rivalries within OoL research, the abiotic sources of α-amino acids and polypeptides, their chiral amplification, their prebiotic stability, and the difficulty of finding a naturalistic explanation for the origin of homochirality.

Introduction

Homochirality is an essential physical-chemical characteristic of amino acids, proteins, sugars, polysaccharides, and DNA in all biochemical systems and living organisms. Since Louis Pasteur's discovery of molecular chirality in the 1840s, the homochirality of biological molecules has been recognized as a significant demarcation line between living and nonliving matter, a signature of life (Gol'danskii, 1997; Blackmond, 2010). If there were no naturalistic route to homochirality, then chemical evolution is stopped in its initial steps. In the early twenty-first century, what progress in chemistry, biology, geology, astronomy, and physics supports a naturalistic origin of homochirality in amino acids and polypeptides? The scientific community may never know if a naturalistic route to homochirality in biochemical molecules was possible, but an assessment of research published over the last 15 years or so should indicate whether a naturalistic route is even remotely possible. The recent article "Left-Handed Puzzle Remains" (Coppedge, 2012) whet appetites for a more comprehensive review of the latest research toward understanding the origin of homochirality in α-amino acids and polypeptides. This paper is written to review the origin of life (OoL) research to date regarding homochirality.

OoL researchers have produced elaborate scientific results without solving any of the profound difficulties of a naturalistic explanation for life's origin. Modern OoL publications are filled with optimism, speculation, and awareness of the significance of their research. Here are a few examples. Bergman (2000) noted that abiogenesis, the theory

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that life can arise spontaneously from nonlife molecules, has many scientific obstacles to overcome, including the origin of homochirality. Meinert et al (2010) concluded that scientific studies on the origins of life in general and on the origin of biomolecular homochirality are of interdisciplinary interest and will continue producing important and highly intriguing data on our origins. Meierhenrich (2009) wrote that the inability to link chemical and biological evolution is one of the unsolved fundamental mysteries in modern natural science that continues to puzzle scientists. Colonna et al (2009) noted that the emergence of homochirality in the prebiotic world is on the one hand a major open problem, while on the other hand it provides a fascinating challenge. Powner et al (2011) remain optimistic that the basis in organic chemistry contains a system of chemical transformations that can provide all the vital ingredients of life. Ávalos (2000) stated that the origin of life on earth is linked to the origin of enantiomerically pure compounds (homochiral compounds). Percec (2011) highlighted the significance of the homochirality problem by concluding that questions about the origin of homochirality in biological systems are almost synonymous with questions related to the origin of life.

Rivalries within Origin-of-Life Research

Because no scientific consensus exists on any critical step in the OoL, including the origin of homochirality in α-amino acids and polypeptides, researchers with competing explanations continue to advocate for their positions while simultaneously pointing out the weaknesses in their rivals' theories. Life consists of two key, interdependent biopolymers: DNA and proteins. DNA is the genetic biopolymer that stores information and directs the biosynthesis of proteins. Proteins provide a diversity of structure, metabolism, and catalysis. Benner (2002) stated that since it is difficult to envision a naturalistic mechanism that would allow either proteins or DNA to emerge spontaneously, it is highly improbable that both proteins and DNA arose simultaneously and spontaneously, and as an encoder-encoded pair. Menor-Salva and Marin-Yaselli (2012) argued that any proposed intermediate or transitional OoL system creates a rivalry between a genetics-first and a metabolism-first model. No transitional, remotely plausible system is known to exist today, nor has any specific abiogenic transitional system been proposed.

RNA is the leading "single-biopolymer" model proposed for OoL that may have preceded the current two-biopolymer system. RNA entities can exhibit both self-replication and catalytic properties (Luisi et al, 1999). Benner and Hutter (2002) concluded that catalysis and information storage place competing and contradictory demands on molecular structure. Plankensteiner et al (2005) and others advocate a metabolism-first origin model and propose a peptide/protein world as a precursor to the "RNA world" scenario. They argue that RNA or DNA is not a suitable starting point for the OoL due to the very limited stability of RNA or DNA in a primordial ocean (Plankensteiner et al, 2005). Jakschitz and Rode (2012) have proposed polypeptides as a way to transport information and to provide stability under the harsh conditions of the primordial ocean.

Another rivalry among OoL researchers is the abiotic–biotic dichotomy for the origin of homochirality of biological molecules. In the abiotic position, homochirality precedes life—either metabolic, genetic, or both. In the biotic position, homochirality is not a requisite for life or some intermediate chemical system evolving towards life (Ávalos et al, 2010). In the biotic proposal for homochirality, prebiotic amino acids and sugars did not evolve completely to chiral purity before the formation of the first "living" biopolymer systems. Blackmond (2010) speculated that perhaps chiral selectivity increased as the complexity of "life" increased. Percec and Leowanawat (2011) and others postulated that early life on earth was racemic and/or heterochiral and then slowly evolved over time at the biological level to homochiral. Coveney et al (2012) emphasized that intermediate metabolic-only or genetic-only phases toward "living systems" have not been found in nature, have not been verified experimentally, and no specific intermediate systems have been proposed, though theoretical research and modeling continues.

What were the likely sources of the prebiotic molecules necessary for the OoL? Three chemical reaction conditions have been the focus of the abiotic source of α-amino acids and proteins in research: (a) early earth atmospheric conditions (oxidizing or reducing), (b) the extreme conditions of hydrothermal vents on the ocean floor, and (c) a wide range of extraterrestrial environments (Evans et al, 2012). The famous Miller-Urey experiment was a milestone in origins research, showing that organic compounds necessary for life, including amino acids, could be synthesized from a gaseous mixture of water, ammonia, methane, and hydrogen. An electric spark provided the energy for bond formation (Miller, 1953). While there is much controversy regarding the composition of early earth atmosphere (oxidizing vs. reducing), the consensus is that the reducing environment necessary for Miller's experiment was not likely ever present (Coveney et al, 2012; Chen and Chen, 2005).

An early OoL hypothesis was the "warm little pond" idea attributed to Darwin. Coveney and Maurel and Décout argue that the traditional concept of a "warm little pond" or a "prebiotic soup" suffers from (i) the absence of geological evidence, (ii) the lack of a free energy source, (iii) a high dilution of the critical organic materials, (iv) vulnerability of the biopolymers to hydrolysis, and (v) a lack of favorable selection for monomer sequences (Coveney et al, 2012; Maurel and Décout, 1999). The "prebiotic soup" model has been essentially abandoned.

Another possible source of organic compounds for life is hydrothermal vents on the ocean floor, which postulates a reducing, aqueous environment with elevated temperatures (Podlech, 2001). One interesting possibility with the "vent theory" is the formation of thioester derivatives of amino acids, which are "activated" alternatives to amino acids, as a route to polypeptides. Plankensteiner et al (2005), however, argued that the localized nature of hydrothermal vents probably would not allow large-scale abiotic syntheses of α-amino acids and polypeptides.

The panspermia theory proposes an extraterrestrial source of critical organic materials for the OoL. Over eighty amino acids have been detected in the Murchison meteorite from Australia in 1969, but only eight are the standard α-amino acids found in proteins (Sephton, 2002; Burton et al, 2012). Amino acid precursors also have been observed in meteorites, which could hydrolyze once they reached the earth's ocean. Terrestrial contamination and the complex mixture of materials complicate the chemical analyses of meteorites. Burton et al (2012) argued that isotope analysis has strengthened the argument that some amino acids on earth could have had an extraterrestrial origin. Menor-Salva and Marin-Yaselli (2012) postulated that extraterrestrial delivery could compensate for a possible lack of availability of materials from terrestrial synthesis of life. Extraterrestrial sources allow researchers to explore a wide range of temperatures, chemical building blocks, reaction conditions, and electromagnetic radiation energy for potential abiotic syntheses (Gol'danskii, 1997). Pizzarello (2007) noted a significant challenge for the panspermia theory: the selection problem, i.e., how small amounts of standard α-amino acids or their precursors (<100 ppm total) were separated and preserved from the vast amount of other chemical compounds also transported by meteorites.

Importance of Chirality in Biochemical Materials

A linear sequence of α-amino acids joined by peptide bonds constitutes the primary structure of a protein. For polypeptides to become biologically significant enzymes, hormones, muscles, etc., a protein's three-dimensional secondary, tertiary, and quaternary structural features must be meticulously and precisely bonded, folded, and coiled. Three important characteristics of the standard α-amino acids are harnessed to achieve precise and diverse functionality in proteins: (i) ionic charge (anionic, neutral, cationic), (ii) hydrophilic-lipophilic balance (water soluble, oil soluble), and (iii) molecular shape and size. The simplest aspect of the molecular shape and size of α-amino acids and proteins is chirality or "handedness." Nineteen of the twenty standard α-amino acids are chira; i.e., they can exist as either left-handed or right-handed, mirror-image enantiomers that are nonsuperimposable (Hames, 2000). Only L α-amino acids are found in the proteins of living animals. The precise L α-amino acid sequence (primary structure) in a polypeptide is a necessary but not sufficient requirement to define the shape and size of a protein. All four structural aspects (primary, secondary, tertiary, quaternary) must be correctly designed to direct and achieve a protein's intended structure and functionality.

Figure 1 shows a pair of mirror-image structures with four groups (A, B, D, E) tetrahedrally oriented around a central (C) group. These structures model the orientation of the four groups chemically bonded to a tetrahedral carbon atom, including the amino group and carboxylic acid group in α-amino acids. The two structures in Figure 1 have the same five groups, but the geometric relationships of these five groups are distinct. These two structures are different in a way that your right hand is distinct from your left hand. In proteins, this subtle spatial difference is magnified as each α-amino acid in the polypeptide sequence adds another chiral distinctiveness to the protein.

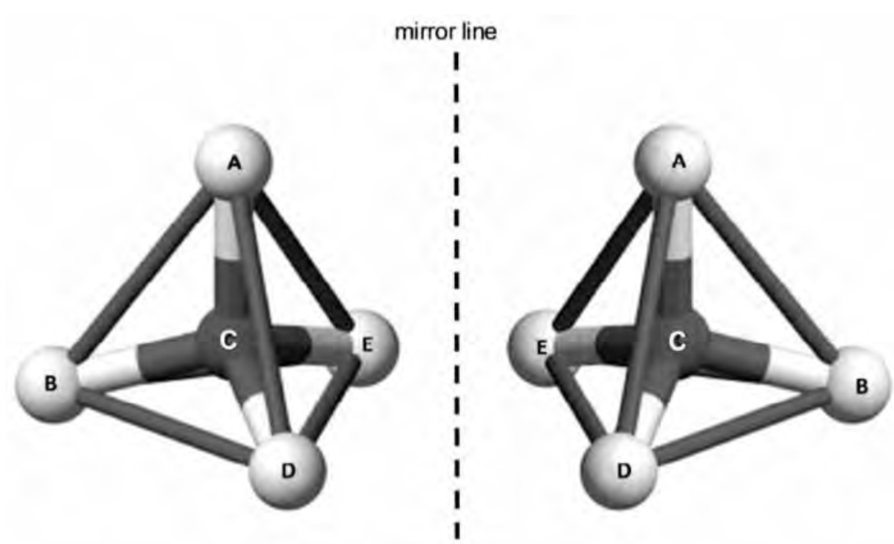

Figure 1. Mirror images demonstrating chirality around a tetrahedral carbon atom (C)

Individual α-amino acid are either D or L, but mixtures of D and L α-amino acid isomers can range from 100% D to 50/50 D/L to 100% L. The enantiomeric excess (EE) of the L α-amino acid is the difference between the amount of the two isomers, divided by the total amount of the two α-amino acids. If EE=0, then the α-amino acid mixture is racemic with equal amounts of both isomers. If EE=10%, then the α-amino acid mixture has 55% of the L α-amino acid and 45% of the D α-amino acid. Each α-amino acid in a polypeptide sequence can be either D or L. Polypeptide chains can therefore vary in chiral composition from 100% D to 50/50 D/L to 100% L. In all living systems, apart from very rare exceptions, peptides and proteins consist of entirely L α-amino acids. Proper structure and function for proteins strongly depend on the enantiomeric purity of each α-amino acid. Jakschitz and Rode (2012, p. 5487) stated, "If only one amino acid is replaced by its optical (chiral) counterpart the formed protein will not fulfill its tasks properly because of destabilization effects induced by the distorted structure of σ-helices and β-sheets." Amino acids synthesized by ordinary methods invariably result in 50/50 D/L mixtures (EE=0).

Roadmap to Chiral Polypeptides

Colonna et al (2009) have outlined the generally accepted scheme for abiotic generation of homochiral polypeptides, which consists of four fundamental steps: (i) the abiotic formation of racemic α-amino acids; (ii) symmetry breaking leading to chiral α-amino acids having small EE; (iii) the chiral amplification to enantiomerically pure substances; and (iv) their organization into self-sustaining systems. Figure 2 is a chemical roadmap to L α-amino acid polypeptides (V). This chemical roadmap is not comprehensive but emphasizes chirality and provides an overview of the kinetic and thermodynamic challenges to synthesize homochiral L α-amino acid polypeptides (V), especially in a prebiotic environment.

Many different organic and inorganic compounds (I) can be converted to vari-

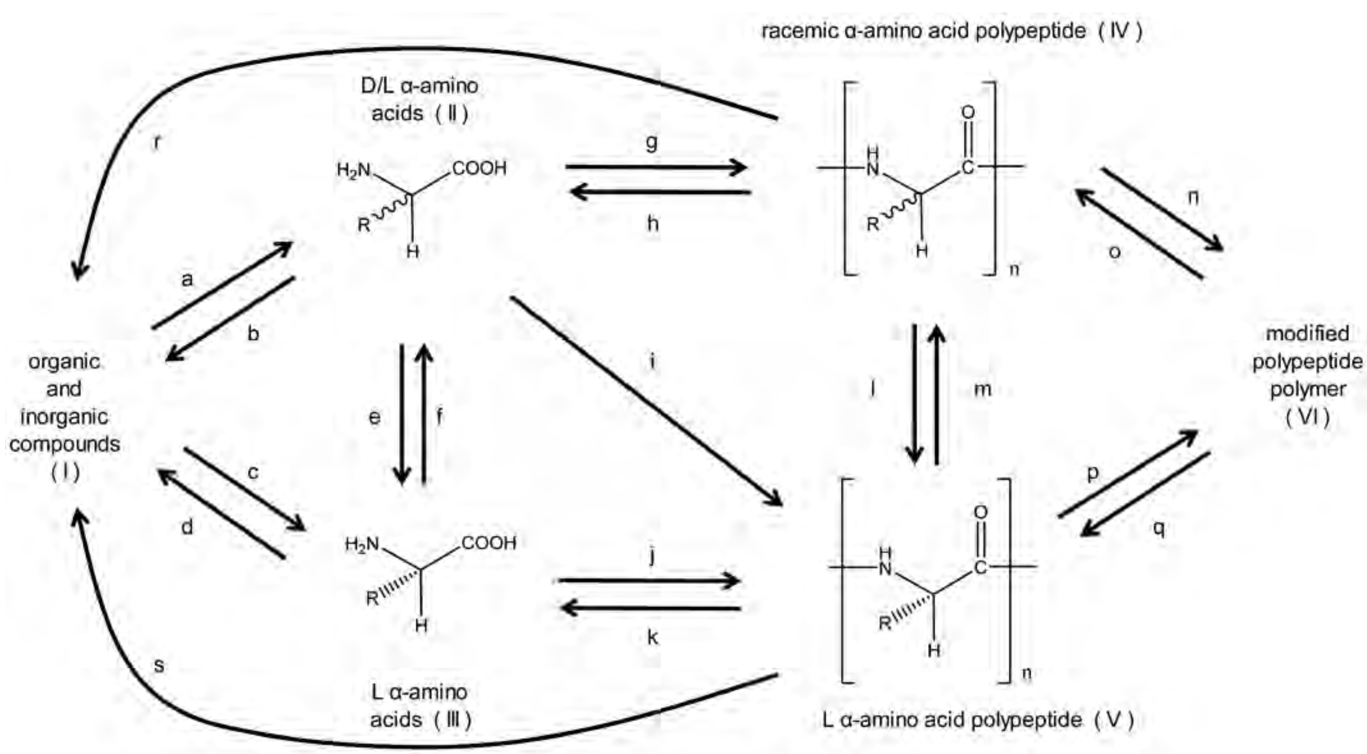

Figure 2. Roadmap to L α–amino acid polypeptides. (a) racemic amino acid synthesis, (b) racemic amino acid decomposition, (c) L amino acid synthesis, (d) L amino acid decomposition, (e) chiral separation or transformation, (f) racemization, (g) racemic polypeptide formation, (h) racemic polypeptide hydrolysis, (i) chiral L polypeptide formation, (j) L polypeptide formation, (k) L polypeptide hydrolysis, (l) chiral separation or transformation, (m) epimerization, (n) racemic polypeptide conversion, (o) racemic polymer transformation, (p) L polypeptide conversion, (q) L polymer transformation, (r) racemic polypeptide degradation, (s) L polypeptide degradation.

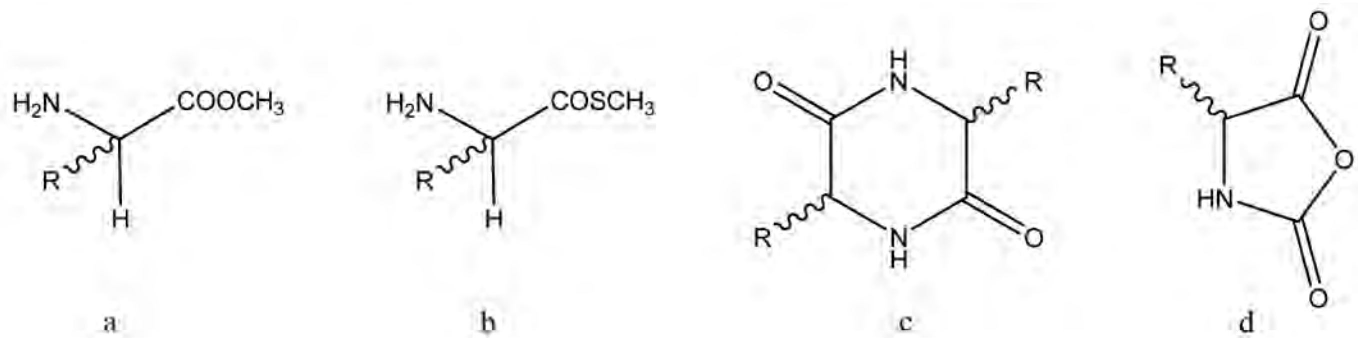

Figure 3. Examples of activated α–amino acid: a) ester, b) thioester, c) diketopiperazine (DKP), d) N-carboxyanhydride (NCA)

ous α-amino acids (routes a and c). Both D and L α-amino acids are vulnerable to decomposition (routes b and d). Amino acids (II and III) can be anionic, cationic, or zwitterions, depending on solvent, pH, concentration, solution salinity, phase, temperature, etc. Amino acids exist as zwitterions at or around physiological pH. "Activated" derivatives of amino acid (e.g., thioesters in Figure 3) can also form polypeptides, and consideration of the chirality of their syntheses and decompositions would parallel the Figure 2 chemical roadmap. Activation of amino acids *in vivo* involves ATP and specific transfer RNA molecules. Route e emphasizes that chiral separation is necessary to transform a racemic mixture of D/L α-amino acids to chirally pure L α-amino acid. Route f shows the effect of racemization on chirally pure L α-amino acids (III) to the racemic mixture (II). Polypeptides (IV and V) are formed by the dehydration between two α-amino acids in routes g, i, and j. Hydrolyses of polypeptides to α-amino acids are shown in routes h and k. As with α-amino acids, polypeptides can undergo chiral separation or transformation (route l) or epimerization (route m) as the D/L configuration of individual α-amino acids interconvert. Polypeptides can be transformed into other polymers (VI) or degraded directly to various organic and inorganic compounds (I).

The challenge for the naturalistic origin of homochirality in α-amino acids and polypeptides is to demonstrate a plausible, prebiotic route from various, available organic and inorganic compounds (I) to chirally pure L α-amino acid polypeptides (V), and to stabilize those chirally pure L α-amino acid polypeptides (V) against back reactions to reactants, oxidation, decomposition, hydrolysis, and racemization. Providing an abiogenic origin of homochirality is essential to a naturalistic worldview of life's origin. However, this does not begin to solve the naturalistic problems for the origins of the primary, secondary, tertiary, and quaternary structures of the diverse proteins necessary for living creatures.

Synthesis of α-Amino Acids

Many OoL experiments demonstrate potential prebiotic routes to amino acids, polypeptides, and other biochemical building blocks, but the yields for these syntheses are generally less than 3% even for glycine (the simplest amino acid). In all cases, prebiotic routes to amino acids (terrestrial or extraterrestrial) give racemic product mixtures that contain many impurities; note Figure 2, route a (McNichol, 2008; Pizzarello, 2006). Meierhenrich (2009) gives a survey of the leading prebiotic routes to amino acids, and a few routes are worth highlighting. The Strecker-cyanohydrin synthesis utilizes the reaction of ketones or aldehydes with ammonia, then with HCN, and finally hydrolysis (Smith and March, 2007). Photochemical syntheses from amines and carbon dioxide can yield amino acids (Meinert et al, 2010). Several syntheses of amino acids from carbon monoxide, water, and nitrogen are catalyzed by high-energy particles, UV irradiation, or electrical discharge (Chen and Chen, 2005). Debates about which synthetic pathway is more "prebiotic" abound. Regardless of their source, Ávalos (2010) argued that it is unclear how many α-amino acids could have been formed, preserved, and concentrated for further reactions in significant amounts and formed polypeptides or proteins in the early earth by any known route.

Synthesis of Polypeptides

The abiotic linking of monomers to form polymers is an important step in the naturalistic vision for life's origin. Danger et al (2012) have summarized many of the reaction conditions that have been proposed for the formation of peptide bonds between α-amino acids (Figure 2, routes g, i, and j). Proposals include hydrothermal systems, catalytic surfaces (e.g., clays, minerals), salt-induced peptide formation, condensation agents, and "activated" α-amino acids. Thermodynamically, the formation of polypeptides from α-amino acids is mildly unfavorable. The free energy of hydrolysis of an internal peptide bond into two α-amino acid segments is favored (ΔG) by about -2 to -6 kJ/mole (Figure 2, routes h and k). The formation of long chain polypeptides in aqueous solution from realistic concentrations of α-amino acids remains highly unfavorable (Danger et al, 2012). The concentration of monomers for polymerization to proteins, polysaccharides, DNA, and RNA is a difficult OoL problem within prebiotic limits. Importantly, the linking of a particular sequence of α-amino acids into the primary structure of a protein followed by coiling and folding into a protein requires extremely complicated processes far from thermodynamic equilibrium (Hames, 2000). These processes are separate and distinct from the mere kinetics and thermodynamics of homochiral polypeptide synthesis discussed in this review.

One approach to overcoming the thermodynamic barrier to prebiotic peptide formation, which is considerable, involves postulating the participation of condensation reagents, such as cyanamide (H_2NCN) or cyanoguanidine ($NC\text{-}N{=}C(NH2)_2$) (Menor-Salva and Marin-Yaselli, 2012). None of the commonly used condensation reagents for modern polypeptide synthesis have been postulated in the early earth environment. Other potential prebiotic activating agents for the formation of polypeptides include urea (NH_2CONH_2), carbonyl sulfide (COS), carbon monoxide (CO), pyrophosphate ($P_2O_7^{-4}$), fulminic acid (HCNO), hydrogen cyanide (HCN), carbodiimide (NHCNH), acetylene (HCCH), and N-carboxyanhydrides (Danger et al, 2012; Chen and Chen, 2005). There is still a sizable gap between the proposed syntheses and the experimental verification for the role of condensation agents in the abiotic formation of polypeptides from α-amino acids.

Podlech (2001) and others have proposed "activated" α-amino acid monomers to form polypeptides in a prebiotic environment: for example, the condensation of α-amino acid esters or thioesters (see Figure 3). Activated α-amino acids are analogous to α-amino acids (II and III) in Figure 2 with similar synthesis and decomposition reaction pathways and chiral characteristics. Danger et al (2012) have shown that activated α-amino acid monomers can accelerate polypeptide synthesis and improve polymer yields, but these activated compounds are also increasingly likely to undergo decomposition reactions. In condensation polymerization, monomers can either form long polymer chains or can cyclize into various-sized rings. Any two α-amino acids can dehydrate and cyclize into a six-membered diketopiperazine (DKP) ring, which can hydrolyze back to the pairs of α-amino acids or can undergo ring-opening polymerization directly into a polypeptide, in which DPK acts as an activated α-amino acid monomer (Danger et al, 2012).

Amino acid polymerization to polypeptides will be thermodynamically favored only under highly dehydrating conditions (Saladino et al, 2012). Salt-induced peptide formation (SIPF) depends on high concentrations of salt, especially sodium chloride, to absorb the water formed between amino acids forming polypeptides (Plankensteiner et al, 2005). Evaporation in tidal pools can produce SIPF conditions, which are further favored by elevated temperatures and/or transition metal catalysts (e.g., copper) to give good yields of polypeptides. SIPF works well with a wide range of amino acids, favoring α-amino acids over the β-, γ-, or other analogs (Jakschitz and Rode, 2012). SIPF does not provide a selective route to the required homochiral L polypeptides and demonstrates that polypeptide polymer end groups (amines and carboxylic acids) can undergo condensation reactions with a variety of compounds that compete with the formation of polypeptides. Most of the standard amino acids have chemically reactive side-chain groups, which would compete with the normal bonding pattern of polypeptides.

The effects of reaction temperature create a challenge for the abiotic syntheses. Menor-Salva and Marin-Yaselli (2012) asserted that higher reaction temperature gives better yields of polypeptides from α-amino acids, but higher temperatures also accelerate decomposition of α-amino acids, chiral racemization, and hydrolysis of polypeptides. Prebiotic chemistry in eutectic frozen solutions and at liquid water–ice interfaces (terrestrial or extraterrestrial) has been studied to overcome the ambient concentration and stability problems and may provide enhanced polypeptide synthesis reaction rates and/or yields, diminution of racemization, and the suppression of side reactions (Menor-Salva and Marin-Yaselli, 2012). Research continues to postulate and to pursue a role for low-temperature chemistry in the naturalistic routes for life's origin.

Chiral Symmetry Breaking

While individual α-amino acid molecules are either D or L, mixtures of α-amino acids synthesized from achiral precursors, without chiral catalysts and without a chiral template, are racemic mixtures of D and L α-amino acids. Finding the initial source of chiral symmetry breaking that tips the balance toward L α-amino acids remains a critical goal in abiogenesis research. Sephton (2002) reported that some α-amino acids and amino acid precursors of extraterrestrial origin have shown a very slight EE (<1%). Circularly polarized light (CPL) across the UV-visible spectrum interacts differently with each isomer of a pair of enantiomers. Podlech (2001) postulated that chiral symmetry breaking in extraterrestrial amino acids could be due to exposure to one or more of the different extraterrestrial sources of CPL: β-decay cosmic radiation, ultraviolet CPL, or infrared CPL. The theory that ultraviolet CPL provided the initial enantiomeric enrichment in the universe is a popular one in abiogenesis research. Evans et al (2012) summarized the three ways that CPL can potentially produce a chiral symmetry break: (i) photolysis, preferential destruction of one enantiomer; (ii) isomerization, preferential conversion of one enantiomer to the other; and (iii) synthesis, preferential creation of one enantiomer. Research continues to seek experimental verification of the role of CPL in the chiral symmetry break in amino acids. The photolysis/decomposition route to EE requires a high photolysis rate from CPL. Meinert et al (2010) concluded that to reach an amino acid EE of even up to 10%, a photochemically initiated decomposition of at least 99.99% would be necessary. Extraterrestrial α-methyl amino acids with higher EE (up to 15%) have been found on meteorites. The EE for these α-methyl amino acids may be due to a favorable chiral synthesis mechanism, a chiral bias in photolysis/degradation, or some other chiral separation process. Research continues in order to understand how these nonstandard amino acids could induce EE in the standard α-amino acids through an amplification or template mechanism (Meinert et al, 2010; Pizzarello, 2006).

In his book, Meierhenrich (2009) summarizes how differences in physical properties between D and L α-amino acids have attracted attention as a source of chiral symmetry breaking and challenged the long-held belief that enantiomers have completely identical physical properties except for interactions with other chiral materials or with polarized light and other polarized electromagnetic energy. Blackmond (2010) claimed that enantiomer partitioning via sublimation for α-amino acids in space is a possible extraterrestrial origin of chiral symmetry breaking. However, serine, the α-amino acid giving the highest initial enantio enrichment in sublimation, has not been observed in meteorites or in space (Blackmond and Klussmann, 2007). Also, the parity violation of the weak nuclear force results in extremely minor thermodynamic differences between D and L α-amino acids, which might contribute to the origin of their homochirality, but experimental verification has not been obtained (Evans et al, 2012).

Mineral catalysts are effective in the synthesis of polypeptides from α-amino acids. The "mineral basis" for the OoL describes the syntheses of homochiral sequences of small polypeptides formed from racemic mixtures of amino acids in the presence of quartz, sand, clay, or other minerals (Zaia, 2004; Chen and Chen, 2005). This line of research seeks to synthesize a chirally pure, L α-amino acid peptide from a racemic mixture of α-amino acids (Figure 2, route i). So far, these experiments usually have been performed with a single amino acid, with ionic amino acids, and in distilled water. The "mineral basis" for the origin of homochirality in peptides has not yet been generalized to mixtures of amino acids, salt/seawater conditions, or nonpolar amino acids.

The solubility and crystallization of α-amino acids have been studied for the effects of solvent, temperature, pH, concentration, additives, and mixtures as a possible source of their chiral symmetry breaking. Under carefully controlled conditions, chiral symmetry breaking can lead to either an enantiometric enrichment of the soluble, solution phase or the insoluble, solid phase. Blackmond (2007) described "chiral amnesia" as the formation of solid-phase homochirality from a racemic mixture of rapidly racemizing enantiomers. An initial precipitation of an enantiometrically pure or enriched solid phase leaves a solution depleted in that one enantiomer. Subsequent solution-phase racemization reestablishes the balanced racemic mixture, which leads to further precipitation of the pure enantiomer, and so on. Solution-phase racemization becomes the postulated driving force that leads to enantiomeric purity in the solid phase.

While the mechanism has intrigued and puzzled chemists, aspartic acid and a few amino acid derivatives have undergone chiral enrichment using cycles of crystallization and dissolution (Viedma and Cintas, 2011; Viedma et al, 2010). One explanation is Ostwald ripening, the diminishing of small crystals as large crystals increase, combined with solution racemization leading to enantiomeric purity. Chiral symmetry breaking and/or amplification of α-amino acids by crystal grinding can occur when the racemic α-amino acid mixture crystallizes into two enantiomerically pure α-amino acids. So far, a crystallization-grinding mechanism for chiral separation has been demonstrated only for aspartic acid and threonine (Budin and Szostak, 2010). The effects of contaminants and conditions (solvent, concentration, temperature, pH, etc.) on chiral symmetry breaking and on chiral enrichment using cycles of crystallization and dissolution in a prebiotic world remain controversial and not well understood.

Since current explanations for chiral symmetry breaking in prebiotic environments are not universally convincing, some researchers postulate a random or statistical source for the initial chiral symmetry break in nature, including α-amino acids and proteins. Coveney (2012) and others theorize that nonlinear effects caused an initial instability in the racemic state with random fluctuations selecting one handedness over the other, and further nonlinear interactions resulting in chiral amplification ultimately drive the system to chiral purity.

Chiral Amplification of Amino Acids and Polypeptides

No synthesis of any enantiomerically pure α-amino acids or polypeptides from racemic or achiral starting materials has been discovered or postulated (see Figure 2, routes c and i). Therefore, the origin of homochirality in α-amino acids or polypeptides requires prebiotic chiral amplification of any small EE, coupled with the preservation of that chiral purity as EE increases. Chiral symmetry breaking and chiral amplification share many characteristics, but their dual importance to life's origin is unmistakable. "Whether or not the imbalance in enantiomers came about by chance, arising on earth or elsewhere, an amplification mechanism remains the key to increasing EE and ultimately to approaching the homochiral state" (Blackmond, 2010, p 2).

Solubility-based chiral amplification of α-amino acids depends on the solubility properties of the different racemic mixtures relative to their corresponding enantiomerically pure D and L α-amino acids (Ávalos et al, 2010). Klussman (2006) has shown that repeated cycles of dissolution-precipitation-separation produced chiral amplification of one enantiomer from a racemic mixture of the two enantiomers, including for some α-amino acids. Blackmond (2010) reported that several of the standard α-amino acids form relatively insoluble D,L crystals in water and therefore show high eutectic EE values, including serine (>99%), histidine (93%), phenyl alanine (88%), leucine (87%), and methionine (85%). Eutectic EE values are dependent on temperature, pH, salinity, and other components in the solution. Many other standard α-amino acids have not shown a significant eutectic EE value, and much more research is suggested on chiral amplification of α-amino acids using prebiotic conditions to understand the versatility of this mechanism. Kojo (2010) showed that chiral enhancement in one α-amino acid or chiral material can impart chiral enhancement in other α-amino acids through recrystallization of a mixture of the materials. Chiral enhancement through recrystallization does not appear to be general, and a unique set of conditions may be necessary for each standard α-amino acid (Kojo, 2010). The role of impurities in chiral symmetry breaking and chiral amplification remains controversial.

The Frank model for chiral amplification postulated that synthesis of one enantiomer would catalyze its own production while simultaneously suppressing the production of its mirror image. The only experimental verification of the Frank model is the Soai reaction for the anhydrous synthesis of secondary alcohols (not amino acids) from aldehydes and dialkyl zinc compounds (Ávalos et al, 2010; Blackmond, 2004). While the Frank model has been proposed for an abiotic amplification by stereoselective autocatalysis and inhibition for the synthesis of L α-amino acid or L polypeptides, no experimental results have demonstrated a Frank-like synthesis route to chiral enrichment for either α-amino acids or polypeptides. The Soai reaction does not directly translate to any known prebiotic abiogenesis reaction conditions, whether terrestrial or extraterrestrial.

Since chirally pure enantiomers are very far from thermodynamic equilibrium, much research has focused on kinetic approaches to chiral amplification. Various α-alkyl amino acids with slight EE were found on carbonaceous chondritic meteorites. Extraterrestrial α-alkyl amino acids could be the origin of terrestrial homochirality if certain abiogenesis conditions were met: (i) their chiral EE was preserved, (ii) their chiral EE was transferred to standard α-amino acids or polypeptides; and (iii) their modest chiral EE was amplified to very large EE in standard α-amino acids or polypeptides (Breslow and Levine, 2006). Research continues toward experimental verification.

Some OoL research focuses on aggregates of α-amino acids for chiral symmetry breaking and/or chiral amplification. Ávalos (2010) reported that right-handed α-helix seed composed of L α-amino acids incorporates L-configured monomers around 18 times faster than D-amino acids. Nanita and Cooks (2006) noted that the α-amino acid serine can undergo repeated crystallization-dissolution, forming stable octomer clusters with high enantiomeric enrichment. Experiments have shown that mixtures with other α-amino acids give serine with mixed octomer clusters leading to their enantiomeric enrichment. No convincing prebiotic chiral amplification process for L α-amino acids or L polypeptides has yet emerged.

Degradation of Amino Acids and Polypeptides

Schwartz (2007) admitted that in prebiotic chemistry, unwanted by-products often consume most of the starting material and lead to nothing more than an intractable mixture, or "gunk." Chemical degradation and side reactions always compete with reactions that produce synthetic targets. Toward the goal of synthesizing homochiral L α-amino acid polypeptides, Figure 2 (V), any chemical reaction of the α-amino acids or the polypeptides that moves the chemical composition away from the intended product diminishes the yield. Chemical degradation is a serious concern in OoL research. "The conditions in primitive earth are very atrocious, so even if early life could be generated, how could it survive is a problem" (Chen and Chen, 2005, p. 995). At least three types of degradation reactions shown in Figure 2 compete with the abiotic formation of L α-amino acid polypeptides: (1) chemical decomposition (routes b, d, n, p, r, s), (2) polypeptide hydrolysis (routes h and k), and (3) racemization or epimerization (routes f and m). Some by-products of these degradation reactions may be recycled to α-amino acids or to polypeptides, but all reaction kinetics and thermodynamics requirements must be met in a quest for a naturalistic origin of homochirality in α-amino acids and polypeptides.

While the chemistry of α-amino acids and polypeptides is extensive (Hughes, 2009), a few important abiogenic degradation reactions shown in Figure 2 are highlighted here, specifically routes b, d, n, p, r, and s. While the terrestrial origin of α-amino acids and proteins could have occurred in the small amount of available freshwater on earth (the conditions used in most OoL experiments), Deamer (1997) points out that the more abundant terrestrial seawater is a mixture of relatively high ionic-strength mineral salts, giving conditions adverse to the formation and persistence of α-amino acids and proteins. One common example of the decomposition of proteins and α-amino acids is the family of Maillard reactions that occur between sugars and proteins. Maillard reactions are responsible for much of the browning and flavor development in food (Nursten, 2005). Formic acid decomposition reactions of amino acids and polypeptides have recently been reviewed (Boudreaux and DeMassa, 2013).

Amino acids are highly susceptible to ultraviolet (UV) photochemical decomposition, even under exposure to relatively low energy UV-visible photons. Ehrenfreund et al (2001) argued that amino acids in the diffuse gas phase, in ice crystals, in aqueous solution, or in any substance that can be penetrated by UV photons have a limited stability against photolysis. Extraterrestrial delivery of amino acids to the early earth required that amino acids were shielded from UV radiation in protected environments such as the interiors of comets or meteorites (Ehrenfreund et al, 2001). Thermal degradation of amino acids is also a critical problem for extraterrestrial delivery of OoL materials through the earth's atmosphere.

Polypeptide hydrolysis (the back reaction of synthesis) can occur between any pairs of α-amino acids in a polypeptide chain. Danger et al (2012) add that the half-life of the uncatalyzed hydrolysis of polypeptides to α-amino acids in neutral water varies from about 100 to 1000 years, depending on the amino acid and its position on the polypeptide chain (Figure 2, routes h and k). Metal ions (such as iron, copper, and zinc), aqueous base or acid, and elevated temperatures can accelerate polypeptide hydrolysis. Decomposition of polypeptides to diketopiperazines (DPKs) is direct decomposition route to organic and inorganic compounds (I) (Figure 2, routes r and s, and Figure 3; Danger et al, 2012).

Any emerging EE in amino acids or polypeptides is constantly jeopardized by spontaneous racemization (Jaakkola et al, 2008), which has been described as the "catastrophe of racemization" (Pizzarello 2006, p. 236) Klabunovskii (2012) estimated that early earth racemization of any EE of L α-amino acids could be *complete* in about 1000 years. Danger et al (2012, p. 5424) questioned how the chiral imbalance in α-amino acids or polypeptides "could be maintained in aqueous solution over long periods," and declared that this "remains to be explained."

In biological environments, the racemization of biological L-amino acids toward D-amino acids starts when counteractive biological processes involving D-amino acid oxidase metabolism becomes inactive after the death of a living organism. The increase of the proportion of D-amino acid in living organisms is used for archaeological and geochemical dating by a method called "the amino acid clock" (Meierhenrich, 2009; Grun, 2008; Miller et al, 2013). The amino acid clock has a considerable margin of error, because the rate of racemization of all α-amino acids is influenced by temperature, pH, humidity, and their position in a polypeptide. Csapó et al (1998) concluded that the half-lives of racemization of α-amino acids in proteins from biological systems generally range from a few thousand years to more than a hundred thousand years. While these racemization half-lives seem long, chiral preservation is a critical unsolved problem in abiogenesis research that postulates and requires millions and billions of years of naturalistic chemical evolution. Helmick (1976), writing from a creationist perspective, reviewed the significance of L-isoleucine racemization and presented a mechanism for both acid and base catalyzed racemization of this key amino acid.

Conclusion

In this early twenty-first century, no comprehensive, naturalistic explanation exists for life's origin, including even the relatively minor but essential challenge of the origin of homochirality in biological materials. Scientific research, instead of advancing the possibility of an abiogenic origin, actually continues to eliminate many mechanisms and reaction pathways as potential prebiotic routes to homochirality in α-amino acids and proteins. As all naturalistic routes to the OoL become more unreasonable and more unbelievable, fiat creation by God remains the realistic and sensible explanation for our existence. While many scientists remain nearly universally optimistic about the significance and future success of their own research, serious OoL researchers are expressing the scientific difficulty of finding a naturalistic explanation for life's origin, and even for just the small step on the origin of homochirality.

The existence of homochirality in all organisms on earth raises a question not satisfactorily explained in any current theory. We understand fundamental biomolecules better than ever, but the transition from chemicals to biochemicals in life is one that is elusive (McNichol, 2008). Work funded by the National Natural Science Foundation of China concluded that "in fact, there is no known way by which life could have arisen naturalistically" (Chen and

Chen, 2005, p. 996). "The ultimate origin of asymmetry in the universe is an unanswered question. … the large gap between molecular chirality and molecular evolution has become painfully clear" (Avalos et al, 2000, p. 891). The topic of the origins of life on earth is still largely one of theory and conjecture, given the vast period of time separating us from those key events (Coveney et al, 2012).

Meierhenrich (2009) opined that the problem (of the origin of homochirality of biological systems) may remain unsolved for a long period of time, if not forever. It is a shared opinion that we will never know exactly how life started on this planet (Saladino et al, 2012). Viedma and Cintas (2011) remarked that the genesis of enantiomer purity in nature (e.g., amino acids) has fascinated scientists for more than 150 years and the most that researchers can state with conviction is that we know what we do not know. A re-creation of the life's origin on earth will likely remain merely a surmise. Orgel (1998) concluded that it is not currently possible to decide issues of life's origin: not rejecting any theory out of hand, but admitted no theory is compelling and definitive answers will always be elusive.

Recent publications lead us to conclude that a scientific search for a naturalistic explanation for the origin for homochirality in amino acids and polypeptides will continue to fail for the foreseeable future. Many other aspects of the origin of life also remain unexplained by naturalistic science, including the irreducible complexity of living systems from the smallest biochemical systems to the largest ecosystems. It is important to realize that researchers assume evolution must have occurred in order to pursue experimentation that seems doomed to fail. Creationists assert that everything living is by God's command, "Let there be…" Even if a natural explanation for chirality (after all the failures mentioned above) becomes plausible, this still is a very minor step toward showing that life came from nonlife. With Louis Pasteur, creationists can boldly state that life comes only from life. The creationist explanation for the origin and preservation of life remains by far the only believable one.

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Fifty Years of Physics: Some Observations Regarding Radiohalos and Magnetic Fields

Eugene F. Chaffin*

Abstract

Some important evidence regarding tiny, spherical discolorations in rocks, seen in photographs as radiohalos, was reported in the *Creation Research Society Quarterly* in Volume 3, 1966. In 2002, another report was made regarding the decrease in energy in the earth's magnetic field over historical time. In retrospect, both of these papers were highly successful in advancing the creation model, and their significance will be reviewed here in honor of the 50-year anniversary of the Creation Research Society and its technical journal, the *Creation Research Society Quarterly*.

Introduction

When Creation models, or models of origins, are published, there is always some risk involved, the same as in studies of science that do not have much to do with origins. By "risk" I mean the likelihood that the proposed explanations may turn out to have little to do with reality. Subsequent observations or experiments may show that proposed explanations do not work or were based on assumptions that turned out to contradict other known results. So, in any scientific journal, there will be articles in the older issues that were based on sincere work by the scientists involved, but the results of that work are now mostly discarded. In this summary, I will review a few physics articles published during the 50 years of existence of the *Creation Research Society Quarterly* and will concentrate on a couple of articles I view as having been largely successful, at least in the furthering of Creation models.

Parentless Polonium Halos

In volume 3 of the *Quarterly*, issue 2, there appeared an article by Robert V. Gentry that brought the subject of radiohalos to the attention of the creationist community and showed that certain halos due to polonium isotopes were difficult to explain in the traditional uniformitarian paradigms (Gentry, 1966). Gentry did extensive observational and experimental work on radiohalos over his career and is arguably the world's leading expert on this subject. Halos are formed when small radiocenters of the size of a few microns are accumulated in rocks, and over time the subsequent radioactive decays send alpha particles out in all directions, forming a spherical region of damage to the crystalline structure of the surrounding mineral, which may be mica, corderite, sphene, etc. These spherical deformation regions are typically tens of microns in size and show up in photographs as circular, colored "halos." For creationists, Gentry reported the importance of halos due to Po-210 (half-life 138 days), Po-214 (half-life 164 microseconds), and Po-218 (half-life 3 minutes), which are distinguishable by the number of rings in the halo—one for Po-210, two for Po-214, and three for

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fully developed Po-218 halos, as shown in Figure 1.

The sizes of these rings are correlated with the predominate energies of the alpha particles emitted in the decay of the parent nuclei. Using various advanced experimental techniques, Gentry and his colleagues at Oak Ridge National Laboratory cast doubt on the idea that the polonium was a result of the accumulation of uranium-238 or any other radioactive precursor at the radiocenter that subsequently formed the radiohalo. He instead favored the hypothesis that these halos were the result of the Creator forming them along with host granite rocks during the six-day Creation week. After all, numerical simulations of the accumulation of the polonium at such sites could not result in the formation of a halo, since that would require somewhere around 10^8 to 10^9 decays, and the halo rings due to the progenitors such as radon are not found and the half-lives of the polonium isotopes in question are much too short for them to accumulate in the short times that are necessary. Snelling (2005) favored the hypothesis that many of these halos were formed during the Genesis flood and cited overwhelming geological evidence that these halos are found in Flood rocks (Phanerozoic rocks) rather than Creation-week rocks. However, Snelling (2005) did not offer a way for these halos to form on the time scales involved, instead he appealed to other evidence uncovered in the RATE (Radioisotopes and the Age of the Earth) project that half-lives may have changed over earth history and particularly at the time of the Genesis flood.

My own work (Chaffin, 2000, 2005, 2008), which was done along with some former students of mine, offered possible mechanisms for the accelerated decay that was involved. In the case of alpha-decays, the proposed mechanism involving a change in the strength of the nuclear force over earth history could also result, for some isotopes, in a decrease in the half-life, while others would have an increase in half-life. The work showed that the half-life for alpha-decay, proceeding by quantum mechanical tunneling, could radically change as a function of the strength of the nuclear force. Figure 2 shows a plot of the decay constant, which is the fraction of the

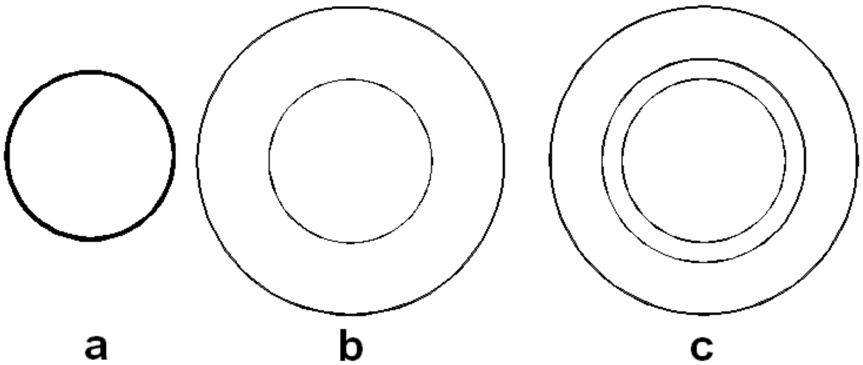

Figure 1 Polonium halos. Part a represents a Po-210 halo, which has a radius of 18.8 microns. Part b is a Po-214 halo, which includes the Po-210 ring plus another ring of radius 34 microns. Part c is a Po-218 halo, which adds a ring of radius 22.5 microns to the Po-214 halo. The corresponding alpha-particle energies are 5.30 MeV for Po-210, 6.00 MeV for Po-218, and 7.69 MeV for Po-214.

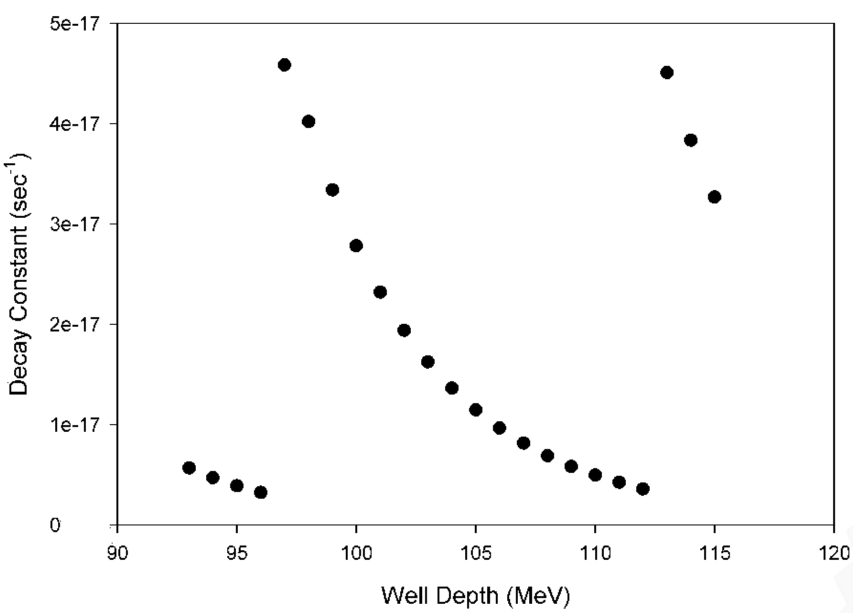

Figure 2. The decay constant, which is the fraction of the nuclei decaying per unit time, is plotted versus the nuclear well depth for the alpha particles. If the well depth, which measures the strength of the nuclear force, were to change over earth history, then there could be either increases or decreases in the decay constant, depending on the initial value of the well depth.

nuclei decaying per unit time, versus the nuclear well depth, which measures the strength of the nuclear force. I also presented experimental evidence, based on studies of double-beta-decay, which indicate a change in beta-decay half-lives at the onset of the Genesis flood (Chaffin, 2009, 2013) and, by implication, alpha-decay half-lives also.

The mechanism of halo formation supported by Snelling's work could not occur unless the very short half-life polonium isotopes had a prolonged half-life during the time they were being formed, i.e., while the polonium precursors were being transported by hydrothermal flows to the sites where the halos formed.

One should also mention the helium diffusion work of Humphreys (2005), which continues to offer evidence for a period of accelerated decay in order to explain the amounts of helium in zircons from the Jemez Mountains boreholes, New Mexico. This work was originally begun by Gentry, Glish, and McBay (Gentry, et al., 1982).

Thus, in spite of the questioning of the model that Gentry put forward to explain his halos (Brown, 1990; Gentry, 1990; Snelling, 2005), I still consider his work to be highly successful, since it brought the relevance of these polonium halos to the attention of creationists and offered the results of various very technical procedures as supporting data. Gentry's article in the *Quarterly* was a milestone that deserves applause.

Earth's Magnetic Field Is Fading Away

Another example of a successful model is a 2002 scientific paper by D. Russell Humphreys showing that Creation models of the decrease in the earth's magnetic field were not guilty of neglecting higher order effects. Barnes (1973) had originally proposed a test of origins models based on the observationally observed decrease in the earth's magnetic dipole. A simple dipole consists of a north pole and a south pole, a short distance apart. The earth's magnetic field, at least in the first approximation, can be represented by imagining a dipole located deep within the earth. Observational data, beginning with measurements of the earth's magnetic dipole dating back to the early 1800s, showed that the earth's dipole strength has been decreasing exponentially over time.

When we try to represent a magnetic field that is only approximately a dipole field, the necessary next-to-leading order correction is called the *quadrupole term*. We add the field produced by the quadrupole term to correct the dipole field found at each point. Prior to the 2002 work of Humphreys, an anticreationist could have claimed that the decrease in the earth's dipole field was compensated for by an increase in the quadrupole term. Humphreys, however, gathered the necessary data and actually did the calculations of the total energy in the earth's field due to both dipole and quadrupole contributions. His results showed that the non-dipole is increasing, but the energy gained by the total non-dipole contributions is not nearly as much as the energy lost by the total dipole contribution. This net decrease in the energy is a fact that has not been successfully explained by advocates of the traditional evolutionary timescale. According to their model, the total energy should not decrease appreciably except over a timescale of millions of years. Hence, the earth's magnetic field offers evidence of a timescale of only thousands of years, not billions of years, for Earth history.

Conclusion

The Gentry work on radiohalos is very difficult to explain, unless radioactive decay rates have varied over Earth History. Andrew Snelling's work speaks in favor of a large amount of change in decay rates during the Genesis flood, since rocks attributable to the Genesis flood contain numerous halos due to polonium isotopes. If it is possible to explain these halos as due to hydrothermal flows, it is only by also involving changes in decay rates after their formation. Humphreys' work on energy contained in the earth's magnetic field indicates a much more rapid decline in this energy than should be occurring if the field were due to the mechanisms offered by the old-earth advocates. Those interested in accurate views of Earth history would do well to consider these results.

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Fifty Years of Chemical and Biochemical Examination of Evolutionary Theory in the *Creation Research Society Quarterly*

Theodore J. Siek*

Introduction

The subject matter in this review focuses on the application of chemistry and biochemistry to the presumptions, speculations, and theories of chemical evolution. This review, covering articles published from 1964 to the present, is not presented chronologically. Rather, the order of presentation here follows the alleged route of "chemical evolution," or abiogenesis, which occurred in an assumed primitive, reducing (no oxygen) atmosphere by purely natural processes without divine guidance or direction.

Formation of Amino Acids in the "Primitive Atmosphere"

An Israeli scientist, M. Trop (1979), presented substantial, if not fatal, problems in the chemical evolution of amino acids, pointing out not only the chirality issue but also the many competing reactions that would occur from any realistic consideration of chemicals present in the primitive atmosphere. There is no empirical evidence for an oxygen-free atmosphere in the history of the earth.

The famous Miller experiment was closely examined by DeMassa and Boudreaux (2013). They noted that the organic substance present in the highest yield (3 X more than the highest yield amino acid) was formic acid. Formic acid would act to terminate peptide formation beyond a few amino acids, stopping chemical evolution at the onset.

First and Second Law (Entropy) Considerations

In 1966 Emmett Williams began his argument that the first and second laws of thermodynamics are incompatible with biological development and provided articles in *CRSQ* over three decades. His 1971 *CRSQ* article considers entropy flux as heat flow, steady states of living organisms, and entropy. Williams (1967, 1969, 1973, 1979, 1992) addressed the "entropy excuses" of materialist scientists such as Prigogine. Penny (1972) considered the distinction between the first and second laws, useful energy becoming unavailable, dispersed heat, the role of our sun, and life's destiny assuming universal evolution. An improbability of forming one 300-amino-acid peptide (protein) by random chance is given as $1/10^{515}$—an impossibility.

D. Russell Humphreys (1978) presented a brief but important consideration of whether the earth's sun and source of enormous energy could provide the entropy uptake for the entropy loss during evolutionary gain in complexity. The answer to the sun as entropy gain during entropy loss as life emerged and evolved is presented in this short article. The sun provides 140×10^{12} cal/deg/sec (entropy flux unit), and this heat energy influx necessarily increases entropy on the earth. The sun is acting on the earth to provide energy for food production, and food in turn will keep the entropy in living things in check. The total entropy of the earth and sun, however, will continue to increase (also discussed below).

Creager (2012) applied second law considerations to the origin of life, information theory, DNA matters, and whole living systems. Whether or not entropy increases or decreases depends on (1) what form of energy or information is provided, and (2) whether a designed system to receive the energy is present

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in life, such as chloroplasts in plants or metabolic systems in animal life.

Secular scientists fully admit that the chemistry of life depends on "non-equilibrium but steady state" biochemistry. Nobel Prize winner E. Schroedinger stated that the defining property of living systems is the ability to reverse entropy and keep it in check throughout life (Ricardo and Szostak, 2009). Biochemical processes move to equilibrium and maximum entropy at the time of death. Exact quantitative measurements of entropy during life are far too complex to measure; biochemical steady states may be considered metastable equilibria removed from true equilibrium or maximum entropy.

The Chirality Problem and Synthetic Problems

Coppedge (1971) wrote concerning the probability of purely L-amino acids being formed by natural processes and provided a number of probability calculations supporting his thesis that that such stereo-specificity is flat-out impossible.

Helmick (1976) noted that L-amino acids racemize (convert from L to the D form) with time by acid or base catalysis, and this rate provides a molecular clock if properly used. Racemization of chiral amino acids and peptides would prevent chemical evolution.

Murphy (2013) critiqued the attempts by investigators to overcome the chirality issues and the immense difficulties in forming peptides from amino acids by a fortuitous, purely naturalistic process, one unassisted or caused by God.

Formation of Proteins, Carbohydrates, and Nucleotides including ATP by Evolution

Trop and Shaki (1974) found the naturalistic evolution of proteins to be a mathematical impossibility, even with absurd rates of protein formation (10^{13}/sec.) over all of evolutionary time. Baurer (1971) considered how life, being carbon-based, is designed for great versatility in the kinds of molecules available, including alkanes, alkenes, alcohols, aldehydes, acids, amines, ketones, ethers, esters, and a vast variety of carbohydrates. Boudreaux (1997) reported on the thermodynamic possibility of silicon and not carbon as foundational atom for life. Silicon was proposed as a possibility, reasoning that since life is an accident, life based on silicon's four bonds, instead of carbon (four bonds), may be expected in other inhabitable planets or could have been the evolutionary outcome on earth if there had been a different chemical evolution history.

Bergman (1999), a prolific contributor to creationist science, noted the design aspects of ATP, the perfect energy currency for living cells. He examined the endosymbiosis theory of mitochondria (with ATP) being initially a primitive stand-alone life-form. Design in lipid molecules was presented by Heyes (1986). Smith and Brown (1985) reviewed the conjecture that mitochondria existed independently and then fused with prokaryotes to form eukaryotes. Anderson (1989) noted that even given the production of necessary biochemicals through chemical evolution, the formation of an initial living cell capable of reproduction is still far too complex to have occurred by natural means.

From Prebiotic Chemistry to "Protocells" and on to LUCA, to Bacteria, and Up

Boylan (1978) reviewed the entire speculated sequence from the primitive atmosphere to the multiplication of species. He noted the thermodynamic and probability barriers to common descent (universal evolution). He noted that the number of possible arrangements for a small protein formed with the 20 standard amino acids of 100 in length is 10^{130}. In addition, the probability of the chance occurrence of life on earth, even with repeated trials of a billion/second for all of supposed evolutionary time, spirals to 1 in 10^{103}, which makes it beyond any reasonable definition of possible.

Biochemist Duane Gish, a noted creationist, presented a thorough discussion (1979) covering all the origin-of-life proposals up to that time and detailing the experimental failures. All steps from nonlife to life proposed by evolutionists were discussed by Gish. John Moore (1985) also reviewed origin-of-life proposals.

Extraterrestrial Origin-of-Life-on-Earth Theories

Intractable barriers to the evolution of life on earth have led to the desperation of proposing that life exists on other planets and this life was transported to earth in the distant past. This "exobiology" became widely popular in the 1960s and 1970s through the topic of unidentified flying objects (UFO's). Bergman (1995) reviewed the ideas surrounding life from outer space promoted by notables such as Carl Sagan, Orson Wells, and H. G. Wells.

Nobel Prize winner Francis Crick once proposed life from outer space to overcome the incredible improbability of life appearing on earth. Many astronomers today are searching for signs of life on other planets, some thinking that finding extraterrestrial water is evidence for life beyond earth. Some theologians have argued that because God created life on earth, He could have done so elsewhere in the universe (the Bible does not specifically preclude this). Countering the extraterrestrial speculations are those showing the unique location (distance from the sun), physical constants, temperature, rotation time, and atmosphere that are just right for life to exist on the earth and only on this earth. Clearly, there is not a hint in the Bible of sentient life beyond earth.

Life in the Test Tube Studies

Biologists generally agree that the essential characteristics of life are (1) complex organization, (2) metabolic energy transformation, (3) growth, (4) reproduction, (5) irritability, and (6) adaptation within limits. Creationists and some evolutionary biologists have pointed out another mandatory characteristic, (7) information to direct and control life processes. Creationists rightly insist that Information can arise only by the design of superior, transcendent intelligence—God. Materialists have falsely assumed that information can arise in the genome (DNA) by accumulated random additions to the genome—a theory that is becoming more and more difficult to defend.

Frair (1968) examined the speculations of evolutionary biologists in progressing from virus to protocells. A particular *in vitro* experiment cited showed that DNA polymerase did not produce "test tube" DNA if nuclease were present, as it is in every cell. In living cells, the polymerase and nuclease activities are prevented from countering each other at the same time. Because viruses lack many of the classic characteristics of living systems (e.g., metabolic transformation of energy) and can reproduce only in a host cell, they are not considered living organisms and are considered just replicative entities.

McDowell (1971) connected information to entropy by pointing out how the statistical form of the second law of thermodynamics resembled the relationship of information content and probability. Anderson (1989) critiqued the alleged primitive predicament, particularly the supplying of energy to protocells existing before LUCA (last universal common ancestor) and prokaryotes. Moore (1985) commented on what would be the creationist response if life were synthesized in the test tube.

When insulin was first synthesized, some claimed this was the creation of life in the test tube. This claim is no longer made since biochemists have become more skilled in taking components from cells and inserting them into other cells and producing a metabolic step or reaction. Evolutionists will always utilize biochemical components produced and taken from living cells in their "life-in-the-test-tube" experiments.

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Fifty Years of Earth Science in the *Creation Research Society Quarterly*

John K. Reed*

Introduction

In 1964, the first issue of the *Creation Research Society Quarterly* (*CRSQ*) appeared in print; an annual issue, preceding volume 1, number 1. In it, Clifford Burdick published the first geological article, entitled "Streamlining Stratigraphy." Since then, 851 articles, letters, notes, and photo essays, contributed by 276 authors, have slowly developed geological thinking within the creationist framework.

At heart, the Creation Research Society (CRS) is a Christian organization, although people who are not Christians might agree with many of its positions, especially those warning about problems with the modern secular academic establishment. That CRS is Christian should not be surprising; science is, after all, a Christian endeavor. Although it was hijacked by secularists during the Enlightenment, its roots have always remained firmly embedded in biblical theology.

As a Christian organization in the midst of a secular intelligentsia, the path of CRS has been uphill. Money, power, numbers, publishing outlets, and honors are not the lot of creationists, and our work is often less polished and sophisticated than that of the world. But these things are not the measure of truth; truth has its own power, granted by the Author of truth. God does not work with the proud; instead, he uses the weak and foolish things of this world to shame the wise.

The power of truth is the most precious commodity of our work. It works through the balance between innovation and apologetically addressing the claims of secular natural history. In the first case, the work of creationists needs to be groundbreaking, questioning the most basic assumptions and methods. In the latter sense, the sheer volume of work generated by secular scientists inevitably drives their disciplines' trends, and so we must follow after, like janitors sweeping up the detritus of deceit from the floor of truth.

Creationists have done both, although perhaps not in a self-conscious manner. Fulfilling our apologetic duty, we have shed light on the false ideas of uniformitarianism, actualism, naturalism, deep time, evolution, and the twisted meme of "science vs. religion." But we also have been forced to address current theories, especially in stratigraphy and tectonics—two of the most powerful topics in today's earth sciences. We do not have the luxury of thousands of educated, trained, and paid staff. Instead, we must find the weaknesses in the edifice and bring the power of truth to bear on those parts. Doing so is not only a service to our faith, but it is a service to science, which, thanks to its Christian roots, has preserved at least a superficial regard for truth. Furthermore, we must be in the business of creating disciples, so that the next generation will not lose the light of truth.

It is in this context that the work of the past fifty years must be measured. An examination of trends, topics, and contributors to the geological corpus of the *CRSQ* reveals a long history of faithful service in search of truth. It shows the self-correcting benefits of scientific debate and the means by which such debate should (and should not) take place.

Please note that categorization of articles, especially the older ones, is largely based on abstracts and that a degree of error is unavoidable. Some contributions are not easily classified. However, these errors are small compared to the general trends shown, and the conclusions that can be drawn from them are probably sound. For convenience, we will examine the earth sciences in the *CRSQ* on a decade-by-decade basis.

Earth Sciences Articles

Over the past five decades, a variety of trends can be discerned from the *CRSQ* contributions in the earth sciences. During the 1970s, contributions

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climbed as authorship grew, although most of them were articles (Figures 1 and 2). Total contributions soared again in the 1990s, and many of these were letters to the editor, Panorama of Science notes, photo essays, and other special papers. That decade also marked more debate, as well as the introduction of a new generation of productive writers.

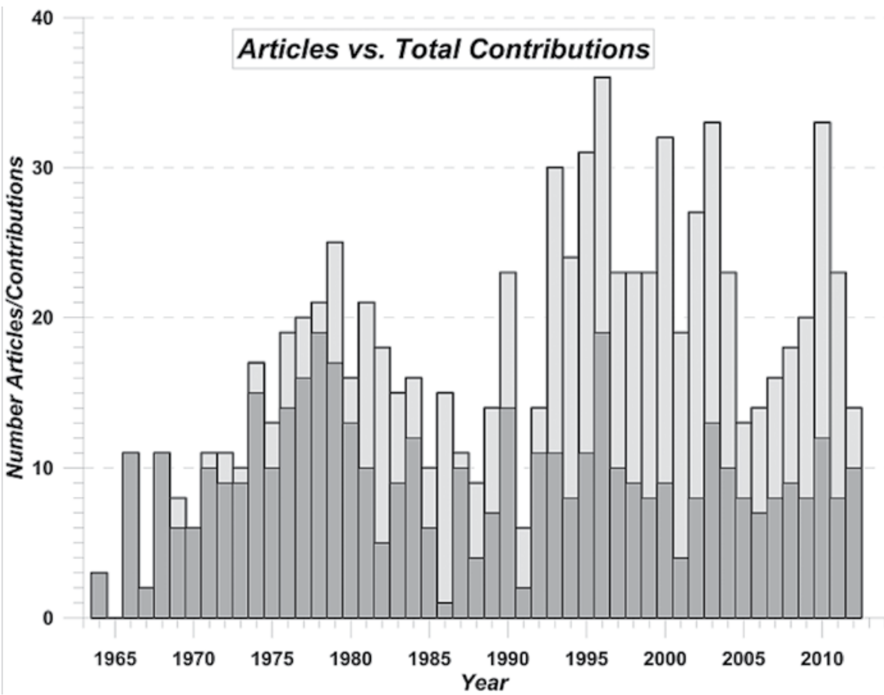

Figure 1. Comparison of total earth science articles (dark gray) and contributions (light gray) by year. Articles peaked in the 1970s, but total contributions soared in the 1990s with an increase in letters, Panorama of Science notes, and special papers.

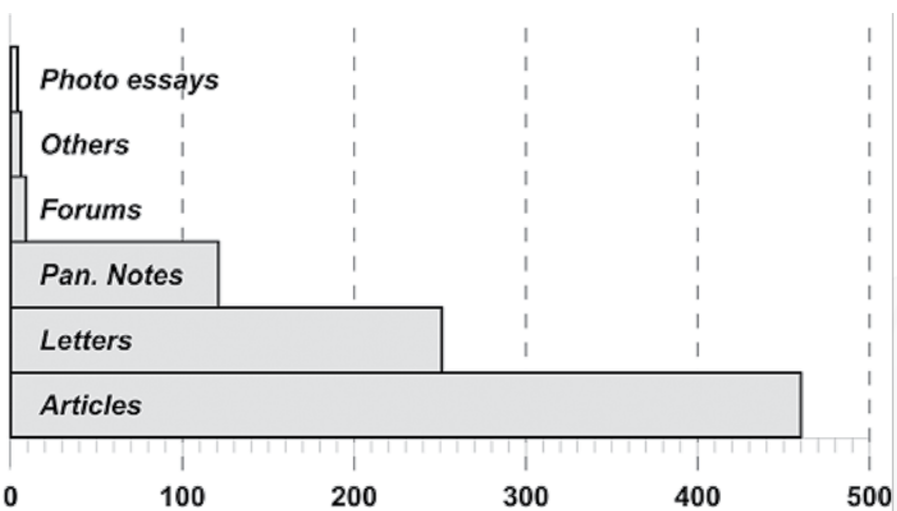

Figure 2. Total contributions by type over the history of the *CRSQ*. The large number of letters indicates an informed readership and many good discussions.

Articles have been the staple of the *CRSQ*, as would be expected (Figure 3). In addition, a steady stream of letters to the editor developed into a number of good exchanges on controversial topics. Current policy allows one letter and response per published paper; those desiring a more in-depth discussion can participate in an Editor's Forum, which allows several exchanges.

1960s

The first six volumes of the *CRSQ* saw 35 contributions in earth sciences and related fields by 22 authors. Clifford Burdick wrote 5 of these; Henry Morris and Harold Slusher contributed 3 apiece. Eight authors wrote multiple pieces, while 14 others wrote one. Of the 35 articles, 33 were written by a single author. Whether this was from the individualistic nature of the men or from the newness of the concept is not clear.

I would classify 21 of the articles as "field studies" in the sense that they worked with specific data or at specific locations. Eight of the others were general conceptual articles, and 6 others were critiques of secular ideas. Most of the papers dealt with radiometric dating, paleontology (including paleoanthropology), and sedimentation/stratigraphy.

This decade saw several significant articles. Robert Gentry wrote on the significance of pleochroic haloes. His research was later summarized in a book (Gentry, 1986). Harold Coffin began his decades-long study of petrified, polystrate trees at Joggins. He would later do definitive research at the Yellowstone fossil forests. Clifford Burdick reported fossil pollen in Precambrian strata in Grand Canyon—a report that still generates interest and controversy.

1970s

The 1970s (volumes 6–16) saw an explosion of earth science publications in the *CRSQ* with 124 articles, 6 notes, and

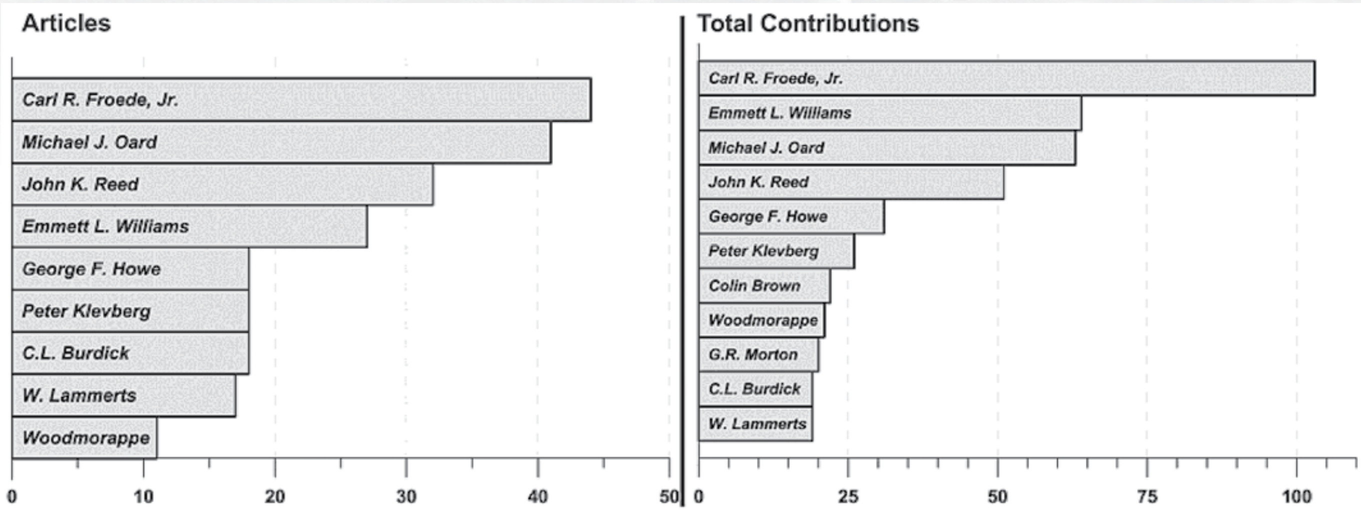

Figure 3. Many authors have contributed to the *CRSQ*. These graphs show contributions by article and by total contributions, including articles, panorama notes, letters to the editor, photo essays, and editor's forums. These include single and multiauthor efforts.

23 letters. Of the articles, only 8 were by multiple authors, suggesting that creationism was still a highly individualistic endeavor. Clifford Burdick wrote 12 articles, Douglas Cox contributed 8 articles and a letter, and Joseph Dillow published 5 articles and a letter, setting the stage for his book on the vapor canopy (Dillow, 1982). Altogether, 26 authors published multiple papers, with early efforts from later prolific authors like George Howe and Emmett Williams, and those of leaders in the field like Don DeYoung, D. Russell Humphreys, and Steve Austin (writing as Stuart Nevins).

This decade also saw the initial publications by two prominent contributors to the *CRSQ*, Michael Oard and John Woodmorappe. Oard was to become one of the most prolific writers in creationism, while Woodmorappe would set high standards for exhaustive research and technical insight.

I would classify 64 of the articles as "field studies" in the sense that they worked with specific data or at specific locations. Another 43 were general conceptual articles, and 17 were critiques of secular or creationist ideas or responses. Most of the papers dealt with sedimentation/stratigraphy, radiometric dating, and paleontology. But the 1970s saw an increase in the variety of papers, especially in glaciology and meteorology. Some of these reflect a growing interest and investigation into the possibility of a pre-Flood vapor canopy and into the post-Flood Ice Age.

The late 1970s marked the beginning of a protracted debate about a pre-Flood vapor canopy. Today, few believe that such a canopy could have accounted for the total rainfall of the forty days and nights of rain. Others think a canopy existed but was not a significant source of the Flood's rain. In either case, the debate itself marked a high point in the history of the *CRSQ*. An important idea was discussed in a professional and courteous fashion, stimulating new research. It largely stayed on subject, kept to the substance of the issue instead of the personalities, and moved creationist thinking forward. In these ways, it provides a template for addressing controversial topics.

1980s

The 1980s (volumes 16–26) saw a leveling off of earth science publications in the *CRSQ* with 85 articles, 19 notes, and 41 letters. Of the articles, 11 were by multiple authors, an increasing percentage suggesting the development of networks among creationists. There were fewer articles in the 1980s than the 1970s, but a greater number of Panorama of Science notes and letters. Glenn Morton led the way with 18 contributions, Walter Lammerts wrote 12 papers, Emmett Williams had 13 contributions, and George Howe, 11. During the early part of the decade, the debate on the vapor canopy came to an end, although the total count for meteorology remained high, as the debate was intense before it ended. Many of Morton's articles were skeptical of creationist ideas, marking his evolution to an old-earth opponent of the movement. Old stalwarts, such as Clifford Burdick and Thomas Barnes published several articles apiece.

This decade also saw the detailed and comprehensive papers of John Woodmorappe on the rock and fossil records. He would later use them as the basis for a book on the Flood in 1993 that was later republished by the Institute for Creation Research (Woodmorappe, 2000). These articles remain examples of some of the finest work the *CRSQ* has published.

I would classify 23 of the articles as "field studies" in the sense that they worked with specific data or at specific locations. Another 32 were general conceptual articles, and 30 were critiques of secular or creationist ideas. There was a marked increase in the percentage of critiques; creationists were investigating problems with uniformitarian ideas to a greater extent. A number of these were the series by Walter Lammerts on out-of-order strata. Most of the papers dealt with paleontology or sedimentation/stratigraphy, with a large number of papers and letters addressing the vapor canopy concept early in the decade.

Another debate focused on the earlier discovery of fossil pollen in the Precambrian Hakatai Shale by Clifford Burdick. George Howe and Emmett Williams addressed criticisms of Burdick. Another interesting research project was the work done by Eugene Chaffin on the Oklo natural reactor.

1990s

The 1990s (volumes 26–36) saw a significant jump in the number of earth science publications, with 233, including 103 articles, 44 Panorama of Science notes, 82 letters, a photo essay, and three Van Andel Center research notes. Of the articles, 31 were by multiple authors, an increasing percentage suggesting increasing networking. Fourteen other contributions were also from groups. This decade saw a mix of new and established authors. Carl Froede Jr. wrote an amazing 45 contributions to the *CRSQ*, followed closely by Emmett Williams with 34. Michael Oard followed with 22, John Reed with 15, and George Howe with 14. This decade saw the beginnings of debates over Flood models: the hydroplate model introduced by Walt Brown and the catastrophic plate tectonics model presented by a group of six scientists and since pursued most vigorously by John Baumgardner (Austin et al., 1994; Baumgardner, 2003). Other creationists began to develop their own comprehensive Flood models (Bardwell, 2011). Other discussions addressed the role of the geologic timescale in creationist geology, with an array of opinions, ranging from full acceptance of the chronostratigraphic timescale through a rejection of both the chronostratigraphic and geochronologic scales.

I would classify 57 of the articles as "field studies" in the sense that they worked with specific data or at specific locations. Another 29 were general conceptual articles, and 17 were critiques of secular or creationist ideas. There was a marked increase in the percentage of field articles, helped by a CRS research project at Big Bend and fieldwork by Carl Froede Jr. Most of the papers dealt with sedimentation/stratigraphy or paleontology, with an increasing focus on geomorphology, Flood models, and the history and philosophy of science.

2000s

The 2000s (volumes 36–46) remained at historically high levels for earth science publications, with 215, including 84 articles, 44 Panorama of Science notes, 72 letters, 9 forum contributions, and 6 others. Of the articles, 21 were by multiple authors, although groups of authors tended to remain fairly fixed. Fifteen of the other contributions also were from groups. This decade saw a decrease in the total number of authors from the previous decade, with several of the older members completing their writing careers or passing away. Carl Froede Jr. remained the most prolific writer with 39 contributions to the *CRSQ*, followed by John Reed, Michael Oard, Peter Klevberg, Emmett Williams, Colin Brown, and Jerry Akridge. This decade saw growing debates over Flood models, and the review group sponsored by *In Jesus' Name Productions* compiled a voluminous but helpful e-book on the most prominent (Bardwell, 2011). Another source of controversy was the use of the standard geologic timescale in Flood geology, which prompted an anthology by CRS in 2006 (Reed and Oard, 2006).

I would classify 57 of the articles as "field studies" in the sense that they worked with specific data or at specific locations. Another 29 were general conceptual articles, and 17 were critiques of secular or creationist ideas. There was a marked increase in the percentage of field articles, helped by a research project at Big Bend and fieldwork by Carl Froede Jr. Most of the papers dealt with sedimentation/stratigraphy or paleontology, with an increasing focus on geomorphology, Flood models, and the history and philosophy of science (Figure 4).

Contributors

Over 250 authors have contributed to the geology section of the *Quarterly*, including such notables as Dr. Henry Morris, Dr. Walter Lammerts, Dr. Thomas Barnes, Dr. Emmett Williams, Dr. George Howe, Dr. Russell Humphreys, Dr. Harold Coffin, Dr. Robert Gentry, Dr. Steve Austin, Dr. Andrew Snelling, and John Woodmorappe. However, the most prolific authors are Carl R. Froede Jr., Dr. Emmett L. Williams, and Michael J. Oard (Figure 3). Nineteen authors have authored 10 or more contributions, 98 authors have authored between 2 and 9, and 159 authors have made a single contribution.

From 1964 to 1993, from volumes 1 through 29, editorial direction of the earth sciences was undesignated. The senior editor was able to call on the expertise of engineer Henry Morris and geophysicists Thomas Barnes and Donald Acrey. Acrey ended his service in 1978, during volume 14. Barnes and Morris continued until 1993, when they completed their long and distinguished service to the *Quarterly*. At that time, senior editor Donald DeYoung called on the expertise of geologist Robert Gentet and physicist Russell Humphreys to provide editorial direction in the earth sciences. In 1998, during the tenure of Eugene Chaffin, John K. Reed became the geology editor and has since served under Chaffin, Emmett L. Williams, and Kevin Anderson.

A summary of broad topics shows significant diversity of interests (Figure 4) but emphases that mimic the secular earth sciences. Field studies combined with articles critiquing secular stratigraphy lead the way, with paleontological articles and notes following after. Isotopic dating methods have always been of interest, and the subject is well represented. Creationism diverges slightly from secular earth history in an ongoing emphasis on geomorphology, especially by those authors who believe that many extant landforms are relics of the Flood rather than post-Flood processes. Michael Oard has been a leader in this field. There also has been a strong interest in the assumptions and methods underlying earth history research, as is reflected by a steady stream of articles within the topics of the philosophy and history of science. An area that is gaining in popularity over the past decades is the creation and debating of various Flood models and their ability to explain Earth's tectonic features and new data from its interior.

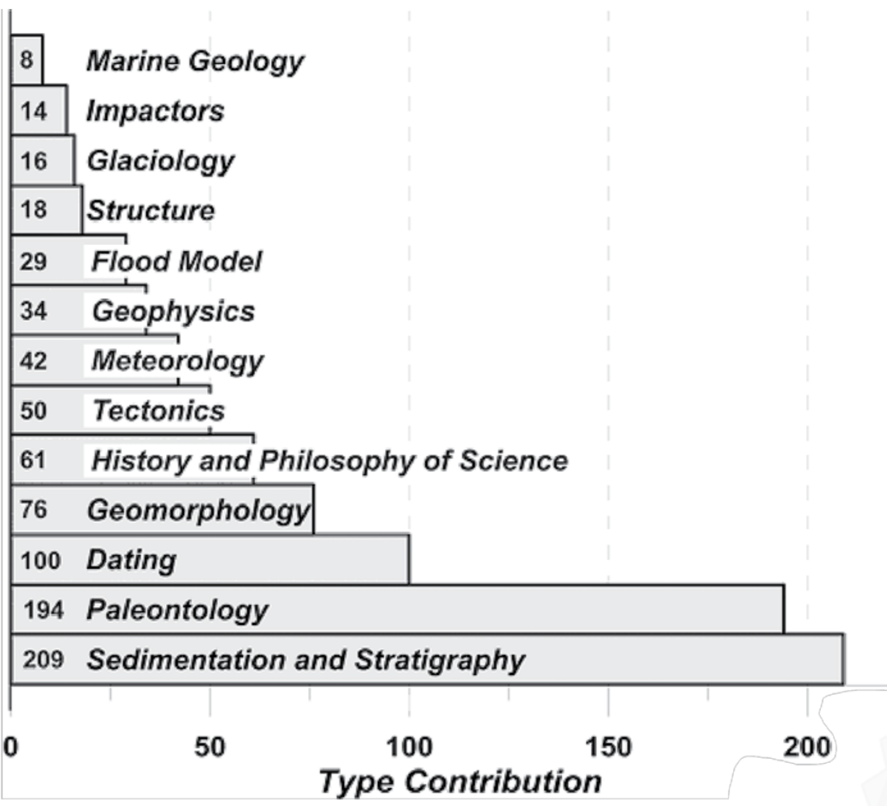

Figure 4. A breakdown of the categories covered by papers, notes, and letters is shown above. While stratigraphy, paleontology, tectonics, and dating methods are of obvious interest, the number of papers on geomorphology illustrates that this relatively minor discipline in secular geology is of great interest to creationists. Papers on the history and philosophy of science indicate a concern with the extent to which the worldview of naturalism has infiltrated the sciences over the past two centuries.

A Look Ahead

What does the future hold for the earth sciences in the *CRSQ*? It remains the grandfather of creationist journals, celebrating its 50th anniversary, and today is joined by the *Journal of Creation* and the *Answers Research Journal*. It has seen a wide variety of papers submitted both by degreed professionals and enthusiastic amateurs. Although articles provide the bulk of the *CRSQ* publications (Figure 2), the increase of notes, letters, and debates has produced a lively and interesting mix. The combination has resulted in a diversity of opinion that has stimulated a number of welcome discussions. Professional and courteous discussion of the many issues that face creationism will continue to be an emphasis of the *CRSQ*. Especially welcome are the numerous letters and the new Editor's Forum debates.

CRS is unique in several ways. It is a professional society that relies on the volunteer efforts of its members to do research and publish articles in the *CRSQ*. It is not an organization that focuses on public presentation by paid staff, although some staff provide popular presentations to church and parachurch organizations. The society welcomes and supports any efforts that promote the truth of Genesis and its application to science, religion, and life.

We thank God for the faithful work of many people over the past 50 years to maintain the quality of the *CRSQ*. It is truly a team effort. We also hope to see a new generation of scientists dedicate themselves to the work of the society and to the continued publication of interesting and informative technical articles for another 50 years, if God allows it.

The *CRSQ* is dedicated to professional and courteous discussions of topics related to Creation and Earth's history. Reinterpreting the vast data of related secular sciences is an enormous task, and there are still foundational issues that are not well understood or have not reached consensus among creationists. Many secular academic debates appear to be founded on pride. We must make sure our arguments are directed toward pursuit of truth within the biblical framework of Earth history.

Conclusion

Over the past five decades, more than 250 authors have expressed their support for biblical truth in a dedicated, insightful, and professional effort. Many subjects of the earth sciences have been discussed; many more require work. It is my profound hope that God will raise up many more workers in this field—"the harvest is plentiful, but the workers are few" (Matthew 9:37 NASB).

In addition to addressing current topics in the earth sciences, creationists need to develop their own ideas and models. While a comprehensive Flood model may not yet be possible, models of smaller, more specific processes and events within the Flood would be welcome, both to pave the way to a fuller understanding of this great event and to provide greater explanatory value to creationist work.

Finally, as we see ourselves in God's economy—the weak and foolish things that shame the wise (I Corinthians 1:27)—let us make sure we do not become so caught up in shaming the wise that we lose sight of the fact that even the best of us are still weak and foolish. We can do anything through Christ who strengthens us, but apart from Him, we can do nothing.

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Author and Title INDEX for Volume 49, 2012–2013

Robert Mullin*

This title/author index covers articles, panorama notes, and other features. For items with two or more pages, the reference is to the first page only. After the page number, a letter indicates which type of entry is involved: article (A), panorama note (P), letter to the editor (L), book or video review (R), cover photo (CP) or other departments (such as editorials, editor's forum, laboratory director's comments, president's remarks, photo essays, etc.) (D).

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Letters to the Editor

The policy of the editorial staff of CRSQ *is to allow letters to the editor to express a variety of views. As such, the content of all letters is solely the opinion of the author, and does not* ***necessarily*** *reflect the opinion* ***of the*** CRSQ *editorial staff or* ***the Creation Research Society****.*

The Origin of the Virus

Editor,

The origin of the virus is a mystery. Animal and plant viruses can be DNA or RNA. The plants these viruses attack are angiosperms and fungi.

There may be a slight hint at where the virus comes from in the type-C virus, so called because of its spherical shape. These seem to be generated by the cell itself (Hoyle and Wickramasinghe, 1981). We need more data on this.

Something quite amazing in the virus story has come to light with the discovery of a virus so large it can be seen through a standard laboratory microscope. Its size is 1000 nm, and it has been given the name Pandora (Coghlan, 2013). A common virus has fewer than 10 genes; Pandora has 2556. It is jokingly said of it that its cellular ancestor has disappeared!

This virus has posed even greater challenges to understanding the true origin of viruses, which still remains unknown and requires more data.

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Darwin's Theory Inspired by Charles Babbage

Introduction

Charles Babbage, FRS (December 1791–October 1871), an English polymath, was a mathematician, philosopher, inventor, and mechanical engineer (Bell, 1975). Today he is best remembered for originating and developing a programmable mechanical computer. He invented a practical, but enormously complex, machine that he called a *calculating engine*, later known as a *difference engine* (Hyman, 1982). From 1828 to 1839 Babbage was Lucasian Professor of Mathematics at Cambridge University.

Babbage was a creationist, but he attempted to harmonize the scientific speculation of his day with the Scriptures by rationalizing that God used natural law to create. As such, he argued that creation within the bounds of natural laws does not negate God's role in Creation. The end result was that Babbage played a role in reducing the popularity of the teleological argument for God (a reason many people give for their belief in God). His father, a wealthy banker, left him a fortune, yet the "cheerful young man [turned] into a bitter old one" (Morrison, 1995, p. 418). One wonders if Babbage's revised view of God contributed to this change in his personality.

His Influence on Darwin

It is well known that Charles Darwin was not the first to suggest the idea of evolution guided by natural selection (Bergman, 2011). Evidence exists that no less than a dozen scientists in Darwin's time proposed views similar to those of Darwin (Ospovat, 1981). Furthermore,

> Darwin was well aware that he would not be the first to propose the evolution of organic species. Darwin's own paternal grandfather, Erasmus Darwin, had noted in his book *Zoonomia* (1794–96) that "all warm-blooded animals have arisen from one living filament," and that this filament was endowed with the capacity of "continuing to improve by its own inherent activity" (Snyder, 2011, pp. 330–331).

When Darwin referred to "species," he meant the evolution of all life-forms. A few years later, French biologist Jean-Baptiste Lamarck proposed "the first coherent theory of evolution, asserting that organisms gain and lose characteristics based on their use or disuse … (for Lamarck, unlike for Darwin, these characteristics did not arise as random variations)" (Snyder, 2011, pp. 330–331).

The next step in the theory's establishment was an anonymous author, now known to be Robert Chambers, who published a book titled *Vestiges of the Natural History of Creation*. Chambers "agreed with much of what Lamarck had argued," and he "reintroduced Victorian audiences to evolution." Chambers

> used the example of Babbage's Difference Engine to make the point that just as Babbage's device operated in accordance with a greater pattern that might not be apparent to the observer, so too the laws that governed the process of species evolution might be invisible to us but nevertheless present (Snyder, 2011, pp. 330–331).

The difference engine is considered the first computer, and it inspired others to replicate his idea. This inspiration influenced not only Chambers but also Charles Darwin. For example, "Darwin's close reading of the [Ninth] Bridgewater Treatise had led him to realize that he had to show how his theory could offer an alternative explanation for the fitness of organisms to their environment, an explanation that relied neither on pure chance nor on God's special creation" (Snyder, 2011, p. 331).

The Bridgewater Treatise series of eight volumes was commissioned by the Earl of Bridgewater to illustrate divine design in nature in order to defend the teleological argument for God's existence (Hyman, 1982, p. 136). The 8,000 British pounds to finance the books was controlled by the president of the Royal Society, who appointed and paid writers to write "on the Power, Wisdom and Goodness of God as Manifested in the Creation" (Hyman, 1982, p. 136). Inadvertently, some sections of the series did the opposite (Ospovat, 1981). The book Babbage wrote, which actually was not part of the series, he titled the *Ninth Bridge Treatise; On the Power, Wisdom and Goodness of God, as manifested in the Creation.* He was hoping to capitalize on the prestige of the series to help him sell his book (Millhauser, 1959, p. 98). His book was published in 1837, and its theme was that God was a like a computer programmer

> who defined the entire future of the universe at the time of the Creation as a sort of infinite set of [computer] programs. It was a Newtonian universe, determinist and mechanistic…. Few others at the time could really grasp the concept of programs

> and by the time modern programming came to be developed in the middle of the twentieth century the self-confident Newtonian world had long been replaced by the shifting uncertainties of quantum mechanics. To this extent Babbage's philosophy is unique. It is presented with much grace, and the 'Fragment' is an elegant work (Hyman, 1982, p. 137).

In this work Babbage supported a uniformitarian creationism in which natural law dominates to the extent that no need exists for any intervention by God (Gillispie, 1996, p. 247). All of creation, including all life, can create itself by the outworking of natural law. The book incorporated extracts from Herschel and Charles Lyell and was quoted extensively in *Vestiges of the Natural History of Creation*.

Babbage's thesis was that God possessed the omnipotence and foresight to make natural laws that could evolve all species of life, rather than continually interfering with creation by miracles to create each new species. In short,

> a set of special creations seemed to imply a God 'perpetually interfering, to alter for a time the laws he had previously ordained; thus denying to him the possession of that foresight which is the highest attribute of omnipotence.' Drawing on his experience with the calculating engines Babbage succeeded in devising a novel picture of God whose undeviating law would be consistent both with successive special creations and with miracles. This was Babbage's unique view of the Creation (Hyman, 1982, p. 138).

In other words, machines could easily be programmed to use

> one law for any number of operations and then proceed according to some other law, the change in operation being programmed *ab initio*. Similarly, reasoned Babbage, the changes in natural law, as evidenced by the creation of new species, were not proof of Heavenly intervention but could also have been programmed by the Creator *ab initio*: that is to say at the time of the Creation. In a similar manner miracles appeared as singularities in the Celestial Program: a miracle was merely a subroutine (Hyman, 1982, pp. 138–139).

In *Vestiges*, the parallel with Babbage's computing machines was made explicit, supporting the theory that evolution of species could be preprogrammed (Chambers, 1994, pp. xvi–xvii).

Darwin Meets Babbage

When Darwin moved to London in March of 1837, he mentioned in a letter to Caroline Darwin that he had been socially active with Charles Lyell (where he interacted with Charles Babbage, who was also part of Lyell's social circle). For example, when Darwin was visiting Cambridge six years after he had graduated from the college, he

> informed his sister that Charles Lyell was insisting he hurry on up to London. He "wants me to be up on Saturday for a party at Mr. Babbage," Darwin halfheartedly complained. "Lyell says Babbage's parties are the best in the way of literary people in London—and that there is a good mixture of pretty women!" (Snyder, 2011, p. 189).

In the meetings of scientists and philosophers that Darwin attended, Babbage portrayed God not as a mechanic who was required to be

> constantly tinkering with his invention, but a divine programmer who had preset his Creation to run according to natural law, requiring no further intervention. By explicitly linking this image of God with the origin of new species, Babbage was characteristically jumping headfirst into controversy … Were new species created by an act of God, intervening outside of natural law—by a new "miracle" each and every time? Or—and few people would seriously consider this—could they [a new species] have emerged through some sort of purely natural process, perhaps even by a kind of "transmutation" from the older species? (Snyder, 2011, p. 194).

In other words, he proposed a form of naturalistic evolution. In his work, Babbage "included a remarkable extract from a letter of John Herschel, a passage which later became famous as one of the steps toward the theory of evolution." The letter states:

> that mystery of mysteries, the replacement of extinct species by others…. For my own part, I cannot but think it an inadequate conception of the Creator, to assume … that he operates through a series of intermediate causes, and that in consequence the origination of fresh species … would be found to be a natural in contradistinction to a miraculous process (quoted in Hyman, 1982, p. 139).

Of note is that at the very time Darwin

> was introduced to Babbage and his machine, Darwin was questioning the fixity of species and the prevalent notion of special creation. Sitting in the drawing room of Babbage's house, witnessing his display with the demonstration model of the Difference Engine, and hearing Babbage propose the view that God did not need to intervene each time in order to bring about new species—because God could have preset the lawful change into His Creation at the beginning of time—Darwin must have been struck by how Babbage's notion of a divine programmer could explain the observations he had made on the *Beagle* ... Darwin did not record in his notebook, "Babbage gave me this idea" … But it is clear that Darwin would have seen how Babbage's view of a divine programmer gave him a way to reconcile his

> belief in God with his growing sense that new species arose from old ones in a purely natural, evolutionary process (Snyder, 2011, p. 219).

In his work, Babbage implied that "a purely natural process, even if it was one [that was] started off by a divine programmer, was the answer to the origin of species" (Snyder, 2011, p. 219). Professor Snyder added that with this new

> and, in most circles, heretical view of God, Babbage would lead the way …. toward a new view of the relation between science and religion, one in which religion and science could coexist without religion being given the upper hand. This view would soon come to dominate the scientific world (Snyder, 2011, p. 219).

The result was that Babbage

> very likely planted a seed in the mind of … Charles Darwin, who at that moment was trying to reconcile his belief in God with his growing suspicion that species were not "fixed," that they in fact changed over time into new species. Darwin, too, would soon come to see God as a kind of divine programmer, setting his creation in advance with the conditions for the origin of new species (Snyder, 2011, p. 195).

Darwin was influenced by many contemporaries and was fully aware that he was only one of many researchers hypothesizing about the evolution of all life from one simple form, but he was still very concerned about the potential of the public's adverse reaction to his theory. When *The Origin of Species* was published, "he wrote to Asa Gray, the American botanist and a strong supporter of Darwin's work, that he still felt that 'my work will be grievously hypothetical, and large parts by no means worthy of being called induction, my commonest error being probably induction from too few facts'" (Snyder, 2011, p. 331). Another reason he was fearful of the possible adverse public reaction to his book was because he saw

> the vitriolic reaction of most men of science to the *Vestiges*…. Adam Sedgwick had accused the writer … of ignoring the … scientific method…. After reading Sedgwick's review, Darwin admitted to Lyell, "It is a grand piece of argument against mutability of species, and I read it with fear and trembling." Darwin was determined that any book of his would not meet the same fate (Snyder, 2011, pp. 330–331).

Darwin would in time also go down this slippery slope, so that he would not see God as having any role in Creation. He also said, "I would give absolutely nothing for the theory of natural selection if it requires miraculous additions at any one stage of descent" and makes "my Deity 'Natural Selection' superfluous," which would "hold *the* Deity—if such there be—accountable for phenomena which are rightly attributed only to his magnificent laws" (Burkhardt and Smith, 1991, p. 345; Burkhardt et al., 1994, p. 161; Moore, 1979, p. 322).

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Jerry Bergman

Fish with Limbs—An Illusion

Notes from the Panorama of Science

Hox genes guide other genes to do a job. An American woman had a damaged leg, and hox genes from the limbs of a fly repaired the bone by helping to produce growth of the bone needed to do the job (Brown, 2000).

The gene HoxD13 was put into a zebrafish. This altered the structure of the zebrafish's fins, producing the illusion of limb-like structures (Anonymous, 2012). However, it would take numerous gene mutations to produce a real limb. Symmetric variation will never allow this to happen. A Drosophila (fruit fly) underwent 270,000 positive mutations yet remained unquestionably *Drosophila* (Brown, 2003).

In the valine codon, changes to the third base position will still result in the valine being placed into the peptide chain (known as silent mutations). However, changes in the first or second base positions will alter the amino acid placed into the peptide (known as missense mutations). The body's DNA repair systems will restore most of these base changes to their original form. In mice, they returned 85% within just 24 hours (Brown, 1989). Those changes, allowed to remain, will only do so if they do not upset the balance of development. This limits the type of changes such mutations will produce.

One lungfish has the same HoxD13 gene, but no limb-like structures are produced (Hect, 2007, p. 14). Evolutionists date tetrapods back as far as 397 million years, with a history extending into the Silurian period, before the main lines of lobe-finned fish (Brown, 2010, p. 314). This removes links of the HoxD13 gene with the evolution of limbs in fish.

Evolutionist claims again fall short—just like the claims about this experiment with the zebrafish.

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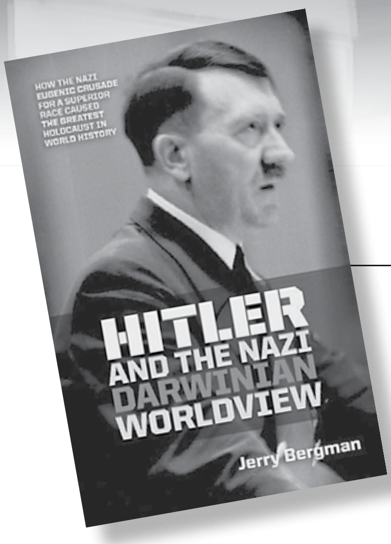
Media Reviews



Hitler and the Nazi Darwinian Worldview

by Jerry Bergman

Joshua Press, Kitchener, Ontario, Canada, 2012, 356 pages, $26.00.

As a journalism student back in the 1970s, I spent every precious elective on history classes. My favorite subject was twentieth-century German history. This coursework did some damage to my near-perfect grade-point average, because it meant studying under a professor who considered C an adequate reward for mastering the material. I knocked myself out for him, studying obsessively, and reading all the best books about that era—everything from Allan Bullock's acclaimed *Hitler: A Study in Tyranny* to Albert Speer's fascinating *Inside the Third Reich*.

Yet, somehow, I don't remember hearing much about the philosophy underlying Hitler's attempt to exterminate the Jews. Maybe if I'd read *Mein Kampf*, I would have had a clue, but not one professor ever recommended it. Maybe they believed, with George Eliot, that cruelty requires no motive.

But Eliot was wrong, and I'm afraid my beloved professor was too. The "why" of the Holocaust is critically important, both for evaluating our past errors and for doing everything possible to prevent another, perhaps even deadlier, catastrophe.

That's why I so appreciated this book with the subtitle *How the Nazi Eugenic Crusade for a Superior Race Caused the Greatest Holocaust in World History*. It is one of those books that explores what should be obvious but, like the proverbial elephant in the room, is for some reason rarely discussed in polite company.

Hitler and the Nazi Darwinian Worldview explains the inexplicable, makes sense out of the nonsensical, and reveals the thought that allowed the unthinkable to come to pass. It should be mandatory reading in college history classes. And it should top the reading list of anyone who understands that what we believe really does matter.

Bergman exhaustively documents his contentions about "doctrinaire Darwinist" Adolf Hitler, including this foundational premise:

A central goal of Hitler and his government was the development and implementation of eugenics to produce a "superior race," often called the Aryan, Teutonic or Nordic race. At the very least, this goal required preventing the "inferior races" from mixing with those judged superior in order to reduce contamination of the gene pool. Hitler believed that what we today recognize as the human gene pool could be improved by using selective breeding, similar to how farmers breed superior cattle (p. 38).

In the process, Bergman makes an airtight case that this was indeed the philosophy driving Hitler's murderous machine—the philosophy that unfortunately "culminated in the Final Solution, the extermination of 6 million Jews and over 5 million Poles and others who belonged to what German scientists judged were 'inferior races'" (p. 38).

Acknowledging that there were many factors leading up to the Holocaust, Bergman points out, "Of the many factors that produced Hitler's eugenic and genocidal [programs], according to his own writings, one of the more important was Darwin's notion that evolutionary progress occurs primarily as a result of the elimination of the weak in the struggle for survival and allowing the strong to flourish. Darwin-inspired eugenics clearly played a critical role" (p. 51).

He then goes on to prove it, point by frightening point, in a book that's both terrifying and compelling. He uses excellent techniques to pull the reader through, for instance by foreshadowing what we'll learn in subsequent chapters to give context to the subject at hand. In addition to setting the stage generally, Bergman provides up-close-and-personal analyses of Hitler's most important and influential henchmen, including Mengele, Bormann, Himmler, Goebbels, Göring, Heydrich, Rosenberg, and Streicher.

Bergman closes his book with a weighty chapter titled "What Can Be Learned from Attempts to Apply Darwinism to Society." This chapter alone is worth the cost of the book.

Hitler and the Nazi Darwinian Worldview is full of surprises. The margins of my copy are filled with exclamation points to highlight facts about, for instance, the German government subsidizing reproduction among "racially and biologically desirable" couples (p. 84), perfecting its *Lebensborn* program to advance the breeding of the Nordic super-race (p. 256), and sponsoring mass kidnapping of "racially valuable" children (p. 257).

Another recurring (and not at all surprising) theme was the enthusiastic support that members of the scientific establishment gave Hitler. Germany was known in the first part of the twentieth century as the home of the most accomplished scientists in the world, including the majority of Nobel Laureates. These were the experts who gave Hitler the scientific justification he needed to advance his horrific programs.

Noting that some Nazi scientists received accolades and awards long after the fall of the Third Reich, Bergman provides this chilling insight from Susanne Heim: "Scientists are highly vulnerable to intellectual and moral corruption—opportunities will be used if they promise more influence and success" (p. 126).

Apparently not even medical doctors could resist. Forget the Hippocratic Oath, "the psychiatric and medical professions were among the most enthusiastic supporters of Nazi race programs" (p. 121).

Dr. Bergman is far from alone in believing that Darwinism influenced Hitler and his supporters. He quotes other authorities extensively throughout his book and notes that scholars such as Richard Weikart also have documented Darwinism's role in Nazism (p. 125). Even outspoken Harvard professor Stephen Jay Gould noticed. As he wrote in his 1985 book *Ontogeny and Phylogeny*, "'Biological arguments for racism … increased by orders of magnitude following the acceptance of evolutionary theory' by scientists in most nations" (p. 83).

Hitler and the Nazi Darwinian Worldview may be the first to gather all this evidence under one convenient cover and to make such a persuasive case for what happens when Darwinism is taken to its logical conclusion. It's not a book I'd recommend for bedtime reading.

In the midst of reading *Hitler and the Nazi Darwinian Worldview*, I had the chance to watch Ray Comfort's powerful pro-life documentary *180*, in which he uses the Holocaust as an apt analogy for abortion (watch it at www.180movie.com/). Ray opens with clips of interviews with young people. Astoundingly, almost none knew who Hitler was.

And there you have it. We are raising a nation of people who don't know who Adolf Hitler was or what he did; yet they have been raised on the same existential philosophy that drove his killing machine. If Dr. Bergman is correct about the parallels that he and others are drawing to events in our world today, this is a problem of potentially tragic proportions.

Consider, for example, the alarming increase in reports of anti-Semitism in many parts of the world. Or consider the "weaning of Americans from Christianity by banning public display of Christian symbols and ritual." This is, Bergman points out, "remarkably reminiscent of what Nazi Germany did" (p. 16).

Or consider any of the other steps the Western world is taking, from gun control legislation to interfering with (and in some cases persecuting) homeschooling parents—all echoes of Hitler's own policies.

Then read *Hitler and the Nazi Darwinian Worldview*, and consider the similarities between the philosophies underlying the Third Reich, and those prevailing in our culture today. What do you think? Is there cause for concern?

Many in Germany, early on, recognized the harm of Darwinism, and the Prussian Minister of Education for a time in 1875 forbade the "schoolmasters in the country to have anything to do with Darwinism … with a view of protecting schoolchildren from the dangers of the new doctrines." A significant question is this: Would the Nazi Holocaust have occurred if this ban had remained in effect (p. 96)?

Great question—one that I believe Dr. Bergman answers affirmatively and persuasively in this very important book.

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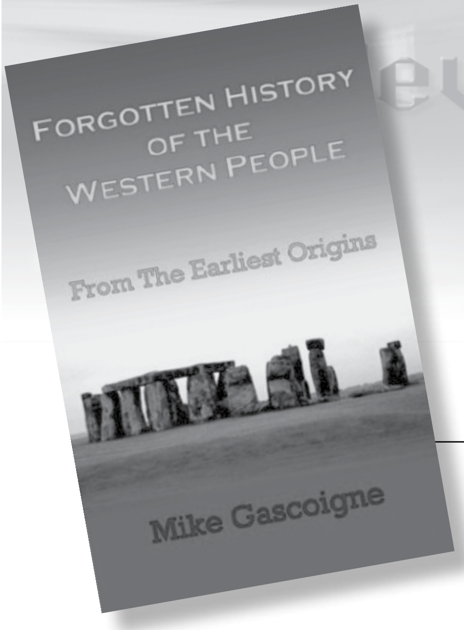

Forgotten History of the Western People

by Mike Gascoigne

Anno Mundi Books, 2002, 245 pages, $24.00.

Since Bill Cooper's 1995 *After the Flood* book, there have been a number of books published about the origin of ancient nations and ancient people groups. Gascoigne endeavors to mine ancient extrabiblical accounts and mythology to compare with biblical history. His sources include Berosus, a third-century BC Babylonian astronomer/historian, an even more ancient Phoenician author named Sanchoniathon, Annius of Viterbo (authenticity questioned), the twelfth-century Welsh historian Geoffery of Monmouth, Nennius (a ninth-century Welsh historian), and many others. Gascoigne compares, contrasts, and analyzes these accounts using the biblical texts (where appropriate) as the standard of comparison.

Like other historical researchers, the author has sifted through various records and gives conclusions as to their plausibly and reliability. Gascoigne notes, "I am only trying to find secular evidence for something we already know from the Bible, that we are all descended from Adam and then from Noah" (p. 89). He first deals briefly with the period before the Flood, comparing men from the early chapters of Genesis to ancient Babylonian king lists.

The second chapter on the early post-Flood world strives to depict how various mythological gods and their genealogies, both Egyptian and Greek, could correspond to biblical personages (p. 63). For example, Noah could be Ouranos, and his two sons Ham and Japheth are perhaps Kronus and Iapetus, respectively. Ham's (Kronus) descendants Cush or Mizraim could have been Zeus, who was the father of Dardanus, the first king of Troy. Dardanus was supposedly the ancestor of Aeneas, the legendary founder of Rome and who likewise was great-grandfather of Brutus, who ended up settling on an island called Albion (Great Britain) and becoming the founder of the British people. After listing a set of genealogical assumptions, the writer cautiously states, "If all this can be believed, then we have a continuous line of descent, or at least a continuous succession from Adam to the Welsh kings" (p. 68).

The author devotes the third chapter to "dubious histories." Here he deals with supposed historical accounts from the Middle Ages that are largely based on fiction and conjecture.

The fourth chapter narrows the research focus to the early history of Britain, starting with Dardanus, Aeneas, Brutus, the arrival of the Romans, and the Anglo-Saxon invasions and the Welsh kings. Gascoigne then deals with Anglo-Saxon genealogies, exploring the possibility of the Norse myths comingling with the Greek myths. Scotland and Ireland (chapter 6) then are examined with a possible connection to ancient Egypt shortly after the Israelite Exodus.

Next is a lengthy discussion (chapter 7) concerning the earliest origins of British Christianity, laying out the claims that Joseph of Arimathea and Jesus' disciple Simon the Zealot came to Britain proclaiming the gospel. The final chapter compares visions of ancient apocalyptic legends and their modern counterparts with the end times described in the Bible and a warning to be ready for very difficult days ahead.

This reviewer found the book a fascinating read, as Gascoigne grapples with attempts to uncover the nuggets of truth that have survived the process of myth and legend embellishments in ancient literature. He strives to help the reader understand more about the history that has been lost or buried over the past several centuries of secularization. This secularization often transforms the lives and deeds of real individuals into impersonal movements of peoples from one land to another bereft of any anchor in biblical history. Gascoigne's accounts are somewhat choppy, as this volume is obviously a "continuing research" effort rather than a final word on the subject.

The writer summarizes: "We have already seen that behind the Greek Mythology we have the vague shadow of Noah and his family. It would have been nice if the Greeks had told us the plain facts, without all the embellishments, but we have to accept what they have given us. All ancient history is like that. You just have to study it, in all its fantastic detail and you get a 'feel' for what actually happened" (p.145–146).

Gascoigne, like Bill Cooper and others, is to be commended for his efforts to resuscitate historical records that can help us gain important knowledge about our very early ancestors from a Biblical perspective.

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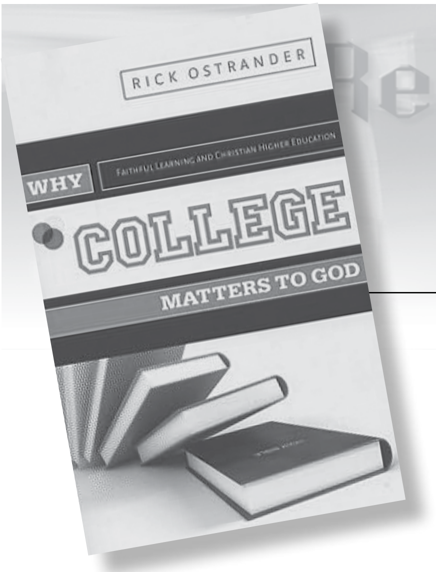

Why College Matters to God

by Rick Ostrander

Abilene Christian University Press, Abilene, TX, 2009, 141 pages, $13.00.

Writer Rick Ostrander is provost at Cornerstone University, Grand Rapids. He holds undergraduate and doctoral degrees in history. This book parallels Arthur Holmes's classic *The Idea of a Christian College* (Holmes, 1975). Both books are widely read and discussed by college faculties, especially those that are part of the Council for Christian Colleges and Universities (CCCU), a network of nearly 200 private schools enrolling 0.3 million students.

This review is included in the *CRS Quarterly* because the Creation worldview is a key part of the agenda of higher Christian education. As one might expect, however, young-earth creation is a minority emphasis in the CCCU. Author Ostrander himself apparently assumes the reality of the big bang (p. 118) and evolution theory (p. 121). At the same time, he refers to the literal Adam (p. 59), and he challenges the extreme scientific materialism of Richard Lewontin and Richard Dawkins (pp. 80–81).

In the broader context of Christian liberal arts education, author Ostrander includes valuable material. Nineteenth-century Dutch theologian Abraham Kuyper is quoted: "There is not a square inch on the whole plain of human existence over which Christ, who is Lord over all, does not proclaim, 'This is Mine'" (p. 50). Ostrander declares that Christian colleges must be concerned with "molding the character of its students … linking head and heart" (p. 46). Likewise, the overused phrase "All truth is God's truth … is true nevertheless" (p. 63). These words are a refreshing contrast to the impoverishment of education at most public universities, a result of their hijacking by extreme affirmative action, gay lobbyists, multiculturalism, political correctness, radical feminism, and more.

How far educational society has fallen is apparent from the original motto of Harvard University, founded in 1636: *Christo et Ecclesiae*—"for Christ and the Church" (p. 35). Conservative Christian Colleges are nothing less than a "recovery project" to rebuild this foundation (p. 16).

Ostrander discusses "common grace," the concept that "God has liberally sprinkled his grace over all of creation … even after the fall" (p. 63). Thus James Watson and Francis Crick were gifted to discern the structure of DNA even while they held to an atheistic worldview. John Calvin likened such insights from his day by non-Christians to that of "a traveler passing through a field at night who in a momentary lightning flash sees far and wide, but the sight vanishes before he can take even a step" (p. 63). Such is Calvin's view of those who are not yet in the kingdom.

The book discusses the extent to which academic content interfaces with faith. A continuum is suggested from the least interaction to the most: mathematics, natural science, social science, history, arts and literature, philosophy and theology (p. 115). Since Dr. Ostrander is a historian and administrator, and an outsider to natural science and math, it is understandable that he is not familiar with the rich faith applications in technical fields. Math study, for example, should include the faith positions and motivations of pioneer mathematicians, the obvious design in nature as, for example, the Fibonacci sequence, the beauty of math functions, math as the language of creation, and "The Unreasonable Effectiveness of Mathematics in the Natural Sciences," a classic 1966 essay by Eugene Wigner.

The book makes several comments about restoring or redeeming creation, thus promoting the viewpoint of Reformed or covenant theology (pp. 99, 122). Each book chapter includes questions for reflection and discussion. There are references but no index.

Reference

Holmes, Arthur. 1975. *The Idea of a Christian College*. Wm. B. Eerdmans Publishing Company, Grand Rapids, MI.

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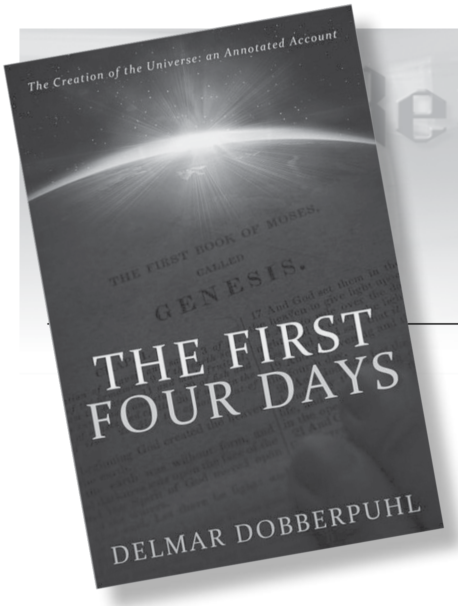

The First Four Days

by Delmar Dobberpuhl

Winepress Publishing, 2011,
203 pages, $18.00.

Delmar Dobberpuhl has thought very deeply concerning what happened during the first four days of Creation as described in Genesis 1. His model of origins is called the "creating-and-making account" (CMA). The days of Creation are described as divine actions, supernatural actions by God in the creation process using physical materials.

Divine Action 1 is the creation of the physical substance of the universe, which is described as a perfect fluid of "very low velocity." Dobberpuhl likens this perfect fluid to quark soup: "When protons and neutrons collide with enough velocity, they form a fluid-like substance that splatters initially but in a very short time reforms into protons and neutrons again" (pp. 20–21). Dobberpuhl does not say quark soup is the original substance God used to make the planets and stars but is similar (p. 24).

Divine Action 2 describes the formation of light (both as particles and waves) and subatomic particles (electrons, protons, and neutrons). During this period on the first day, the physical laws of electromagnetism and nuclear forces were created, causing these subatomic particles to come together to form atoms. Likewise, the atoms formed molecules, which grew into "larger and larger clumps" (p. 45). The author refers to the process and end results of this stage as the "primordial blob." During this time black holes came into existence as a result of this creation process.

Divine Action 3 shows God as an architect and builder. He separated the primordial blob into "many ultra-massive black holes formed from a fluid like substance" (p. 75). The black holes are filled with large amounts of atomic matter. God used these black holes to transport this material to where the galaxies are today, and then God turned the black holes into "at least three white-hole configurations to form galaxies." At this stage these galaxies were filled with proto-stars and proto-planets and spherical moons.

Divine Action 4 has to do with the separating of the seawater from the emerging dry land on the earth. Dobberpuhl speculates that as the water ran off the land, it caused a great deal of erosion, which formed the basis for fertile soil, along with the formation of the atmosphere, both taken as miracles of God (p. 139).

Divine Action 5 sees the preparation of an ecosystem by the introduction of plant life both on land and the sea.

Divine Action 6 sees God transforming the proto-stars "into light providers all over the universe by igniting them" (p. 169). The author notes that the distant starlight problem can be answered by "superluminal light speeds and gravity wrapping of 4-D space-time." Further he states, "The effects of this wrapping are recorded in nature as drastically accelerated natural processes, perhaps by factors of millions or billions in the far off heavens."

Dobberpuhl is candid about his model. Referring to the formation of galaxies from white holes, he states, "The details of how it was done are mainly speculation because it was done by supernatural means. There are at present no experiments or even realistic computer simulations that can be used to demonstrate the processes involved during the rapid maturations because they do not occur in our universe today" (p. 76). This statement could be made for much of the rest of Dobberpuhl's model. However, the model appears plausible on how God could have created the heavens and the earth. Dobberpuhl is certainly right that the supernatural creative actions of God during the formation of the universe are not merely extensions of today's naturally occurring processes.

While Dobberpuhl does not engage in advanced mathematical formulas to advance his model, the prose is quite dense and is not an easy read. Each chapter concludes with a helpful summary that condenses the technical material. This reviewer has tried to summarize the writer's salient points, but to get the full force of his arguments one must give the text a thorough examination. The book has an appendix showing how the CMA model fits the scriptural narrative of Genesis 1:1–2:4, plus diagrams, an endnote section, and an index.

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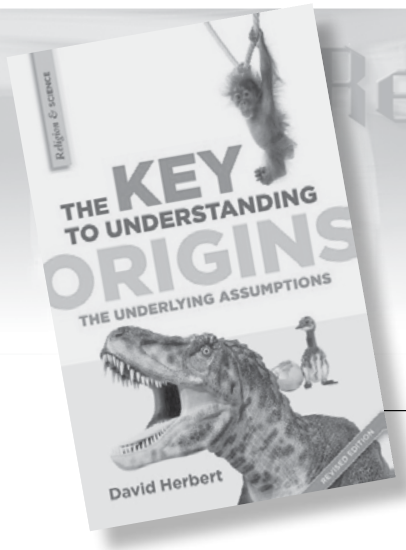

The Key to Understanding Origins: The Underlying Assumptions

by David Herbert

Joshua Press, Kitchener, Ontario, Canada, 2013, 76 pages, $12.00.

With its multicolored, animal-adorned paper cover, this short book is an eye-catcher. The back cover states that the assumptions of both creation and evolution are open for inspection as well as for dialogue.

The first and foremost goal of this book is to show students and parents that creation and evolution are two competing religious systems. Upon this foundation, "students then can be equipped with the tools to examine the issue of origins in a critical and informed manner" (p. 12). Herbert states that "from the primary grades to graduate school" (p. 67) most students now are force-fed only evolution. He strongly opposes this indoctrination and advocates teaching both evolution and creation.

There are seven chapters and three pages of bibliography. Only two of the 45 references are dated more recently than 2009. An appendix includes Herbert's discussion of his experiences while interviewing students at the University of Western Ontario, especially regarding religion and the subject of origins. These interviews are interesting when students become aware that there are convincing creationist interpretations of history.

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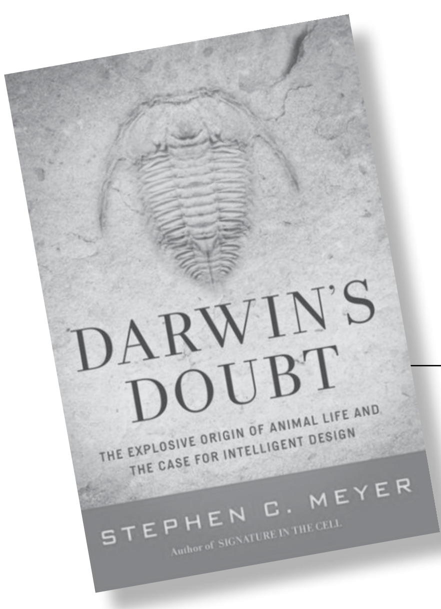

Darwin's Doubt: The Explosive Origin of Animal Life and the Case for Intelligent Design

by Stephen Meyer

HarperCollins, New York, 2013, 498 pages, $19.64.

This book by Stephen Meyer will appeal to many readers. The style follows Meyer's 2010 *Signature of the Cell*, which deconstructs chemical evolution as a possibility. Part I of this new volume is "The Mystery of Missing Fossils," which starts in the Cambrian, where numerous new animal forms (23 of 27 phyla represented) suddenly appear without a trace of ancestry. Using evidence from the Burgess Shale in Western Canada and other evidences, Meyer undercuts Darwin's tree of life: "The tree of life lies in tatters … torn to pieces by an onslaught of negative evidence" (p. 119). The chapter on Stephen Jay Gould's punctuated equilibria discusses how Gould recognized the fossil gap and then adjusted his evolutionary views to accommodate the absence of fossils. Gould needs large populations to get mutational trials and small populations to fix mutations, but small populations are susceptible to inbreeding problems. Gould died in 2002, and not much is being said about "punk eek," the slang term for punctuated equilibria.

Part II is "How to Build an Animal." Noted evolutionist T. H. Huxley said, "All aspects of reality are subject to evolution … all reality is a single process of evolution" (p. 159). Meyer discusses information including the lack of "probabilistic resources" to make all the trials get the right proteins for specific enzyme activities. The biochemical work assignments of proteins are discussed later in the book, but I will add that many enzymes work in groups. For example, the spliceosome is some 150 individual proteins that insert introns and cut out exons in the DNA. Needless to say, junk DNA has all but vanished from discussion.

Part III is "After Darwin, What?" The theories of evolution not strictly neo-Darwinist, or else outside of neo-Darwinism, include the genetic engineering of James Shapiro; neo-Lamarckism and symbiogenesis of Lynn Margulis; facilitated variation of John Gerhart and Marc Kirschner; self-organization of Stuart Kauffman (this approach seems new age to me); evo-devo of Derek Raff, Sean Carrol, and Eric Schwartz; and neutral evolution of Michael Lynch and Jon Stoltzfus. None of these post-Darwin ideas have any real scientific evidence. They all criticize neo-Darwinism, but none of these variations offers a step-by-step solution to evolution problems. Instead, the approach that "maybe this will help us understand evolution" is as far as the newer theories have advanced.

The Meyer book is devoid of young-earth creation (either for or against), Genesis teaching, or religious talk. While young-earth creation is not demeaned in the book, theistic evolution (including Francis Collins) takes some criticism. A statement gives me some hope about what Meyer's next book might cover: "Yet humans and chimps are thought to have diverged from a common ancestor only 6 million years ago. Behe's calculation does not have the capacity to generate even two coordinated mutations in the time available for human evolution—*and thus does not explain how humans arose*" (p. 248). Will Meyer's next book take on the establishment's scientific case for the evolution of an apelike creature to humans? It is possible.

One very important part of this book is defining (or attempting to locate and identify) the epigenome. This is a record of the chemical changes to the DNA and histone proteins of an organism. Many researchers (up to now) identify the epigenome as the nonprotein portion of DNA, the former "junk" part of DNA. Meyer points out that removing the nucleus (DNA) from sea urchins did not immediately stop cell division, which went on up to 500 cells (p. 271).

Information drives embryological development, which goes "beyond genes." The epigenome in addition to nonprotein coding DNA may involve RNA molecules, microtubules consisting of tubulin protein outside the nucleus, the centrosome, ion channels, the sugar code on the exterior surface of embryonic cells, and morphogenic molecules attached to the surface of the inner cell. *Hox* genes also are discussed. Meyer presents the idea that body plan (the shape and contour of the body) is not determined by DNA, a rather startling notion for most biologists (p. 269).

Numerous provocative diagrams and tables are in the book and help present the concepts being expressed. If you have an interest in whether or not evolution is possible from a scientific perspective, you should read this reasonably priced book. There is far more content than I have touched on that will help to update the reader concerning the evolution-intelligent design-creation battleground.

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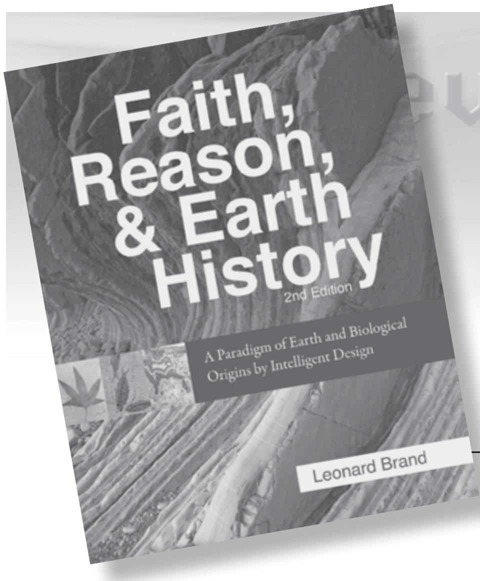

Faith, Reason & Earth History: A Paradigm of Earth and Biological Origins by Intelligent Design

by Leonard Brand

Andrews University Press, Berrien Springs, MI, 2009, 520 pages, $65.00.

Some novels are termed "page turners" for their ability to grab and hold readers' attention until the last page. Typically, books that can be used as classroom textbooks are *not* in this category; more often than not, they are rather seen as cures for insomnia. *Faith, Reason & Earth History* is fortunately much closer to the former category than the latter. This text is authored by Leonard Brand, professor of earth and biological sciences at Loma Linda University. He has a research publication record in the fields of vertebrate paleontology and issues regarding origins and also a current research interest in taphonomy. His basic premise in this book is to introduce the reader to the current state of origins theories (both young-earth positions and prevailing old-earth evolutionary positions) and how scientific facts about our world interact with each of these theories.

In the preface, Brand introduces the term "interventionist"—one who asserts that the world around us could not have come about without the intervention of an outside supernatural force (whom Brand readily identifies as the God of the Christian Scriptures). He prefers this to the more politically charged term "creationist." One of his goals through the book is to reduce destructive verbal attacks by "interventionists" against evolutionists, which he sees as counterproductive in the advance of both good science and the gospel. Brand urges the reader to remember that God loves the evolutionist as well (p. 395). But he also early on reassures the reader that he fully believes that the literal biblical Creation account will eventually explain everything, once we have all of the evidence (p. xi), and he warns of the danger of basing theology on scientific theory (p. 44).

Brand starts with chapters covering a basic description of the scientific method and its history, along the way noting its serious limitations, especially in the study of ancient events (p. 31). He correctly notes that scientific consensus may result not from the data but from social or philosophical factors (p. 69). The author then turns to examine natural processes at work in the world, including chapters addressing the biological processes of change, microevolution and speciation, as well as the geologic record. He addresses these processes from the perspective of the current prevailing theories of the origin of life. In each of these areas, Brand judiciously presents both evolutionary and interventionist theories, comparing and contrasting strengths and weaknesses. His willingness to present an intellectually honest view and note weaknesses in both theories fits well with his desire to reduce the animosity between the proponents of each.

Theologically, Brand notes that our current era is one where, in general, the church and the scientific community are moving toward a point where both can coexist, with the unfortunate stipulation that it is science that dictates the beliefs (p. 59). He correctly asserts that there is no such thing as a truly neutral search for truth: All investigation and interpretation is colored by a person's worldview (p. 128). He also observes that in nonevolutionary fields, interventionists are acknowledged as doing high quality scientific research, dispelling the myth that a theological belief in Creation precludes good science (p. 104).

Scientifically, Brand does an admirable job portraying both the current theories of evolutionary origins and different theories of interventionist origins. He discusses at length how each of these theories is supported by biological and geological evidence and also how the theories are challenged by current data. He notes that there is a "biochemical grand canyon separating microevolution and megaevolution" (p. 291) and that long-age theory cannot explain the many samples from throughout the

Phanerozoic that contain ^{14}C, when it should have all decayed (p. 363). His observations are equitable. He also notes that for interventionists, the fossil record presents large challenges in the existing transitional forms and the general appearance of more complex forms in newer rocks (p. 278). He also notes the challenges of long ages indicated by radiometric dating (p. 385) and the concept of biogeography: Why are not present-day animals more evenly distributed (p. 234)? Brand states that it would be easier to simply accept the long geologic timescale and fit creation into it (p. 389), but he argues that the pursuit of short-age interventionism is worth the effort. His closing comments include the assertion that "God knows much more about earth history than we do and has shown a level of interest in (scientifically) communicating with us that is not consistent with an allegorizing of Genesis" (p. 458).

From a "reader-friendliness" perspective this text is written at appropriate level for a college course yet is very readable by a layperson. The layout is easy to read and includes many figures, although they are in a single color, which lessens the "look" of the text compared with other college textbooks. (This also lessens the cost, which should be appreciated by students.) The book includes a helpful glossary and index, and it is well referenced with recent literature citations; 24 pages of citations are included. For the interested layman or for use in a classroom, this work does an admirable job of supporting the "interventionist" position in an intellectually honest manner. This book was reviewed earlier (DeYoung, 2013).

Reference

DeYoung, D. 2013. Review of *Faith, Reason & Earth History*, *CRSQ* 49:250.

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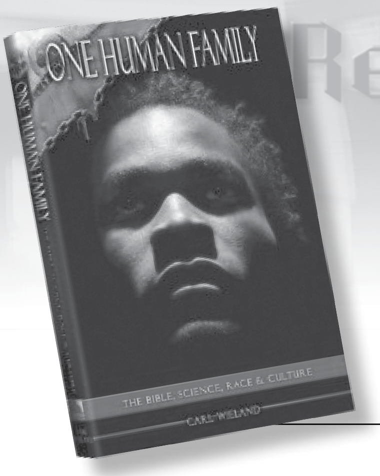

Reviews

One Human Family: The Bible, Science, Race and Culture

by Carl Wieland

Creation Book Publishers, San Diego, 2011, 378 pages, $19.00.

Over the years the creation science movement has published material on how evolution influences public policy and perception regarding race. Carl Wieland's book is one of the more comprehensive treatments on this subject yet published. Much of the discussion of race has to do with a critique of evolution's development of racial myths and stereotypes. However, Wieland does not lay racism completely at the feet of Darwinian evolution. Racism, whether it was called that or not, did not start with the publication of Darwin's *Origin of Species* in 1859. Still, Wieland points to the marked acceleration of mistreatment of Australia aborigines after Darwin's book appeared.

Wieland devotes a lengthy chapter to South African apartheid, untangling the racist mess that had support from both religious and social Darwinist quarters. The author (whose mother lived in pre-World War II Germany) also examines the racial laws and policies of Nazi Germany, as well as the early eugenics movement in America and other countries.

This book contains chapters on slavery, so-called apemen, the uniqueness of language (Tower of Babel), Flood legends, modern "stone age" people, the loss of technology, humanity descended from Adam and Eve, genetic issues, multiculturalism, the good and harmful effects of religion, and numerous other issues.

There are special one- or two-page features that delve into specific topics in more detail alluded to in the main text. Topics like Gandhi and Race, primitive language, the work of John Sanford on genetic entropy, and many other topics are highlighted in these sections. One of the more profound issues addressed is the superficiality and plasticity of the notion of race. On page 85 is a beautiful photo of the twins, Remee and Kian (and their parents), one with black skin tone and the other with white skin hue. This leads to a discussion, complete with genetic diagrams, that all skin colors can be expressed in one generation.

Wieland's book covers a vast area of topics and, while Christian and creationist in perspective, does not fail to call attention to problems on all sides of the issues of race and culture. The book discusses the topic in an extensive manner with much room remaining for the creation research to plumb the depths that Wieland addressses.

One Human Family reveals the lie of several distinct races, separated by skin color and certain other cursory anatomical traits, and points to the fact that there is only one human race.

This book has an extensive table of contents, many color photos, artwork, and charts but no index. This volume is beautifully printed and designed on heavy, coated paper stock.

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Instructions to Authors

Submission

Electronic submissions of all manuscripts and graphics are preferred and should be sent to the editor of the *Creation Research Society Quarterly* in Word, WordPerfect, or Star-Office/Open Office (see the inside front cover for address). Printed copies also are accepted. If submitting a printed copy, an original plus two copies of each manuscript should be sent to the editor. The manuscript and copies will not be returned to authors unless a stamped, self-addressed envelope accompanies submission. If submitting a manuscript electronically, a printed copy is not necessary unless specifically requested by the *Quarterly* editor. Manuscripts containing more than 35 pages (double-spaced and including references, tables, and figure legends) are discouraged. An author who determines that the topic cannot be adequately covered within this number of pages is encouraged to submit separate papers that can be serialized.

All submitted manuscripts will be reviewed by two or more technical referees. However, each section editor of the *Quarterly* has final authority regarding the acceptance of a manuscript for publication. While some manuscripts may be accepted with little or no modification, typically editors will seek specific revisions of the manuscript before acceptance. Authors will then be asked to submit revisions based upon comments made by the referees. In these instances, authors are encouraged to submit a detailed letter explaining changes made in the revision, and, if necessary, give reasons for not incorporating specific changes suggested by the editor or reviewer. If an author believes the rejection of a manuscript was not justified, an appeal may be made to the *Quarterly* editor (details of appeal process at the Society's web site, www.creationresearch.org).

Authors who are unsure of proper English usage should have their manuscripts checked by someone proficient in the English language. Also, authors should endeavor to make certain the manuscript (particularly the references) conforms to the style and format of the *Quarterly*. Manuscripts may be rejected on the basis of poor English or lack of conformity to the proper format.

The *Quarterly* is a journal of original writings, and only under unusual circumstances will previously published material be reprinted. Questions regarding this should be submitted to the Editor (CRSQeditor@creationresearch.org) prior to submitting any previously published material. In addition, manuscripts submitted to the *Quarterly* should not be concurrently submitted to another journal. Violation of this will result in immediate rejection of the submitted manuscript. Also, if an author uses copyrighted photographs or other material, a release from the copyright holder should be submitted.

Appearance

Manuscripts shall be computer-printed or neatly typed. Lines should be double-spaced, including figure legends, table footnotes, and references. All pages should be sequentially numbered. Upon acceptance of the manuscript for publication, an electronic version is requested (Word, WordPerfect, or Star-Office/Open Office), with the graphics in separate electronic files. However, if submission of an electronic final version is not possible for the author, then a cleanly printed or typed copy is acceptable.

Submitted manuscripts should have the following organizational format:

1. Title page. This page should contain the title of the manuscript, the author's name, and all relevant contact information (including mailing address, telephone number, fax number, and e-mail address). If the manuscript is submitted by multiple authors, one author should serve as the corresponding author, and this should be noted on the title page.

2. Abstract page. This is page 1 of the manuscript, and should contain the article title at the top, followed by the abstract for the article. Abstracts should be between 100 and 250 words in length and present an overview of the material discussed in the article, including all major conclusions. Use of abbreviations and references in the abstract should be avoided. This page should also contain at least five key words appropriate for identifying this article via a computer search.

3. Introduction. The introduction should provide sufficient background information to allow the reader to understand the relevance and significance of the article for creation science.

4. Body of the text. Two types of headings are typically used by the *CRSQ*. A major heading consists of a large font bold print that is centered in column, and is used for each major change of focus or topic. A minor heading consists of a regular font bold print that is flush to the left margin, and is used following a major heading and helps to organize points within each major topic. Do not split words with hyphens, or use all capital letters for any words. Also, do not use bold type, except for headings (italics can be occasionally used to draw distinction to specific words). Italics should not be used for foreign words in common usage, e.g., "et al.", "ibid.", "ca." and "ad infinitum." Previously published literature should be cited using the author's last name(s) and the year of publication (ex. Smith, 2003; Smith and Jones, 2003). If the citation has more than two authors, only the first author's name should appear (ex. Smith et al., 2003). Contributing authors should examine this issue of the *CRSQ* or consult the Society's web site for specific examples as well as a more detailed explanation of manuscript preparation. Frequently-used terms can be abbreviated by placing abbreviations in parentheses following the first usage of the term in the text, for example, polyacrylamide gel electrophoresis (PAGE) or catastrophic plate tectonics (CPT). Only the abbreviation need be used afterward. If numerous abbreviations are used, authors should consider providing a list of abbreviations. Also, because of the variable usage of the terms "microevolution" and "macroevolution," authors should clearly define how they are specifically using these terms. Use of the term "creationism" should be avoided. All figures and tables should be cited in the body of the text, and be numbered in the sequential order that they appear in the text (figures and tables are numbered separately with Arabic and Roman numerals, respectively).

5. Summary. A summary paragraph(s) is often useful for readers. The summary should provide the reader an overview of the material just presented, and often helps the reader to summarize the salient points and conclusions the author has made throughout the text.

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Robinson, D.A., and D.P. Cavanaugh. 1998. A quantitative approach to baraminology with examples from the catarrhine primates. *CRSQ* 34:196–208.

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Margulis, L. 1971a. The origin of plant and animal cells. *American Scientific* 59:230–235.

Margulis, L. 1971b. *Origin of Eukaryotic Cells*. Yale University Press, New Haven, CT.

Hitchcock, A.S. 1971. *Manual of Grasses of the United States*. Dover Publications, New York, NY.

Walker, T.B. 1994. A biblical geologic model. In Walsh, R.E. (editor), *Proceedings of the Third International Conference on Creationism* (technical symposium sessions), pp. 581–592. Creation Science Fellowship, Pittsburgh, PA.

7. Tables. All tables cited in the text should be individually placed in numerical order following the reference section, and not embedded in the text. Each table should have a header statement that serves as a title for that table (see a current issue of the *Quarterly* for specific examples). Use tabs, rather than multiple spaces, in aligning columns within a table. Tables should be composed with *14-point type* to insure proper appearance in the columns of the *CRSQ*.

8. Figures. All figures cited in the text should be individually placed in numerical order, and placed after the tables. Do not embed figures in the text. Each figure should contain a legend that provides sufficient description to enable the reader to understand the basic concepts of the figure without needing to refer to the text. Legends should be on a separate page from the figure. All figures and drawings should be of high quality (hand-drawn illustrations and lettering should be professionally done). Images are to be a minimum resolution of 300 dpi at 100% size. Patterns, not shading, should be used to distinguish areas within graphs or other figures. Unacceptable illustrations will result in rejection of the manuscript. Authors are also strongly encouraged to submit an electronic version (.cdr, .cpt, .gif, .jpg, and .tif formats) of all figures in individual files that are separate from the electronic file containing the text and tables.

Special Sections

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Submission of letters regarding topics relevant to the Society or creation science is encouraged. Submission of letters commenting upon articles published in the *Quarterly* will be published two issues after the article's original publication date. Authors will be given an opportunity for a concurrent response. No further letters referring to a specific *Quarterly* article will be published. Following this period, individuals who desire to write additional responses/comments (particularly critical comments) regarding a specific *Quarterly* article are encouraged to submit their own articles to the *Quarterly* for review and publication.

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Occasionally, the editor will invite individuals to submit differing opinions on specific topics relevant to the *Quarterly*. Each author will have opportunity to present a position paper (2000 words), and one response (1000 words) to the differing position paper. In all matters, the editor will have final and complete editorial control. Topics for these forums will be solely at the editor's discretion, but suggestions of topics are welcome.

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All book reviews should be submitted to the book review editor, who will determine the acceptability of each submitted review. Book reviews should be limited to 1000 words. Following the style of reviews printed in this issue, all book reviews should contain the following information: book title, author, publisher, publication date, number of pages, and retail cost. Reviews should endeavor to present the salient points of the book that are relevant to the issues of creation/evolution. Typically, such points are accompanied by the reviewer's analysis of the book's content, clarity, and relevance to the creation issue.

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Creation Research Society

History—The Creation Research Society was organized in 1963, with Dr. Walter E. Lammerts as first president and editor of a quarterly publication. Initially started as an informal committee of 10 scientists, it has grown rapidly, evidently filling a need for an association devoted to research and publication in the field of scientific creation, with a current membership of over 600 voting members (graduate degrees in science) and about 1000 non-voting members. The *Creation Research Society Quarterly* is a peer-reviewed technical journal. It has been gradually enlarged and modified, and is currently recognized as one of the outstanding publications in the field. In 1996 the *CRSQ* was joined by the newsletter *Creation Matters* as a source of information of interest to creationists.

Activities—The Society is a research and publication society, and also engages in various meetings and promotional activities. There is no affiliation with any other scientific or religious organizations. Its members conduct research on problems related to its purposes, and a research fund and research center are maintained to assist in such projects. Contributions to the research fund for these purposes are tax deductible. As part of its vigorous research and field study programs, the Society operates The Van Andel Creation Research Center in Chino Valley, Arizona.

Membership—Voting membership is limited to scientists who have at least an earned graduate degree in a natural or applied science and subscribe to the Statement of Belief. Sustaining membership is available for those who do not meet the academic criterion for voting membership, but do subscribe to the Statement of Belief.

Statement of Belief—Members of the Creation Research Society, which include research scientists representing various fields of scientific inquiry, are committed to full belief in the biblical record of creation and early history, and thus to a concept of dynamic special creation (as opposed to evolution) both of the universe and the earth with its complexity of living forms. We propose to re-evaluate science from this viewpoint, and since 1964 have published a quarterly of research articles in this field. *All members of the Society subscribe to the following statement of belief*:

1. The Bible is the written Word of God, and because it is inspired throughout, all its assertions are historically and scientifically true in all the original autographs. To the student of nature this means that the account of origins in Genesis is a factual presentation of simple historical truths.
2. All basic types of living things, including humans, were made by direct creative acts of God during the Creation Week described in Genesis. Whatever biological changes have occurred since Creation Week have accomplished only changes within the original created kinds.
3. The Great Flood described in Genesis, commonly referred to as the Noachian Flood, was a historical event worldwide in its extent and effect.
4. We are an organization of Christian men and women of science who accept Jesus Christ as our Lord and Savior. The act of the special creation of Adam and Eve as one man and woman and their subsequent fall into sin is the basis for our belief in the necessity of a Savior for all people. Therefore, salvation can come only through accepting Jesus Christ as our Savior.

iDINO

Investigation of Dinosaur Intact Natural Osteo-tissue

A CRS Research Initiative

Scientists of the Creation Research Society are conducting a project to investigate the presence of intact tissue in dinosaur bones.

In the past several years, different studies have reported evidence of non-fossilized tissue (e.g., compact bone cells) and intact protein remaining inside fossilized dinosaur bones. Since these fossils traditionally have been dated at ages greater than 65 million years, the presence of this non-fossilized tissue is a direct challenge to the entire evolutionary "millions of years" time frame.

As part of the iDINO project, supraorbital horn of a Triceratops has been obtained and analyzed. This analysis revealed intact osteo-tissue containing osteocyte-like structures with detailed filipodial-like interconnections and secondary branching. The intricate detail of these observed cells offers a strong challenge to claims that the tissue is bacterial biofilm or microscopic artifacts. Instead, these results give powerful evidence that dinosaur fossils are really only a few thousand years old.

The Society is seeking funding from interested groups, churches, and individuals. This funding for the iDINO project will enable a more extensive examination of this supraorbital horn as well as other dinosaur specimens.

For more information contact us at (928) 636-1153 or crsvarc@crsvarc.com.

Also visit www.creationresearch.org for project updates and details.

Figure 1. CRS excavation team at a site in Hell Creek Formation, MT. Dinosaur specimens were obtained that have revealed the presence of intact tis

Figure 2. CRS team members excavated a large ...ratops horn at a the Montana site. Analysis of ...es the presence of intact compact bone ...fossilized.

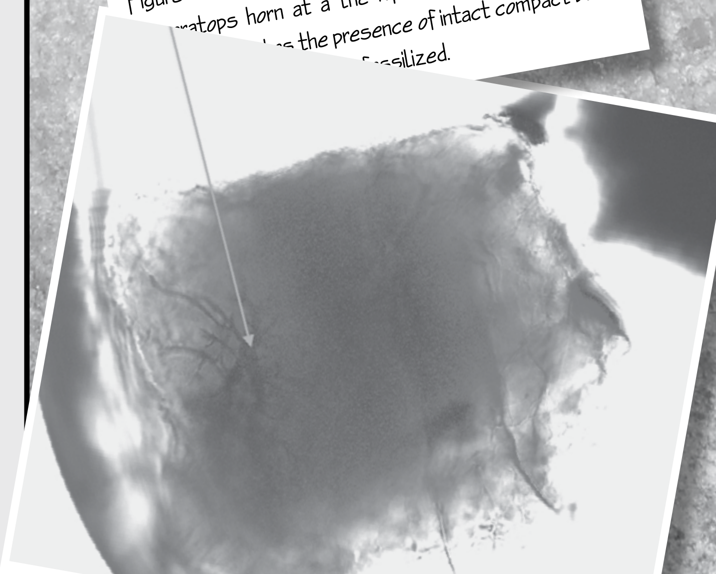

Figure 3. Confocal microscope picture of a thin section of material from Triceratops horn. The arrow points to what appears to be an intact osteocyte cell (a common cell in mature bone). The fluorescence of the cell indicates that it has not yet fossilized.