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Special Edition: Life: An Evidence for Creation

by George T. Javor

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COVER PICTURE

This collage represents a variety of plant and animal life. The layout was created by Clyde L. Webster, who provided all but two of the photographs. The remaining two photographs were provided by Katherine Ching.

ORIGINS welcomes original manuscripts on topics related to an understanding of earth history from a creationist viewpoint. The ideas presented are not necessarily those of the Geoscience Research Institute.

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FOREWORD

PROVING GOD?

Does life have a purpose, or are we here merely by chance? Everyone has probably been confronted with that question at some point in life. Many of us have concluded that life does have a purpose, that there is a Creator who had us in mind. But just when we think we are sure of the answer, some unexpected crisis may bring the question back to haunt us. Is there anything in nature itself that points to an intelligent Designer?

In this special issue, Dr. Javor suggests that life itself provides evidence that there must be a Designer. That evidence can be divided into four arguments.

Dr. Javor's first argument is that living matter is organized into interdependent systems, arranged hierarchically. A large number of interdependent components must all be in place in order for the living system to function. The term "irreducible complexity" has been applied to such systems, with the inference that such systems require intelligent design to come into existence. An intelligent Creator is the best explanation for the interdependent systems of living organisms.

A second argument is that the disequilibrium of living systems could not arise spontaneously. Life is based on many series of interacting chemical reactions, none of which must be allowed to reach chemical equilibrium. All chemical reactions tend toward equilibrium, but chemical equilibrium in living cells means death. How, then, could non-equilibrium conditions originate in a nonliving system? There seems to be no naturalistic answer to this question. An intelligent Creator provides the best available explanation for the origins of the chemical disequilibrium that is responsible for making cells alive.

The third argument is also chemical in nature. What is the source for the biomolecules required for life? These biomolecules apparently require highly improbable conditions for their origins. Conditions to produce one essential type of molecule may prohibit formation of another type of molecule equally necessary for life. Chance seems unable to produce any of the complex biopolymers needed for life.

Molecular sequences with informational content for specific functions are vital for life processes. The potential number of different sequences is exceedingly vast, and it seems inconceivable that the small set of sequences appropriate for life could be preferentially created by random processes. Again, chance seems an implausible explanation for the specific informational content of biopolymers. The best available explanation for the existence of the biomolecules of life is an intelligent Creator.

Dr. Javor's fourth argument is that complex functions, such as seen in living cells, are highly unlikely to arise by chance. Random aggregations of components are highly unlikely to produce any useful function. Functionality of complex systems typically depends on components which are pre-designed. But pre-design implies an intelligent designer and therefore a purpose. Thus, the complex functions of the living cell point to an intelligent Creator as the best explanation for their existence.

These are strong arguments for a Creator. However, they should not be mistaken for absolute proof. God's existence cannot be proved by science. Many intelligent people have chosen to reject arguments such as those presented here. The point of this presentation is not to claim that we have no other choice than to accept the existence of a Creator, but to show that we do have the choice to accept His existence. Not only is it reasonable to do so, but, in view of the properties of living organisms, it is the best choice available.

L. James Gibson

LIFE: AN EVIDENCE FOR CREATION

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INTRODUCTION

The explosion of biological knowledge continues unabated as we enter the third millennium of the modern era. Highlighting the numerous milestones of achievement are the successful cloning of “Dolly” from the nucleus of a sheep udder cell and the accession of complete genomic nucleotide sequences from over twenty organisms. But our knowledge of life will never be complete until an answer is found to the question, “How did life originate on Earth”?

It is certain that not too many scientists spend sleepless nights over this question. Most concern themselves with detailed studies of particular biological systems, which usually demand their full attention. Whatever the origin of life is, more practical concerns have to do with understanding the “here and now”. In addition, there is very little funding for scientists to ponder the origin of life on a full-time basis.

In terms of philosophical interest, life’s origin ranks with the most profound questions ever raised. Wrapped within this problem are far-ranging implications about the nature of the Universe and our place in it, the meaning and purpose of life, and predictions about the future course of life on Earth. Our model of life’s origin also impacts our worldview and religious beliefs.

Thinking about life’s origin, we can walk on one of two mutually exclusive paths. Life on Earth could have been created by an extra-terrestrial Creator, or it could have come into existence by a fortunate interplay of nature’s forces. Information about the history of Earth would be helpful in deciding between the two options. If Earth and the other planets of the Solar System were indeed born out of a spinning cloud of gas over an extended period of time, as is asserted by many, then it would be easier to suppose that the natural development of life is a continuation of some mysterious ongoing process in the Universe. The opinion of the majority of scientists and philosophers certainly leans in this direction.

It is not difficult to appreciate why this is so. Scientists are trained to believe that science can explain and solve any problem. This intrinsic optimism is essential to motivate scientists to wrestle new knowledge from the Unknown. With regard to cosmic questions, if one supposes a universe without a Creator, the green light is on to discover the nature of the mindless mechanisms that were responsible for the existence of everything about us. Furthermore, if natural forces were able to accomplish so much creative work, then it is incumbent on scientists to learn more about these forces and possibly harness them.

But here a problem arises. Scientists are at their best when they study repeatable phenomena. At present, no solar system is forming before our eyes. Even worse, we do not see natural forces producing living organisms from solely nonliving matter. Yet the millions of different life forms we see around us had to originate from somewhere! The scientist, working on the assumption that there has to be a natural explanation for the origin of life, becomes a detective. He is looking for clues to show how Mother Nature brought life to Earth. Experiments are done to test which primordial scenario could more likely bring life into existence.

Most scientists regard the postulate that our world is here as a result of a Creation event as resorting to “magic” instead of a logical explanation — an abandonment of science. It does not help matters that the story of Earth’s creation by a Creator comes from a manuscript that is over three-thousand years old. Since then much has been learned about living things, our world and the Universe. Is it not possible that if the ancients had our scientific knowledge, they would have reported the story of the creation of Earth differently?

We do not know the answer. What the ancient biblical record reports is that Earth and its biosphere were brought into existence in a creation event that took six days for the Creator to accomplish. To most scientists, this sounds incredible. However, a close look at what is occurring in the biosphere reveals many incredible facts.

This brief monograph was written to champion the views of a minority in the scientific community. This minority holds that it is possible to accept this ancient report of Earth’s creation at face value — and still be a true scientist. But the main purpose is to go a step further. It will be argued that a close examination of life can lead observers to the logical conclusion that life itself is an actual **evidence** for creation.

This subject is presented from a biochemical perspective, i.e., looking at living matter at the level of atoms and molecules. Although the use of technical terms could not be avoided, they were kept to a minimum. The intent was to communicate as clearly as possible the important molecular concepts undergirding life. It is this writer's conviction that these may be understood without possessing a formal education in chemistry or biochemistry. The biochemical concepts presented here should be useful to all readers, regardless of their philosophical orientation, even if they cannot accept this writer's conclusions.

ACKNOWLEDGMENT

The author would like to express appreciation for the insightful comments and helpful suggestions from the reviewers of this manuscript. Any remaining errors are this writer's responsibility.

CHAPTER 1

IS THERE SUCH A THING AS LIFE?

“Life is a spiritual pickle which keeps the body from decay”.

A. Bierce

It was Dr. Albert Szent-Gyorgyi, a Nobel prize-winning biochemist, who wrote: “Life, as such, does not exist”.¹ Most of us would quickly disagree with him, Nobel prize notwithstanding, because we know that life is all around us in the forms of people, animals, and plants.

We may not have noticed that he did not actually write “life does not exist”, but rather “**life as such**” does not exist. “What we can see and measure are material systems”, continued Dr. Szent Gyorgyi, “which have the wonderful quality of ‘being alive’”.¹ That is, one cannot put “life” in a test tube. There is no freestanding entity called “life”. The Hungarian-born scientist did not deny the concept of life, only that it can exist autonomously, apart from material systems.^{2,3}

Living organisms blanket the Earth so extensively that a typical gram of soil will contain at least ten thousand microbes. Spores (inert forms of microorganisms) swarm in the air, and specimens of marine life have been seen in the deepest recesses of the oceans, several kilometers in the deep rocks, where hydrostatic pressures approach 1000 atmospheres.

Not only are living organisms everywhere, they come in an astonishing array of forms. It is estimated that the number of diverse species on our globe runs into the millions!⁴ Their combined activities make Earth’s surface a throbbing web of constant change.

An important aspect of the biosphere is that **diverse orders of organisms support the existence of each other**. A prime example is the work of nitrogen-fixing bacteria, without which plants could not access the abundant nitrogen available in the air. Soil microorganisms and bacteria living in the roots of certain legumes in symbiotic relationship convert the nitrogen gas in air to water-soluble nitrates and nitrites. Plants then use these for their growth.

Plants also utilize carbon dioxide from the air to manufacture carbohydrates, harnessing solar energy. This process, photosynthesis, liberates oxygen. Non-plant organisms use oxygen in generating energy by burning up plant material and by releasing carbon dioxide as waste.

This relationship between plants and non-plants is illustrated in Figure 1.1.

The mutual interdependence of organisms, as seen in the biosphere today, brings into question **whether there ever was a time when only a single form of life existed.** While evolutionists have always insisted that this indeed was the case, recently there is a reluctance to become specific about the nature of the putative precursor organism(s) of modern life forms.

This happened partly because of the discovery that the chemical makeup of heat-tolerant microorganisms seems to be more similar to eukaryotes (cells with nuclei), than to other forms of bacteria.

Thus the previously perceived, clearly defined, relative positions in the hierarchy of eukaryotes over bacteria became blurred.

An older pictorial representation of how different organisms were supposed to have evolved from each other is shown in Figure 1.2. All life forms were believed to have originated from ancient “prokaryotic cells”.

This evolutionary bias is seen in the commonly used term “prokaryote”, meaning “before kernel” in Greek, to

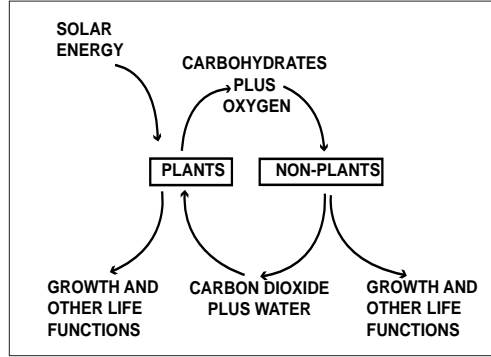


FIGURE 1.1. Photosynthesis and the carbon-oxygen cycle throughout the biosphere.

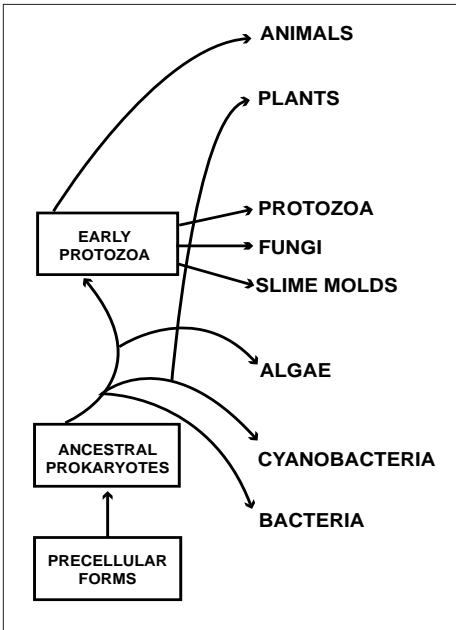


FIGURE 1.2. An earlier version of the postulated evolutionary relations of the major life forms.⁵

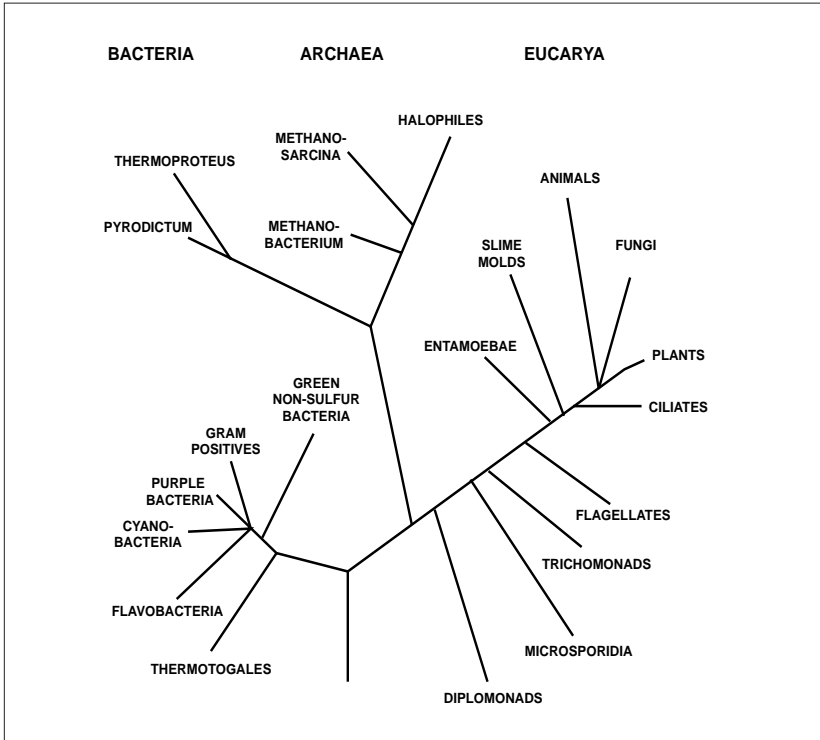


FIGURE 1.3. Phylogenetic relationships among life forms based on ribosomal RNA sequences.⁶

designate any bacterium. (The term “kernel” represents the more commonly used word “nucleus”.) The latest evolutionary scheme, shown in Figure 1.3, features a phylogenetic tree, where the trunk and the branch-points are unidentified and it is no longer clear whether the putative evolutionary ancestor was with or without a true nucleus.

The great variety and abundance of living organisms on Earth is in stark contrast to the apparent sterility of our cosmic neighborhood. Based on several decades of probing, there is no hard evidence to suppose that any extraterrestrial life forms exist in the solar system.⁷ Furthermore, in the past few years very intensive “listening” has been underway for intelligent extraterrestrial radio signals,⁸ again, so far with no results. The apparent uniqueness makes the study of life all the more exciting.

GRAPPLING WITH THE DEFINITION OF LIFE

Entire fields of knowledge are connected with studies of living organisms, i.e., biology, microbiology, biochemistry and biophysics. Yet after two centuries of dedicated study we still do not have a very satisfactory definition of life. For example, one dictionary defines life as “the property or quality that distinguishes living organisms from dead organisms and inanimate matter, manifested in functions such as metabolism, growth, response to stimuli and reproduction”.⁹ This definition accurately describes in a general way the most recognizable features of living organisms, but it does not illuminate the core concept of life. It leaves unspecified what “that property or quality” is, which enables matter to behave in such a unique manner that the term “life” is required to describe it.

Many forms of living matter exist as hierarchies of increasingly complex structures. Cells join to form tissues, tissues interact to fashion organs, and organs compose organisms. The term “life” has different technical meanings, depending on whether it refers to cells, organs or organisms. This concept may be seen when upon the unfortunate death of an accident victim, his or her organs (which are still “alive”) may be transplanted into another person. Under appropriate conditions the new organ will continue to “live” because its individual cells are alive and they interact with each other harmoniously to carry out the organ’s functions. It is the cells of the organs that are the smallest units of life. When they die, life disappears. Thus a good place to begin the study of life is the cell.

Deciphering the composition and workings of cells on the molecular level started in earnest at the beginning of the twentieth century when scientists reached a sophisticated understanding of organic chemistry. Knowledge of the operation of living cells continues to grow to this day at a dizzying pace. As of the middle of 1999 the complete genomic structures of twenty-three organisms are available.¹⁰ With the help of computer analysis it has been possible to parse the chromosomes of these organisms into genes. Furthermore, utilizing the concept that genes with similar nucleotide sequences often code for proteins with similar functions, educated guesses are made about the roles of newly found genes. Within a few years we may have a complete understanding of the internal workings of some bacterial cells.

Beyond achieving an ever-clearer grasp of life-processes, scientists are now able to alter organisms by placing new genes into them. Optimism is rampant that soon we will understand the molecular secrets of cellular differentiation, the formation of diverse daughter cells from one parent cell. Currently a worldwide effort is underway, with the leadership of the United States, to determine the nucleotide sequence of the entire human genome, some 3 to 4 billion nucleotides long. Such knowledge, it is claimed, will enable us to find out how cancer develops and how its spread may be arrested. We may also gain a better understanding of a host of other diseases which are caused by aberrations in the genetic material. Doubtless, we live in the golden age of biology, and we may eagerly anticipate many existing discoveries in the near future! As comprehension of the unique properties of living matter reaches unprecedented heights, we are positioning ourselves to answer the age-old question, **What is the origin of life on Earth?**

SUMMARY OF CHAPTER 1

1. Life is not a freestanding entity. The only experience we have with life is in association with certain types of matter.
2. Organisms in Earth's biosphere are mutually interdependent.
3. It is becoming increasingly difficult to postulate the nature of the hypothetical evolutionary ancestor(s) of modern organisms in the light of the unexpected finding of similarities between certain thermophilic organisms and eukaryotes.
4. The term "life" has different meanings, depending on whether it refers to organisms, organs or cells.
5. A century of biological and biochemical research has propelled us into the golden age of biology.

REFERENCES AND NOTES ON CHAPTER 1

1. Szent-Gyorgyi A. 1972. The living state with observations on cancer. NY and London: Academic Press, p 1.
2. Ibid.
3. This sort of analysis of life may seem too materialistic to many conscientious persons who perceive that the Bible teaches a different view of life — one which does not insist that it be associated with matter. It is true that scientists have experience only with life as it is found here on Earth, and that there may well exist larger realities which are not now accessible to us.

Nevertheless, the Bible supports the notion that life is associated with matter. In the second chapter of Genesis, for instance, where the creation of mankind is described, "...the Lord God formed man of the dust of the ground, and breathed into his nostrils

the breath of life; and man became a living soul” (v 7). It was the combination of the breath of life and the dust of the ground which gave rise to the living person. Similarly, according to biblical teachings, a person dies when his “breath goeth forth, he returneth to his earth; in that very day his thoughts perish” (Psalm 146:4). The “return to earth” marks the end point of human existence. Even though his “breath goeth forth”, the person’s life does not. While one can only speculate on the meaning of the “breath of life” and of the person’s “breath”, it is clear that life did not continue, because the “thoughts perished”. The Bible does not know anything about a disembodied form of life. To embrace the material basis of life on Earth therefore does not make one a materialist.

4. Starr C, Taggat R. 1992. *Biology, the unity and diversity of life*. Sixth ed. Belmont, CA: Wadsworth Publishers.
5. Figure drawn after: Davis BD, Dulbecco R, Eisen HN, Ginsberg HS. 1980. *Microbiology*. Third ed. Hagerstown, MD: Harper and Row Publishers, p 11.
6. Figure drawn after: White D. 1995. *The physiology and biochemistry of prokaryotes*. NY: Oxford University Press, p 4.
7. The claims of Dr. D.S. Mackay et al. (*Science* 273 [1996], p 924) regarding meteorite Alh84001 — that it came from Mars and that it contains organic matter from that planet — cannot be considered evidence for extraterrestrial life. Their assertions are based on a one-sided interpretation of the actual data presented.
8. SETI Institute News release on the Internet, February 12, 1998.
9. *The American Heritage Dictionary*. 1991. Second college ed. Boston: Houghton Mifflin Co.
10. As of June 1999, twenty-three complete genome sequences of organisms have been published. These are: *Aeropyrum pernix* K1, *Archeoglobus fulgidus*, *Aquifex aeolicus*, *Borrelia burgdorferi*, *Bacillus subtilis*, *Caenorhabditis elegans*, *Chlamydia pneumoniae*, *Chlamydia trachomatis*, *Escherichia coli*, *Haemophilus influenzae*, *Helicobacter pylori*, *Methanobacterium thermoautotrophicum*, *Methanococcus jannaschii*, *Mycobacterium tuberculosis*, *Mycoplasma pneumoniae*, *Mycoplasma genitalium*, *Plasmodium falciparum*, *Pyrococcus horikoshii*, *Rickettsia prowazekii*, *Sacharomyces cerevisiae*, *Syneocystis* PCC6803, *Thermotoga maritima*, *Treponema pallidum*. Also available are the complete genome sequences of at least 180 viruses and of 13 bacteriophages. In progress are the genome sequence determinations of at least a dozen other bacterial and 17 multicellular species. This information was obtained from the Internet, under “Genome Sequencing Projects”.

CHAPTER 2

THE MATTER OF LIFE AND DEATH

“Material things I touch and taste and see, all other things are immaterial to me”.

A. Bierce

What is the difference between living and inanimate matter? Intuitively, we are confident that we can easily tell the difference between them. But, with the rapid increase in computer technology, could it happen that artificial intelligence one day will effectively mimic aspects of human reasoning and behavior? Such scenarios have already been presented in science fiction, where humans had to deal with a supercomputer “Hal” in *2001, a Space Odyssey*, or with lifelike robots in the tale *The Stepford Wives*. What criteria would we use in deciding that those moving and talking mannequins were lifeless after all?

Paul Weiss, a well-known biologist, wrote a tongue-in-cheek piece entitled “Life on Earth (by a Martian)”.¹ In this story, some Martians came to visit Earth in search of life. After lengthy and careful observation of our planet, they concluded that life did indeed exist here, and furthermore, one life form was predominant. They named it the “Earthian” and faithfully chronicled its every particular. Apparently the Earthians had intricate symmetrical bodies; they moved, emitted heat and sounds, and ate (mostly liquid food). Sometimes they divided, and they eventually died. Which organism did the Martians observe and describe? Automobiles, of course! (The Martians also noticed some rather unimpressive structures associated with the Earthians, and they concluded that these were some sort of parasites, unworthy of further study.)

Our capacity to determine whether or not an entity is alive is limited by our previous experiences with living organisms. If we landed on a new planet, we could find it difficult to decide whether or not life was present.

LOOKING FOR LIFE ON MARS

In the 1970s the United States sent two automated laboratories to Mars to determine if living organisms existed there. The results of the biology experiments strongly suggested some kind of biological activity on Mars. Carbon dioxide was released when a nutrient-rich liquid mixture

was incubated with a scoop of Martian soil. In an Earth-based laboratory, the results would have constituted compelling evidence for the presence of life. Yet scientists interpreting the data which was radioed back from Mars were forced to conclude that in all likelihood Mars was sterile. The reason was that chemical analyses of the Martian surface indicated the complete lack of carbon-containing substances, other than the gas carbon dioxide.² Now we know that the iron-rich surface, activated by ultraviolet radiation, degraded the radioactive test substances, resulting in false chemical signals. This is an example of carefully designed experiments, aimed at distinguishing between the presence or absence of life on the red planet, that were not quite equal to the task.

IS THERE A DIFFERENCE BETWEEN LIVING AND NONLIVING MATTER?

There are those who see an unbroken continuum between living and nonliving matter. If this is so, the question of life's origin becomes a moot point. Viruses, prions, mycoplasmas, rickettsiae and chlamidia are offered as examples of organisms that bridge the chasm between living and nonliving. But the differences between living and nonliving matter are in fact so great that this chasm cannot be spanned.

Although viruses and prions are made from biopolymers, they are no more alive than the enzyme additives in some detergents. Viruses are lifeless complexes of proteins and nucleic acids. The biological activity of viruses, including their replication, is completely dependent on the metabolic activity of the infected cell. Prions are unique proteins that alter the structure of certain other proteins. The newly changed proteins in turn acquire prion-type activity, creating a domino effect of protein alteration. This property of prions renders them infectious. For reproduction, prions, like viruses, are wholly dependent on live cells.

Rickettsiae, chlamidia and mycoplasmas, on the other hand, are among the smallest known living organisms, and are very much alive. The fact that chlamidia and rickettsiae are obligate intracellular parasites only means that they have serious metabolic deficiencies. A clear distinction between living entities and nonliving substances is essential for a consideration of whether it is possible to go from one state to the other. For this reason we need to descend into the submicroscopic world of matter.

The elemental compositions of living and nonliving matter differ greatly.⁴ The actual chemical determination of living matter is done on “once-living matter”. Before chemists can analyze living matter, they have to take it apart to isolate its individual components, thereby killing it. Thus the actual phenomenon of “life” is not amenable to detailed chemical scrutiny. In the very process of laying hold of isolated “purified” components of living matter, “life” slips out between the chemists’ fingers, and what remains is an inert, “lifeless” substance. This is so because **living cells are composed of lifeless, nonliving components**. The implication is that the difference between life and death is a question of how biomatter is organized. Therefore, it should be possible to reverse the killing of cells by restoring them to their pre-disruption state. Why this has not yet been done in the laboratory will be discussed in the next chapter.

The chemical evolutionary issue can be reduced to answering a two-part question: 1) Is it conceivable that appropriate types of biomatter could have emerged on a hypothetical primordial earth; and 2) If these substances existed, could they have combined to form living matter?

Chemists have obtained valuable information regarding the differences in the composition of “once-living” matter and of “never-living” substances. Never-living matter — rocks, minerals, air, water, etc. — consists of small molecules, often with high oxygen content. These “oxides” are sturdy substances, stable under heat and mechanical stress. A good example is silicon dioxide — sand, a most abundant gritty stuff.

Living and once-living organic matter, in contrast, is predominantly constituted from large molecules which contain thousands, or even millions, of atoms. The oxygen content in these substances is low, but if oxygen is allowed to interact freely with these molecules, they lose biological activity. Surrounded by a sea of oxygen, living matter continually fights the inroads of this element with oxygen-neutralizing mechanisms. Fragile biomolecules are easily degraded or deformed by heat or mechanical stress.

The large qualitative differences between living and inanimate matter have been recognized for hundreds of years. Scientists initially thought that biological material could be produced only by living organisms, so they called these “organic”. But in 1828 the German chemist Frederick Wohler accidentally produced urea by heating potassium cyanate with ammonium sulfate. Urea was at that time already recognized as an animal waste product, definitely “organic” in nature. Scientists quickly

realized the implications of this breakthrough discovery. The production of biological matter did not, after all, depend on “life forces”. The term “organic” was retained to designate all compounds that contain carbon, with a few exceptions such as carbon monoxide, carbon dioxide, carbides, carbonates, cyanides and isocyanates.

Although the types of life-forms run into the millions, their general chemical compositions have important similarities. The gross chemical composition of the well-studied colon organism *Escherichia coli* represents the “typical cell” (see Table 2.1).

Component	Percent of Total Weight	Molecules Per Cell	Number of Different Kinds of Molecules
Water	70	24.3 billion	1
Proteins	15	2.4 million	approx. 4,000
Nucleic acids	7	255 thousand	660
Polysaccharides	3	1.4 million	3
Lipids	2	22 million	50-100
Metabolic intermediates	2	many millions	800
Minerals	1	many millions	10-30

The high water content of living matter prompted Dr. Szent-Gyorgyi to write: “we are a walking aquarium”.⁵ We need all that water to enable most chemical transformations of life to take place.

The importance of water for life-processes can be demonstrated quite dramatically with freeze-dried microorganisms. We can collect bacteria from growth in a liquid medium in the form of a wet paste. Rapidly freezing this material and placing it under vacuum causes the frozen water to leave the bacteria unobtrusively, and the former wet paste turns into powder. The dried microscopic cells are now in a state of suspended animation. They are neither alive, nor are they dead. They can be stored indefinitely in the dried state, without any change in their status. However, by simply mixing the powder with water and the appropriate nutrients, the dormant cells spring into life once again. In this procedure we manipulate life on the cellular level by withdrawing an all-important cellular component. The most remarkable aspect of this

process is the reversibility of the life-processes by manipulating only the water content of the cells!

HOW BIOPOLYMERS ARE PUT TOGETHER

The bulk of dry matter in all organisms (more than 90%) is composed of the biopolymers: proteins, nucleic acids, polysaccharides and lipids. A common feature of these four classes of substances is that they contain many repeats of small building-block substances. Very significantly, all chemical linkages between the building blocks are created by dehydration. That is, the building blocks of all biopolymers are linked by splitting out water between them. This information is summarized in Table 2.2.

BIOPOLYMER	BUILDING BLOCK	CHEMICAL LINKAGE
Protein	Amino acid	Peptide bond
Nucleic acid	Nucleotide	N-glycosidic and phosphodiester bonds
Polysaccharides	Monosaccharide (simple sugar)	Glycosidic bonds
Lipids*	Glycerol, fatty acids	Ester bonds

*Lipids are not true biopolymers, but they often aggregate to form large structures, such as membranes. Also, only a single type of lipid is listed here. In reality, there are many different kinds of lipids, with diverse compositions.

One of the challenges of chemical evolutionary postulates is to explain how these biopolymers could arise in a world assumed to be covered with water. It is a most difficult task to form new chemical bonds by eliminating water in an aqueous environment!

HOW CAN WE HAVE SO MANY DIFFERENT KINDS OF PROTEINS?

The bulk of biomatter is made from proteins. These are a most interesting and versatile class of materials. In each cell there are hundreds

to thousands of different types of proteins, each with different chemical and physical characteristics. Such diversity is due to both their great size (they are composed typically of long strings of amino acids) and to the fact that any amino acid may be one of twenty different kinds.⁷ What each protein is capable of doing depends a great deal on the actual order in which the amino acids are linked. This feature of biology is similar to a written language.

A word's meaning depends on the sequence of its letters. We choose from 26 letters of the English alphabet to make words. An estimated 500,000 different combinations of letters in our language are recognized as meaningful. With some effort, we could come up with many more sets of 500,000 combinations of letters that would be nonsensical (Dr. Seuss started a nice collection of these). Similarly, the millions of proteins represent only a tiny fraction of all possible combinations of amino acids.

Misspelling words jeopardizes their meaning. Likewise, for proteins to function properly their amino acids must follow each other in a correct order.⁸ For example, the oxygen-carrying component in our blood — hemoglobin — is built from 4 separate protein chains, each of which is a string of 142-146 amino acids. In an inherited illness called “sickle-cell anemia”, the gene for one of the protein chains of hemoglobin sends out incorrect information to the protein-making complex. This results in placing a wrong amino acid in the sixth position of a specific sequence of the 146. This alteration is enough to lead to distortion of the red blood cell, to anemia, to many other problems, and, sadly, to death in many cases. While not all changes in amino-acid sequences have such drastic consequences, this somewhat extreme example underscores the importance of the correct order of amino acids for proteins.

The amino-acid sequences of proteins are crucial components of the biological information content of cells. Proteins themselves are considered **informational biomolecules**. But how does the protein-building apparatus know the correct amino-acid sequence for each of the thousands of different proteins found in the cell?

The answer is that the **genes** of each cell are libraries containing just such information. When the cell needs to make a certain type of protein, it sends a copy of its amino-acid sequence information to the protein-synthesizing complex. Bacteria, with a thousand different proteins, have a minimum of a thousand genes. The recent triumph of obtaining the complete nucleotide sequence of organisms has enabled

us to count their genes and even to assign a function to many of them. Table 2.3 shows a compilation for three microorganisms; *Haemophilus influenzae* (1743 genes), *Mycoplasma genitalium* (471 genes) and *Escherichia coli* (4288 genes). The first two organisms grow only inside humans in a nutritionally rich environment. *Escherichia coli*, on the other hand, can proliferate independently and may be considered a free-living organism.

Function	<i>H. influenzae</i>	<i>M. genitalium</i>	<i>E. coli</i>
Amino acid metabolism	68	1	131
Biosynthesis of cofactors, prosthetic groups and carriers	54	5	103
Cell envelope	84	17	195
Cellular processes	53	21	188
Central intermediary metabolism	30	6	188
Energy metabolism	105	31	243
Fatty acid and phospholipid metabolism	25	6	48
Purines, pyrimidines, nucleosides and nucleotides	53	19	58
Regulatory functions	64	7	45
Replication	87	32	115
Transcription	27	12	55
Translation	141	101	182

From this table it is seen that *E. coli* requires more than 1500 different proteins for growth. Most of these proteins are biocatalysts — “enzymes” — that promote specific chemical conversions.

As for the biological functions of the other three classes of biopolymers, nucleic acids are the repositories and transmitters of the genetic information; lipids segregate the interior of the cell from its environment and, along with polysaccharides, serve as energy reserves. In microorganisms, polysaccharides also constitute part of the cell’s outer envelope.

The non-polymeric, small metabolites are only a small portion of the cell by weight, but their presence is absolutely essential for life-

processes. In fact, it is the chemical transformations of these compounds that make life possible. (This topic is explored further in the next chapter.) Metabolic intermediates represent transitional substances between precursors and building blocks. Building blocks are used, of course, to make the all-important biopolymers. These in turn are assembled into more complex supramolecular assemblies and organelles.

Matter is organized into successively more complex hierarchies in cells. The logical interdependency among cellular components in the vertical hierarchy parallels nicely the logical ties that connect letters with words, words with sentences, sentences with paragraphs, etc., all the way to the level of a completed manuscript. This concept is illustrated in Figure 2.1.

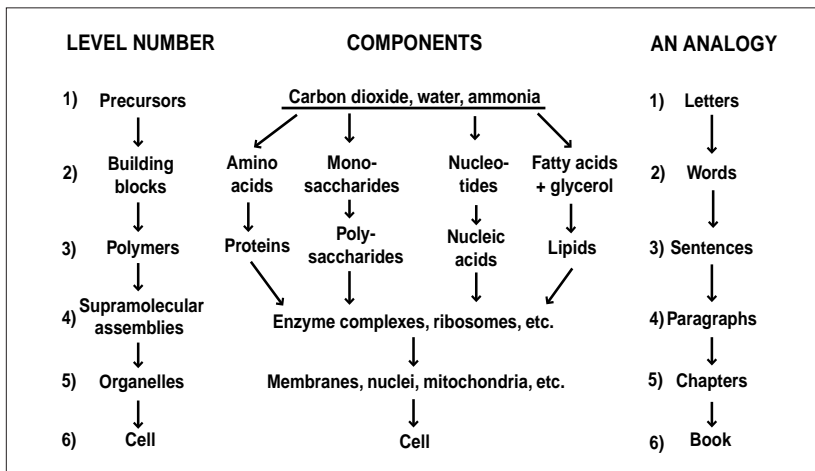


FIGURE 2.1. Organization of matter in the cell.

A crucial difference between biomatter and written material, however, is that the degree of tolerance for error is much smaller in biology. If words are misspelled, sentences are garbled, paragraphs do not hang together, or even if entire chapters are missing from a manuscript, the document may still be partially useful. But given the tight functional interdependence of its components from precursors and biopolymers, cells are in trouble with less than a full complement of all their parts. Each living cell contains thousands of different kinds of substances, present in multiple copies, and sequestered, in the case of a bacterium, in a volume of a few cubic micrometers (see Table 2.1).

At the level of supramolecular assemblies and above, the various strands in Figure 2.1, which represent classes of biopolymers, are intertwined into increasingly complex entities. The biological information in the genetic material and in the many protein molecules becomes a coherent whole somewhat the way paragraphs support each other in a good story. The “story” in this case is the life of the cell.

Besides vertical interdependence, there is also a horizontal complementation among the components. One illustration of this interdependence is that the manufacture of proteins requires nucleic acids and, conversely, nucleic acids cannot be made without proteins. This circular relationship between proteins and nucleic acids from a chemical evolutionary viewpoint resembles the classic “chicken and egg” problem.

SUMMARY OF CHAPTER 2

1. Although there are many differences between living organisms and inanimate matter, in an unfamiliar setting it may be difficult to distinguish between them. On Earth the lines of demarcation between living organisms and inanimate matter are clear.
2. The chemical makeup of living matter consists of large amounts of biopolymers and smaller amounts of metabolites in an aqueous setting.
3. Living matter is organized into hierarchies, with the components being organizationally interdependent in both the vertical and the horizontal dimensions.

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1. Weiss PA. 1973. A random walk in science. London and Bristol: The Institute of Physics; NY: Crane, Russel and Co., p 124-136.
2. Biemann K, Oro J, Toulmin P (III), Orgel LE, Nier AO, Anderson DM, Simmonds PG, Flory D, Diaz AV, Rushneck DR, Biller JA. 1976. Search for organic and volatile inorganic compounds in two surface samples from the Chryse Planitia region of Mars. *Science* 194:72-76.
3. These numbers are based on data from: Neidhardt FC, editor. 1966. *Escherichia coli* and *Salmonella*. Washington DC: ASM Press, p 14.
4. The availability of each type of atom is different; some are very abundant on Earth, while others are quite scarce. Out of every 100 atoms on Earth, 62 are oxygen, 21 are silicon, 7 are sodium, and 2 are iron. The remaining 8 atoms may be any of the other elements. To find a carbon atom, for instance, we would have to sort through about 8000 atoms.

In contrast, among atoms found in living matter, out of every 100, 60 are hydrogen, 26 are oxygen, and 11 are carbon. Thus it is clear that the atomic content of living matter does not reflect the general composition of Earth.

5. Szent-Gyorgyi A. 1972. The living state. NY: Academic Press, p 8.
6. A curious fact about nearly all “building-block” type substances is that they are structurally asymmetric, i.e., these substances do not have an axis of symmetry. As such, each molecule has a non-biological “twin” which has identical atomic composition to the biologically important subunit, except that the atoms are arranged backwards, and the two structures are spatially mirror images of each other.

Asymmetric substances are similar to our left and right hands, which are non-symmetric mirror images of each other. When a chemical process is used in the laboratory to produce one of these asymmetric substances, the outcome is invariably a fifty-fifty mix of the substance and its mirror image.

Biological systems, on the other hand, are able to produce these asymmetric substances without the contaminating presence of their mirror images. This is accomplished with the help of biological catalysts, called enzymes.

7. The number of possible different sequences for a 100-amino-acid-long protein is 1.2×10^{130} , or 12 followed by 129 zeros!
8. The function of proteins frequently depends on their three-dimensional shapes. The order in which amino acids are linked together influences the protein’s shape immensely.
9. The information in Table 2.3 was compiled from three articles: (a) Fraser CM, Gocayne JD, White O, Adams MD, Clayton RA, Fleischmann RD, Bult CJ, Kerlavage AR, Sutton G, Kelley JM, et al. 1995. The minimal gene complement of *Mycoplasma genitalium* [see comments]. *Science* 270:397-403; (b) Fleischmann RD, Adams MD, White O, Clayton RA, Kirkness EF, Kerlavage AR, Bult CJ, Tomb JF, Dougherty BA, Merrick JM, et al. 1995. Whole-genome random sequencing and assembly of *Haemophilus influenzae* Rd [see comments]. *Science* 269:496-512; and (c) Blattner FR, Plunkett G (III), Bloch CA, Perna NT, Burland V, Riley M, Collado-Vides J, Glasner JD, Rode CK, Mayhew GF, et al. 1997. The complete genome sequence of *Escherichia coli* K-12 [comment]. *Science* 277:1453-1474.

In this table the only genes listed are those whose functions have been identified, at least in a preliminary fashion. For each organism, only 50-60% of the genes are accounted for.

CHAPTER 3

WHAT MAKES A CELL TICK?

“Old chemists never die, they just reach equilibrium”.

In presenting a case for a tight logical link between analyzing the molecular aspects of life and the creationist paradigm, it is not enough to enumerate the components of living matter. Simply knowing the components of living matter is not enough to account for its biological activity. **Living matter behaves differently than its isolated components.** Living cells incorporate selected substances and utilize them either for energy or as building blocks for growth. They also secrete metabolic waste. Living cells grow and divide into daughter cells. Lastly, when cells recognize unfavorable environmental conditions, they make metabolic adjustments to preserve their existence.¹ Living matter gives every indication that it “wants” to stay alive. This is a property of the complex network of components in living matter. The whole seems to be more than the sum of its parts. If we collect all of the ingredients from live cells, lace them in a membrane-enclosed vesicle, we have an inert, “lifeless” assembly of biomatter. This bag may be stored indefinitely in an environment hospitable for life, without the actual emergence of life. If we periodically analyzed the contents of this artificial “cell”, we would find little change in its chemical composition. Such an arrangement of matter is called **equilibrium**.²

If we sampled the composition of life cells growing in a defined laboratory setting, surprisingly, the results would be similar. That is, we would find the chemical composition of live cells quite constant. But instead of the term “equilibrium”, we say that matter in live cells is in a “**steady state system**”. The significant difference between the two is the dynamic **flux** of matter through live cells.

A mechanical illustration of this difference is shown in Figure 3.1. Here, the contents of both vessels remain unchanged over time, but there is **constant movement of liquid through vessel A**. The flow of molecules through cells is an essential feature of life. (In contrast, the liquid in container B is stagnant.) The movement of water through a compartment, representing the flux of matter through the cell, is an oversimplification of what actually occurs. In reality matter changes as it travels through the cell. The incoming precursors (biomonomers)

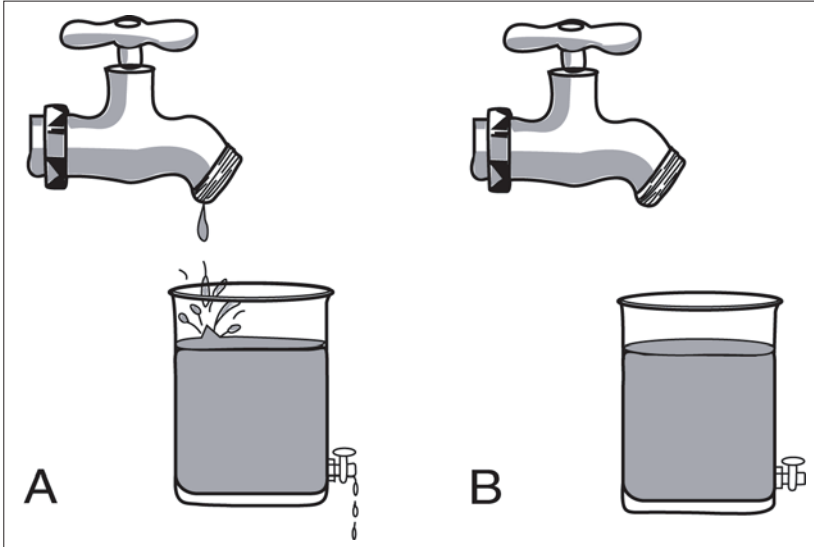


FIGURE 3.1. A comparison of the concept of steady state (A) and equilibrium (B).³

are simple substances which are gradually built up to successively more complex structures. In Figure 3.2 this is represented by the arrows on the right, marked “biosynthesis” and “assembly”.

To complete the circuit, the biosynthetic flow of matter is balanced by a set of degradative pathways. The very existence of degradative pathways in the cell is remarkable, in view of the fact that biopolymers and the successively more complex structures are made at prodigious expenditure of energy. Their constant degradation and remodeling would seem a phenomenal waste. But we now know that in the course of metabolism, components sustain oxidative damage with time. Accumulation of damaged metabolites would clog the cell’s machinery. The constant turnover of biomatter preempts such a scenario.

However, since both biosynthesis and degradation are occurring in the same cell, the two processes need to balance. An excess rate of degradation over biosynthesis would be particularly disastrous. Thus, the rates of all metabolic processes have to be coordinated for this tightrope act of metabolic symmetry (steady state). Figure 3.2 also shows the linkage between energy usage and biosynthesis. The substance abbreviated as “ATP” is the chief carrier of chemical energy in the cell. Most frequently,

when chemical change requires input of energy, ATP (adenosine triphosphate) is degraded to ADP (adenosine diphosphate). The sum total of the chemical changes in the cell equals the essence of life.

WHAT ARE CHEMICAL REACTIONS, ANYWAY?

Chemical reactions are nothing more than the movement of bonding electrons around and between atoms. These electrons hold groups of atoms in clusters called molecules. The fascinating property of matter is that these clusters behave very differently than their constituent atoms.⁴ For example, clusters of oxygen atoms and clusters of hydrogen atoms by themselves are gases. Hydrogen is very flammable, even explosive. But when an oxygen and two hydrogen atoms are combined into a cluster, water forms. The conversion of a mixture of oxygen gas and hydrogen gas to water is a chemical reaction.

In chemical reactions, atoms and their bonding electrons leave an old cluster and join a new one. As a result of changes in their atomic compositions, the chemical properties of clusters change. By “chemical property” we mean the tendency of molecules to acquire or give up atoms.

Why would atoms and their bonding electrons jump from one atomic cluster to another? This is equivalent to asking why chemical reactions occur at all. Chemists tell us that the driving force behind chemical changes is the intrinsic tendency of all matter to exist in the lowest possible state of energy. This is why balls roll downhill spontaneously, electricity flows from the negative to the positive pole,

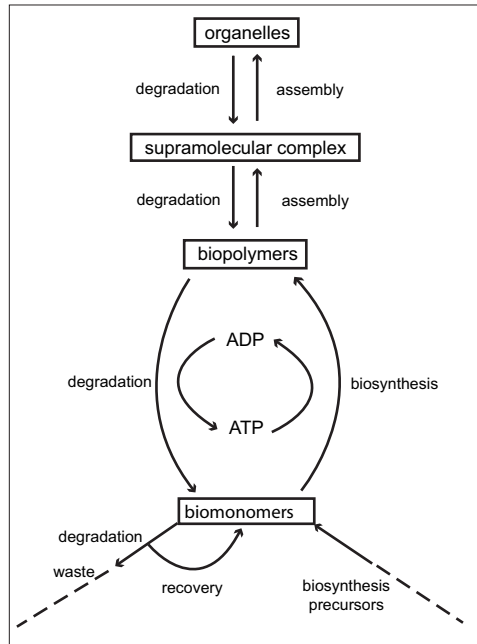


FIGURE 3.2. Movement of matter through the cell.

and hot objects tend to cool down to the temperature of their environment.

Chemical reactions can be compared to a market transaction where molecules trade atoms in order to shed some of their energy content. Just as in business there are sellers and buyers, in chemical reactions there are atom clusters that can achieve lower energy states by rearranging or giving up some of their atoms. These are the “sellers”. Other clusters — the “buyers” — receive new atoms, and their energy levels increase. The important consideration for such chemical transactions to occur is that when all the energy gains and losses are totaled, there should be a net lowering of the overall energy content of the system.

Chemical changes take a finite amount of time. Some rearrangements are faster than others. Chemists have found that if the vibrations of atoms are speeded up by raising the temperature, the chemical change is more rapid. There are also helper agents — catalysts — which facilitate reactions. Remarkably, almost every chemical change in the cell has a facilitator catalyst — an “enzyme”. Enzymes are very large protein molecules, often hundreds of times larger than the atomic groups they manage.

WHY ENZYMES?

The role of catalysts is the speeding up of chemical conversions. In the case of living matter, why are catalysts necessary? Why must there be an increase in reaction rate? If all chemical changes in the cell would slow down due to lack of catalysts, what would happen? The answer is: chaos. Without specific catalysts guiding molecules through precise paths of chemical changes, numerous “unauthorized” chemical side-reactions would occur. This is due to the propensity of substances to interact with each other in more than one way. Only those chemical changes which contribute to the economy of the whole cell are useful.

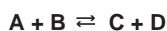
This is a significant point. **Individual chemical changes in the cell (even dozens or hundreds of them) have little utility, unless their end products belong in the closely knit network of substances needed by the cell.** The meaning of each chemical reaction and of each reaction product is derived from the fact that the reaction products contribute to the functions of the living cell. All other chemical conversions are wasteful and detrimental to the cell.

A reaction always runs its course, whether catalyzed or not, by producing a characteristic ratio of reaction products and starting materials. When this ratio is achieved, **no further net chemical change happens** under the conditions of the reaction, and the substances are said to be in a state of chemical equilibrium (Box 3.1).

BOX 3.1

TIME COURSE OF A CHEMICAL REACTION

In a typical chemical reaction between substances **A** and **B**, two new substances form, **C** and **D**:



At the beginning of the reaction there are only the starting substances **A** and **B**.

During the reaction the amounts of **A** and **B** diminish and the amounts of products **C** and **D** increase. The products **C** and **D** react to re-form **A** and **B**. This is the reverse reaction.

At the end of the reaction there will be a constant amount of all four substances **A**, **B**, **C**, and **D**, because forward and reverse reactions balance each other. This state is called chemical equilibrium.

For every reaction there is an “equilibrium constant” K_{eq} , a term which combines the characteristic ratios of reaction products and reactants at equilibrium. Reactions at equilibrium are of little use to the cell because **it is the chemical changes that drive the phenomenon of life**. In fact, when all of the reactions in the cell reach their equilibria, death occurs. This makes the roles of the enzymes paradoxical. They are required to keep the flow of materials on useful tracks preventing side-reactions, but the enzymes push the chemical conversions rapidly toward equilibria which, if achieved, doom the cell. To avoid disaster, the chemical conversions are organized into what amounts to “assembly lines” on the cell. The product of one reaction becomes the starting material for the next. This arrangement prevents the accumulation of products (Box 3.2).

In the hundreds of chemical assembly lines, also called “bio-chemical pathways”, there are multiple chemical conversions. Some of these build larger and larger molecules, while other pathways degrade

BOX 3.2

THE LOGIC BEHIND CHEMICAL PATHWAYS

Catalyst #1

Reaction #1: **Glucose + ATP** \rightleftharpoons **Glucose-6-phosphate + ADP**

By itself, this reaction stops at equilibrium.

But a second reaction occurs in the cells:

Catalyst #2

Reaction #2: **Glucose-6-phosphate** \rightleftharpoons **Fructose-6-phosphate** uses up one of the products of the first reaction, preventing the formation of equilibrium. These two are the first two reactions in a ten-step biochemical pathway called "glycolysis".⁴

substances to smaller pieces. Degradation of energy-rich matter is coupled to the efficient capture of chemical energy. This energy drives the growth and movement of the cell. Figure 3.2 is an attempt to summarize the work of the metabolic paths in the interacting networks.

The metabolic fabric of the cells is seamless; there are no loose ends. All biosynthetic paths lead to the production of more biomatter and growth, and all degradative processes result in the harness of useful chemical energy and in the secretion of waste. Each biochemical pathway has a single "rate limiting" step which governs the rate for output of that chemical "assembly line." The enzyme catalyzing this regulatory reaction is able to speed up, slow down, or even arrest the output of that pathway, depending on the amount of product already available to the cell. Thus, wasteful oversupply of metabolic components is prevented. This is one of the kinds of sensing mechanisms which monitor the composition of the intracellular environment. As excesses or shortages of biochemical intermediates develop, appropriate regulatory adjustments are made in order to preserve the "steady state" of the cell. In a well-functioning cell, the amounts of each of hundreds or thousands of substances remain close to constant during a steady flux of material through the system. **This steady, non-equilibrium state of matter is an absolute prerequisite for the phenomenon of life.**

CHEMICAL DIFFERENCE BETWEEN LIFE AND DEATH

If a single reaction within a metabolic pathway were to reach equilibrium in the cell, it would constitute a metabolic block, because (by definition of what equilibrium is) there would be no net conversion of matter past that point. Some metabolic blocks would not be fatal when alternative pathways could compensate the cell. But when all the reactions in the cell reach their equilibria, life processes cease, and the cell dies. Such a state can be achieved in a bacterial cell such as *E. coli*, by using an organic solvent to poke holes in its membrane. When the membrane is opened the cell is no longer capable of generating energy (an intact membrane is essential for this process). The chemical conversions cease, and soon every reaction will reach its equilibrium. **The difference between non-equilibrium and equilibrium is nothing less than the difference between life and death.**⁵

The equilibrium status of a single chemical reaction can be converted into a non-equilibrium state temporarily by either adding more reactants or by removing one or more reaction products. The non-equilibrium state will last only as long as one of these measures continues. The same considerations apply to biochemical chain reactions (pathways) that have reached equilibrium. The equilibrium of each pathway may be eliminated if it is provided with additional starting material and if the final product is removed. This concept is illustrated in Box 3.3.

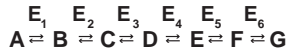
Thus, if the non-equilibrium steady states of all reactions could be restored, the dead cells would live again. In theory this could be accomplished by restoring each of the hundreds of interconnected biochemical pathways to its non-equilibrium condition (Box 3.3). First any breach of the integrity of the cell's membranes would have to be repaired, and a continuous supply of starting substrates of the first reactions of every pathway would have to be supplied in order to launch all of the chemical processes, more or less simultaneously. Such a procedure would begin turning the metabolic wheels of the organisms, and it would live again.

While we can transfer any substance across a cell membrane by "electroporation" (a short pulse of high voltage),⁶ the continuous delivery into cells of large numbers of different metabolites for which there are no built-in transport mechanisms is beyond our current technical capabilities. Herein lies the reason why we cannot reverse death on the cellular level.

BOX 3.3

HOW TO UNDO THE EQUILIBRIUM OF AN ENTIRE PATHWAY

Consider a pathway



at equilibrium. **A** through **G** are metabolites; **E**₁ through **E**₆ are enzymes.

The equilibrium constant for the pathway

$$K_{\text{pathway}} = *K_1 *K_2 *K_3 *K_4 *K_5 *K_6,$$

where **K**₁ through **K**₆ are the equilibrium constants of the individual reactions.

Simplification of this expression yields:

$$K_{\text{pathway}} = [G]/[A]$$

It is possible to undo the equilibrium status of this pathway by supplying more substance **A** and removing substance **G**. In the cell this would be possible only if the pathways supplying **A** and removing **G** were at non-equilibrium.

Closely akin to this is the problem of generating life from an inert collection of biomolecules. To accomplish this, one would need to bring all of the needed substances into a membrane-enclosed space (enzymes, substrates, genetic material, various subcellular organelles) and then create a state of non-equilibrium among the hundreds of substrates of the enzymes. The difficulty in accomplishing this rests with the propensity of enzymes to establish equilibrium rapidly among their substrates. Thus far it has not been possible to overcome this challenge even in the most sophisticated modern laboratory. What would be required here is to be **able to manipulate selected molecules** in the manner of “Maxwell’s Demon.”

HOW MAXWELL’S DEMON WORKS

This theoretical creature occupied space between two interconnected compartments which were filled with gas molecules, and the demon could keep the slow-moving molecules in one compartment

and send the fast-moving ones into the other. Such action would result in one compartment becoming warm and the other cold. In other words, Maxwell's Demon could take a system at equilibrium and manipulate it into a non-equilibrium state.

Whether this feat can be accomplished in the future by scientists is not known. Manipulation of individual atoms and molecules is now becoming possible, using "atomic force" microscopy.⁷ It is certain, however, that **a state of non-equilibrium cannot arise from an equilibrium state spontaneously**. But this is precisely what would be required if a live cell were to emerge from a dead cell (Box 3.4).

BOX 3.4

MINIMUM REQUIREMENTS FOR CELLULAR LIFE

1. Appropriate types and quantity of biomolecules plus water (Table 2.1).
2. The capacity to accomplish the metabolic and regulatory tasks, outlined in Table 2.2
3. A steady state non-equilibrium status among the chemical reactions.

The discussion of life in these three chapters emphasized both the complexity and the dynamics of the chemistry undergirding this amazing process. The minimum requirements for cellular life are summarized in Box 3.4. With these facts in the background we now turn to the current postulates of primordial abiogenesis that attempt to explain how life arose on Earth from nonliving matter.

SUMMARY OF CHAPTER 3

1. Living cells are made from nonliving components.
2. The phenomenon of life is based on continuous chemical conversions.
3. Individual chemical reactions always reach their end points (equilibrium) and come to a stop.
4. In living cells, chemical reactions are linked into chains that prevent individual reactions from reaching equilibrium and stopping.

5. The difference between live and dead cells is the equilibrium or non-equilibrium status of the chain reactions.
6. At the present time, even with our considerable chemical knowledge, we cannot restore dead cells back to life.

REFERENCES AND NOTES ON CHAPTER 3

1. Lehninger AL, Nelson DL, Cox MM. 1993. Principles of biochemistry. Second ed. NY: Worth Publishers, p 3.
2. Equilibrium does not have to be a state of stagnation. There can be many chemical reactions occurring in such a system, the only requirement is that there will be no net chemical change. In other words, in a state of equilibrium, the various chemical changes cancel each other.
3. The original Figure 3.1 was drawn by Mrs. Anita Churches.
4. Timberlake KC. 1999. Chemistry: an introduction to general, organic and biological chemistry. Seventh ed. Menlo Park, CA and NY: Addison-Wesley Longman, Inc.
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CHAPTER 4

ONCE UPON A TIME THERE WAS A MOLECULE...

“Primordial soup again?”

— caveman to wife in a Gary Larson cartoon

“I have made it my rule not to read this literature on pre-biotic evolution until someone comes up with a recipe that says ‘Do this and do that, and in three months things will crawl in there’”.

Max Delbruck¹

The explosive increase in understanding living matter directs our attention forward, toward the utilization of this great body of knowledge for curing mankind’s illnesses. At times, though, scientists glance backwards to gain a perspective on the present, and to ask, “How did this rich ecosystem of Earth come into existence?” The technical details of the answer vary from year to year, but the big picture has not changed for many decades. It is basically as follows.

The Earth formed from a spinning mass of gaseous matter — the “solar nebula” — by a process of accretion. Once this primitive, lifeless planet cooled down it was largely covered by an ocean. Its atmosphere contained nitrogen and carbon-containing substances, but was devoid of oxygen. Then a process called chemical evolution began on this primordial Earth. It resulted in the emergence of the first living cell and initiated biological evolution.

A recent text of biochemistry states these concepts succinctly:

The origin of life probably occurred in three overlapping phases: Phase I, chemical evolution, involved the non-instructed synthesis of biological macromolecules. In phase II, biological macromolecules self-organized into systems that could reproduce. In phase III, organisms evolved from simple genetic systems to complex multicellular organisms.²

Undergirding this scenario of life’s origin is an unstated, but very firm, conviction that under conditions where living organisms can exist, nature will bring life into existence. This notion arises from two indis-

putable facts: 1) on planet Earth conditions are favorable for life, and 2) our planet is teeming with a multitude of living organisms. Despite the circularity of this argument, if one *a priori* discounts the possible existence of a supernatural Creator, all that remain are naturalistic scenarios for the origin of life.³ What follows here is a look at laboratory experiments and theoretical considerations that have been produced in support of evolutionary models.

Scientists are at their best when they study matter under well-defined conditions. While it is true that the time scope of chemical evolutionary postulates covers thousands or even millions of years (time segments unavailable for individuals), **the only function of time in these postulates is to increase the number of opportunities for interaction between substances.** Scientists can accomplish this in the laboratory by various means that compress the time scale of the chemical evolutionary events to manageable size.

We ought to be thankful for the efforts of stalwart chemists who have dared to test the validity of their postulates in the laboratory. Their work gives us a feel for the experimental challenges that confront chemical evolutionists. They are following standard practice in science, in contrast to some in a field of chemical evolution who appear content issuing theories, without a scintilla of experimental evidence.⁴

During the 1960s and 1970s, considerable experimental work was done on the behavior of matter under postulated primordial conditions.⁵ These conditions were very diverse because a “primordial world” could be anything that was sterile and devoid of oxygen. The experiments were conceived to test the validity of the following theoretical transformation of matter on the primordial Earth:⁶

Stage 1 (early Earth atmosphere) → Stage 2 (hot dilute soup)
→ Stage 3 (polymerization) → Stage 4 (protocell formation)
Stage 5 (true cell formation).

CONSIDERATIONS OF THE EARLY EARTH'S ATMOSPHERE AND THE FORMATION OF THE PRIMORDIAL SOUP

Reduced atmospheric carbon dioxide is the only potential source for the production of biologically relevant organic substances. The current atmosphere, which contains 20% oxygen, is very oxidizing. Under synthetic conditions with oxygen present, carbon dioxide yields

only biologically irrelevant materials. Moreover, in the presence of oxygen biologically relevant substances degrade.

Therefore it is axiomatic to any chemical evolutionary scenario that the primordial atmosphere was free of oxygen. Experiments with gaseous mixtures have varied from methane-ammonia-water (most reduced) to carbon dioxide-nitrogen-water (most oxidized).

The classic experiments of Stanley L. Miller, in the laboratory of Harold C. Urey,⁷ circulated the gases methane, ammonia, and hydrogen in a closed system. The apparatus also included boiling a mixture of water and electrodes for spark discharge that simulated lightning. After a week, four of the twenty amino acids found in proteins were produced, along with other organic substances. Later this experiment was repeated using nitrogen and a trace amount of ammonia. With this gas combination, ten different amino acids were made along with other nonbiological amino acids and organic substances.

The Miller experiment was modified by other investigators, who used heat, ultraviolet radiation, and acoustic shock waves in place of sparks as an energy source. Additional gases — such as ethane, hydrogen sulfide, carbon monoxide, or hydrogen cyanide — were added. These efforts resulted in the production of most of the amino acids, except histidine, arginine and lysine.⁸

The synthesis of adenine, one of two purine components of nucleic acids (DNA, RNA), was reported from high concentrations of hydrogen cyanide in the presence of large amounts of ammonia.⁹ Prebiotic scenarios that contain large concentrations of ammonia and hydrogen cyanide are difficult to postulate. Adenine can be formed from hydrogen cyanide, without ammonia, in the presence of sunlight.¹⁰ The production of guanine — the second purine — under prebiotic conditions is less well-studied. However, it is known that guanine can be produced by reacting one of the intermediates of adenine synthesis with cyanogen, a substance derived from hydrogen cyanide.¹¹ The three pyrimidines needed for nucleic acid synthesis — uracil,¹² cytosine¹³ and thymine — were synthesized by reacting selected substances (which could have been potentially available) under prebiotic conditions.

Another important class of ingredients — sugars — could have been produced in a primordial environment by the reaction of formaldehyde with alkaline substances.¹⁵ Two types of sugars, ribose and 2-deoxyribose, are essential for building nucleic acids. These substances link up

with purines or pyrimidines and a phosphate to form nucleotides, which are the building blocks of nucleic acids (Table 2.2). The chemical linkage between sugars and a purine or pyrimidine occurs with the loss of two hydrogen and an oxygen, the equivalent of water. This process may not appear improbable, but thus far it has not been possible to achieve in a simulated primordial environment.¹⁶

In addition to amino acids, there has been successful laboratory synthesis of purines and sugars, short chain fatty acids, fatty alcohols and di- and tricarboxylic acids under simulated primordial earth conditions.¹⁷ These achievements supported the postulate that necessary organic substances were collected in a primitive ocean, forming a “primordial broth”. Initially scientists estimated that about 3% of the primordial ocean by weight could have consisted of organic substances.¹⁸ This estimate was made before the realization that on a prebiotic earth several factors would reduce the amounts of organic matter in the ocean. The very sources of energy that created organic compounds would also destroy some. In addition, other chemical interactions including water’s destructive effect would have diminished the amounts of organics in the primordial ocean by a factor of ten thousand less than originally proposed. This is the level we actually find today in the North Atlantic Ocean!¹⁹ There is no geological evidence available for the existence of a primordial soup either worldwide or in smaller locations.²⁰

Oxygen has been excluded from all prebiotic experiments, because its presence precludes the production of biologically useful substances. Yet no prebiotic scenario can rule out the presence of oxygen. High-energy ultraviolet light, which is now filtered out by a layer of ozone (a very reactive form of oxygen gas) high in the atmosphere, is capable of degrading water to oxygen and hydrogen. Hydrogen escapes from the atmosphere, whereas oxygen remains. On ultraviolet photographs of Earth taken from the Moon during the Apollo-16 mission, there is a large cloud of atomic hydrogen enveloping our planet, extending outward some 40,000 miles. The only conceivable source of this hydrogen is the extensive photodissociation of water vapor above the ozone layer.²¹

Thus laboratory simulations of the primordial production of biomonomers leave substantial unresolved problems that in any other field of science would result in the dismissal of the underlying theory. In this case, however, the attitude is: “since we know that chemical

evolution is true (we are here after all!), we just have to keep on looking for answers”.

An ingenious solution to a seemingly impossible predicament is the notion that many of the required biomonomers were delivered to Earth by interstellar dust, meteorites and comets.²² This mechanism provides, in theory, unlimited amounts of starting material for chemical evolution to proceed.

POLYMERIZATION

Although there are some positive laboratory results showing how biomonomers may have arisen in a primordial setting, there is an almost complete meltdown in experimental efforts to show how biopolymers may be formed. If one stipulates the availability of an unlimited supply of primordial biomonomers, three major obstacles surface on the way toward producing proteins and nucleic acids. (The other two classes of biopolymers — polysaccharides and lipids — are not considered here, because they could be formed enzymatically if the correct proteins were available.)

The obstacles to forming proteins and nucleic acids are:

- 1) How do amino acids and nucleotides link up into proteins and nucleic acids in an aqueous environment, when the linkages involve the **loss of water**?
- 2) In the process of joining biomonomers together, how are only the “left-handed” amino acids selected for proteins and the “right-handed” sugars for nucleic acids, when at the start there is an equal mixture of both?²³
- 3) How are the amino acids and nucleotides arranged in meaningful sequences?

Our biotechnology is at such a level now that we can manufacture protein and nucleic-acid fragments at will in the laboratory. These processes involve chemical activation of the linkage groups of the building-block substances, meanwhile protecting the rest of the molecule from participating in the linkup. The joining of these modified building blocks occurs in the total absence of water.²⁴ The order of amino acids and nucleotides is determined by the experimenter.

Formation of a peptide bond (see Table 2.2) between two amino acids is not favored thermodynamically. [It has been calculated that if

one started with a very concentrated solution of amino acids (a concentration of “one mole per liter”), it would be necessary to have a volume 10^{50} times the Earth, in order to form spontaneously a single protein molecule, 100 amino acids long²⁵!]

Therefore it is not reasonable to suppose that amino acids would ever link up into chains while in the primordial soup. Heating pure solutions of amino acids to 200°C for 6-7 hours has led to the formation of random protein-like polymers.²⁶ But many of the peptide bonds between amino acids were unnatural in these “proteinoids”, and the sequence of amino acids reflected the composition of the initial mixture. Moreover, no suggestion exists to explain how a catalytically active proteinoid could be reproduced. Most recently it was shown that up to six residues of the amino acid glycine could be linked under high pressure in a simulated thermal vent.²⁷ The authors offer a reasonable theory that the chain elongation occurs through a cyclic intermediate (diketopiperazine). However, this mechanism implies that other amino acids may not be able to elongate, because their structures prevent the formation of this cyclic intermediate.

Biomonomers (amino acids or nucleotides) may be linked to each other in the presence of a chemical condensing agent which traps the water molecules that are split out between the monomers. But in an aqueous environment these agents will interact preferentially with the large amount of water in the environment. Thus, condensing materials work only in nonaqueous environments.

The other two grave difficulties with primordial polymer formation — the exclusive use of only “left-handed” or “right-handed” monomers for protein or nucleic-acid synthesis, and the source of information that resides in the sequences of biomonomers in proteins and nucleic acids — have not been satisfactorily addressed.

The synthesis of either proteins or nucleic acids under prebiotic conditions has yet to be accomplished. These necessary processes can be considered the end of the chemical evolutionary road paved only in scattered patches with experimental results. If one wishes to proceed beyond, it is necessary to traverse on the rocky terrain which consists mostly of speculations.

PROTO CELL AND TRUE CELL FORMATION

Using Zubay’s terminology, it is envisioned that the first phase of chemical evolution consisted of the “non-instructed” phase,² where

the emphasis was on the synthesis of random polymers of either proteins or nucleic acids, or both. Current thinking is leaning toward a random synthesis of ribonucleic acid, because it was discovered recently that some ribonucleic acids have catalytic activity.²⁸ This discovery led to the speculation that the first biopolymers had both catalytic and genetic capacities.

The second phase of chemical evolution is the “instructional phase”, where macromolecules would self-organize into autocatalytic systems. That is, self-replicating systems would form from mixtures of random RNA or protein molecules. Somehow such systems would be wrapped into protective membranes, forming “protocells”, the precursors of true cells.

Experimental models of protocells include coacervates (microscopic droplets) of proteins and nucleic acids,²⁹ proteinaceous microspheres,³⁰ and lipid vesicles.³¹ These structures have been synthesized in the laboratory from preformed biopolymers, or from protein-like substances that were obtained by heating pure amino acids at high temperatures. Without entering into detailed considerations of each, it can be said that none of these complexes manifest the essential qualities of living cells. They were aggregates of polymers, predictably held together by physical forces. As such, they represent experimental dead-ends, without any promise of shedding light on the mysteries of abiogenesis.

But having come this far in our hypothetical journey on a primordial Earth, it seems a pity to stop. If self-replicating systems of proteins and nucleic acids could be found, could these serve as precursors to modern cells? Evolutionary theoreticians posit that the Darwinian “descent with modification”, along with “survival of the fittest”, concept of biological evolution may have been at work even during chemical evolution.^{32,33} Thus, through a process of continual modification, different biopolymers would have been formed, and those with useful properties would have been retained.

There is an enormous amount of information stored in the structures of nucleic acids and proteins in modern cells. It has been estimated that one cubic micrometer (one thousand billionth of a cubic centimeter) of deoxyribonucleic acid (DNA) encodes 150 megabytes of information. This is more than an order of magnitude greater than the current CD-ROM optical storage density.³⁴ The complete nucleotide sequence of the genetic material of *Escherichia coli*, printed in a standard book

form, takes up about 1,100 pages. A similar effort for the human genome would fill one thousand volumes of 1,100 pages each.

The rules of grammar define the correct spelling of words and the proper usage of each word in a sentence. **They do not determine the choices of words.** Similarly, although the rules of chemistry determine how biomonomers may be linked into polymers, they are silent on the order in which these should be linked so as to have biological significance.

The question is, by what processes would self-replicating systems of proteins and nucleic acids select for and accumulate biologically valuable polymers? In abiotic systems **no selection pressure exists in favor of biologically useful polymers!** The potential usefulness of biopolymers is manifested only in living cells. In nonliving matter the biological potential of molecules is of no consequence. This point is generally ignored by chemical evolutionary theoreticians. A salient example is the “obcell” hypothesis by T. Cavalier-Smith. He proposes that in the prebiotic era, membrane-protein complexes known as “inside-out cells” (or “obcells”) formed as precursors of true cells. These structures contained transport proteins, as well as nucleic-acid replication machinery and ribosomes,³⁵ and somehow had the ability to harness light energy. He gives no indications whether his “obcell” is alive or dead.

Albert Lehninger, however, clearly states that the hypothetical protocells should have been alive:

*...the first structure possessing ‘life’ was not necessarily a modern cell, complete with a membrane, a chromosome, ribosomes, enzymes, a metabolism, and the property of self-replication. The minimum requirement is that it could potentially evolve into a complete cell.*³⁶

If a cell possessed life, then its molecular components had to be in steady state non-equilibria. Such a state could be maintained only if the individual chemical reactions in the protocell were kept from reaching equilibrium. In modern cells this is accomplished by the linkages of chemical reactions into biochemical pathways and by coordinating the chemical activities of pathways through regulation of key enzymes. **Since protocells were supposed to have risen from random encapsulation of compounds and their catalysts, it would follow that their chemical reactions were neither linked into pathways nor regulated.** Thus, chemical reactions in protocells would

have been expected to reach equilibria some time after encapsulation, resulting in dead protocells.

These considerations apply to all postulates of chemical evolution, regardless whether they approach modern life from the inorganic³⁷ or from the organic world,⁴ whether the first postulated biopolymers were RNA³⁸ or proteins,³⁰ and whether life supposedly evolved on this planet or somewhere in outer space.

SUMMARY OF CHAPTER 4

1. Theories about the abiotic origins of life have been tested extensively in the laboratory.
2. The feasibility of abiotic synthesis of many biomonomers in simulated primordial settings has been demonstrated.
3. Simulated primordial syntheses of functional biopolymers have been unsuccessful.
4. It has not been possible to show, even in theory, how living matter may arise from hypothetical “protocells”.

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CHAPTER 5

MESSAGE OF THE MOLECULES

Question: When is the whole greater than the sum of its parts?

Answer: When one buys a doughnut.

As a child I routinely destroyed my mechanical toys: windup airplanes, automobiles, railroad engines, many of which emitted sparks and sounds, and moved. I just had to see what was inside these marvelous devices. After peeling away the thin layers of metal, I was invariably confronted with jumbles of springs, gears and many unrecognizable objects. My toys lay in ruin, and I was no wiser.

Many useful objects lose their function when they are dismantled. This is true of cars, radios, airplanes, refrigerators, pianos and essentially all manufactured goods. Obviously, appliances function only when completely assembled. The creation of these devices requires planning and execution. Piling microchips, capacitors and resistors into a heap usually yields only a garbage dump instead of some useful electronic equipment.

ACQUISITION OF NEW FUNCTION WITH ORGANIZATION IS THE WAY OUR WORLD IS PUT TOGETHER

The world is made from approximately one hundred different elements, such as carbon, iron and oxygen. The differences among elements are due to the number and arrangement of the protons and neutrons in the nucleus, and electrons in the outer regions of the atom. Although the properties of individual electrons are identical in every element, their differing combinations give a variety of chemical properties to the elements. But, as elements combine to form compounds, their unique properties frequently give way to new characteristics. For instance, inert white table salt emerges from combining the greenish corrosive gas chlorine with the soft metallic, highly reactive sodium.

Linking hundreds of left-handed amino acids into polypeptide chains results in a most impressive variety of proteins. Thousands of different proteins function as molecular machines, each promoting a unique chemical change. Other proteins support biological structures, forming such diverse substances as tooth dentin or muscle fibers.

Living matter consists of a mix of molecular machines that propel synchronized chain reactions. These enable life processes to occur in the cells. In multicellular organisms the work of one cell complements others. Living organisms interact in various ecosystems to form the biosphere that covers the globe. The Earth receives its energy supply from the sun, and solar energy drives most biological systems directly or indirectly. When the lowly *E. coli* utilizes the energy of glucose molecules, this energy originates from an atomic furnace, millions of degrees hot, some 93 million miles away.

The layers of our reality are successively more complex domains (Figure 5.1). A logical way to account for the appearance of new functions at each level of increased complexity is to suppose that the

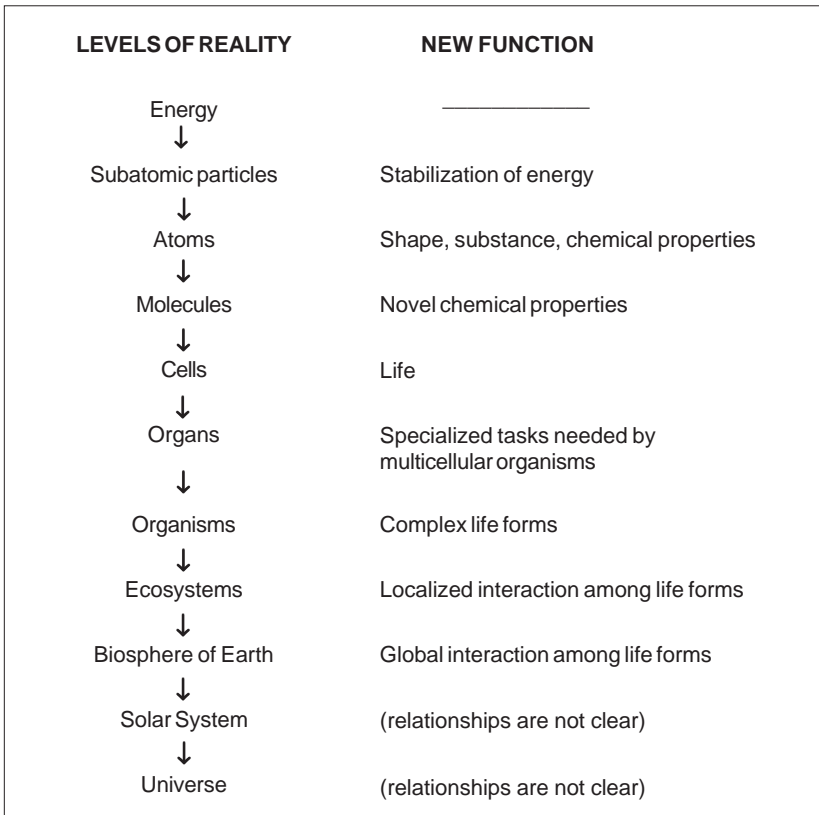


FIGURE 5.1. Reality is organized into increased levels of complexity.

Universe is here by design. Living organisms fit remarkably well into this hierarchical order of reality. It is tempting to adopt a “biocentric” view which would propose that reality was designed for the sake of living organisms.

We attempted to show that living matter cannot possibly spring into existence spontaneously under any circumstance. This is not an argument from ignorance. Theoretically we know what would be required for living processes to commence. **Chemical evolution requires random processes to accomplish that which we are unable to do in the laboratory!** Since there are no selection processes to favor components of a “future” biological system, any appeal to random processes, even if an infinite amount of time were available, is futile.

As matters stand, rejection of the concept of the Creator leaves the naturalistic scientist with the alternative of not knowing where life came from. Usually scientists are comfortable living with uncertainty. In fact, curiosity of the unknown is a chief motivator of scientists. When research uncovers an explanation for a scientific problem, the scientist frequently moves to another area of work, looking for new challenges.

But the question of life’s origin is not just another scientific problem. It undergirds all other human enterprise. If we do not know how life originated, we do not know whether there is a purpose to existence, or whether we are all just participating in an interesting fluke of nature. While scientists have a high tolerance for the unknown, they have low tolerance for meaninglessness. Science is, after all, foremost a search for meaning in nature. It would seem incongruent that so much meaning can be found in nature at the levels on which scientists operate, but the sum total of existence turns out to be meaningless!

Perhaps it is insulting to designate as meaningless the faith of those who believe in the evolution of matter from gaseous nebulae into highly structured biological entities. These evolutionists are awed by the sophistication seen in the biological world and continue to be challenged to gain a better understanding of it. They also take comfort in the apparent kinship between different forms of living matter, and they work diligently toward understanding their phylogenetic relationships. Perhaps it is more accurate to recognize naturalistic scientists as worshipers of nature, modern descendants of the worshipers of objects and of natural manifestations of ancient times.

For these students of nature, science represents rational, logical thinking; and the notion of Supernatural represents the opposite —

irrationality, magic and a return to the pre-scientific age. Indeed, much intellectual mischief has been committed in the past under the guise of religion. However, as was seen in the previous discussion, **the phenomenon of life on Earth cannot be convincingly explained without invoking the work of a supernatural Creator.** The necessity of a Creator is not a plea for a God of the gaps. It is our understanding of how living matter functions that drives the argument for not only a Designer but for also an Implementor who can fashion biomolecules into living matter. This view suggests that the laws of nature have been ordained by the Creator to sustain an orderly Universe. These laws are to be discovered and utilized by us. Belief in a supernatural Creator stimulates students of nature to discover the Creator's thoughts. Contrary to the pronouncements of some¹ that biology is meaningless without evolution, the study of nature draws the student closer to its Author. For the creationist, religion and science are not mutually exclusive domains. Rather, they are different avenues toward the same Source.

SUMMARY OF CHAPTER 5

1. Everyday experience teaches us that manufactured goods with new functions are made from pre-designed components.
2. Successively more complex levels of our reality with new functions are based on the interactions of simpler forms of matter. This suggests that our complex reality is designed.

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EDITORIAL

INTELLIGENT DESIGN, NATURAL SELECTION, AND GOD

Someone once asked me, “Could not God have used the process of natural selection to create living organisms?” What evidence might one use to answer that question?

*Richard Dawkins, biology professor at Oxford University makes the following statement at the beginning of his book *The Blind Watchmaker*:*

Biology is the study of complicated things that give the appearance of having been designed for a purpose.¹

Dawkins then goes on to assure us that living things have not been designed at all, but are the result of unguided natural selection.

It is not my purpose here to point out the flaws in the argument presented in Dawkins’ book — others have already done that.² I wish instead to focus on the meaning of the word “design.” According to Dawkins, living things present a powerful “illusion of design.”³ Thus, he uses the term design in the sense of purposefully crafted. Purpose, of course, requires an intelligence, so Dawkins’ use of the term could also be expressed as “intelligent design.” Dawkins makes clear he is against applying the idea to living organisms. According to him, natural selection mimics design, so that what appears to have been purposefully crafted was actually constructed through unintelligent processes. In this claim, Dawkins is being faithful to Darwin, who intentionally proposed the theory of natural selection to do away with the idea that organisms were purposefully crafted.

*The term “intelligent design” is used with a similar meaning by many scientists who disagree with Dawkins’ view. According to these scientists, living organisms appear to be designed because they were, in fact, purposefully crafted. A group of design advocates, including scientists and philosophers, met at Biola College near Los Angeles, California, to discuss these issues in November, 1996. One outcome of that meeting was publication of a book called *Mere Creation*⁴ (see the review on page 101 of this issue). Another*

outcome was a sharpening of the meaning of the term “intelligent design,” and a new method for detecting design — the “explanatory filter” (see the review for further explanation).

Now the point of all this is that both critics and advocates appear to agree on the definition of “design.” The word “design” refers to effects that are intentionally caused by intelligent agents. Now consider the nature of natural selection, which is, by definition, a process that does not involve an intelligent agent. To use Dawkins’ words:

... [natural selection] has no purpose in mind. It has no mind and no mind’s eye. It does not plan for the future. It has no vision, no foresight, no sight at all.⁵

This is consistent with Darwin’s use of the term.

In other words, if God is involved in the evolutionary process, it is not a “natural” process. If God is involved in selection, it is not “natural” selection. Thus, to the question (see above) whether natural selection might be the way in which God created, the answer must be no. Divinely directed natural selection is a contradiction of terms. Selection might be natural, or it might be intelligently directed, but it is not both.

What then, about “directed selection” as the method by which God created? Could God be directing mutation and/or differential survival to bring about creation of new species? How does such an idea play out?

Evolutionary selection involves two categories of events. The first category is variation caused by genetic change; the second category is differential survival and reproduction due to the effects of preceding genetic change. Theoretically, events in either of these categories could be divinely directed. What is the nature of the evidence concerning whether or not mutations and differential survival are directed?

How would we know whether an intelligent agent is directing mutations? One way would be to observe whether mutations are helpful or harmful. If God is directing mutations, we would expect mutations to be beneficial. There is a strong consensus among biologists that observed mutations are mostly harmful, or neutral at best. Many mutations are known to be associated with disease, which is not what one would expect from guidance by a righteous divinity. Helpful mutations are generally thought to be so rare that

their origin can be explained by chance rather than by design. Some experiments have suggested that helpful mutations seem to occur more frequently than expected by chance in bacteria undergoing nutritional stress,⁶ but this seems to be due to an increased rate of both helpful and harmful mutations in certain genes.⁷ Thus, if mutations are being divinely directed, the divinity directing them appears to be incompetent at best, or evil at worst. Neither description fits the God described in Scripture.

If mutations are not being directed, what about selection? Could it be that God is providentially preserving favored individuals in order to bring about evolutionary change? If so, the implication would be that God evaluates the potential of various individual organisms on the basis of their genes, choosing some to die and some to live. In this scenario, it is not individual organisms who have value, but genes. Unwanted individuals and their offspring are abandoned to die, while the survival of favored individuals and their offspring is enhanced. This is not a particularly flattering picture of God, but it might nevertheless be true.

One possible way to test this idea would be to examine small natural populations, to see whether there is a tendency toward genetic degradation, or whether individuals with favorable mutations are preserved with sufficient frequency to maintain the genetic vigor of the population. Results of such observations⁸ show that small populations tend to lose genetic variability and drift toward extinction. Thus, it appears that selection is not being directed by a righteous divinity, although one could postulate an indifferent divinity who would behave in this way.

The notion of directed selection does not seem to be supported by the evidence. Neither mutation nor differential survival appear to be guided by God. The creation process described in Scripture seems inconsistent with directed selection. In addition, the implications of directed selection for the character of God do not seem consistent with biblical revelation.⁹ Thus both nature and Scripture suggest that divinely directed selection does not appear to be God's method of creation.

But, could God's activity in nature be veiled so that what appear to us as random events are actually being guided by divine intelligence? Perhaps, but why postulate that some "force" is

affecting events when the “force” makes no sensible difference in the outcome?

Is this to say that God does not intervene in nature? Not at all. Indeed, God must have acted directly to bring a variety of living organisms into existence. He may be continually acting in nature to prevent it from falling apart. However, there is no persuasive evidence, empirical or revealed, that directed selection is God’s chosen method of creating. Rather, it appears that selection acts after the origin of biological structure, preserving it or modifying it, but not creating it. Intelligent design seems to be the best explanation for the origin of living creatures and their morphological “adaptations.”

L. James Gibson

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9. The violence and brutality in nature, and the suffering caused by parasites and pathogens seem incompatible with God’s will as revealed in Isaiah 11 and 65, and Revelation 22. Such manifestations of evil are better explained as anomalies caused by corruption of the original peaceful kingdom (Genesis 6:11-12, Romans 8:19-21).

ARTICLES

UNIQUE ENIGMATIC HELIUM

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WHAT THIS ARTICLE IS ABOUT

Among the 92 elements from hydrogen to uranium, helium is unique in not having a universally characteristic isotope ratio. Various mixtures of helium from three primary sources produce He-3/He-4 ratios over a six orders-of-magnitude range. The primary sources are: primordial, radiogenic, and cosmogenic. The concentrations of He-3 in many minerals, sediments, and volcanic provinces indicate that conventional geologic age assignments are grossly inflated, since these concentrations are orders-of-magnitude greater than may be expected on the basis of laboratory measurement of diffusion rates.

Attempts to account for the He-4 in Earth's atmosphere on the basis of diffusion of radiogenic helium from the crust and thermal loss to outer space yield unreasonable models. This consideration, and observations concerning non-thermal escape processes first made during the 1970s, have led to the conclusion that helium escape from Earth is largely by nonthermal processes. Of the seven such processes that have been identified, the greatest loss appears to be in a polar "wind" of ions accelerated along open lines of magnetic field in the regions surrounding Earth's magnetic poles.

INTRODUCTION

Among the chemical elements that exist with significant abundance in the Solar System, helium is unique in that it has the smallest ratio of minimum to maximum isotope abundance among the 86 elements that have more than one isotope (various numbers of neutrons in the nucleus). As given in the standard tables of relative isotope abundance, the Helium-3/Helium-4 ratio is only 0.000,00137 (1.37×10^{-6}). Standard helium is 99.999,863% He-4, and 0.000,137% He-3.¹ These data refer to helium in Earth's atmosphere. The nearest competitors for lowest

isotope abundance ratio among the 92 elements are calcium with 0.004% abundant Ca-46, and uranium with 0.0055% abundant U-234.²

VARIATION OF HELIUM ISOTOPE RATIO

The isotope ratios of an element generally are a physical characteristic that is independent of the source from which a sample may be obtained.³ Helium is a dramatic exception.

In lava samples taken October 1-7, 1996, from various locations on Lohi seamount, an active submarine volcano situated about 30 km south of the island of Hawaii, the He-3/He-4 ratio R varied from 11.5 to 25.3 times the 1.37×10^{-6} characteristic value for air (R_A).⁴ Stepwise heating of limestone from a quarry in Kunnekulle, Sweden, released helium with R/R_A ratios from 0.22 at 410°C, to 8.25 at 796°C just below fusion, and 22.7 at fusion.⁵ Additional significant values of R/R_A are listed in Table 1.

The R/R_A values cited in Table 1 cover a range of over 25,000 from terrigenous sediment to Lohi seamount. It is fully evident that helium does not have a characteristic isotope ratio, as do the other chemical elements. A general characteristic of volcanic regions is that He-3/He-4 ratios in the rocks are similar in the central area, regardless of lithology and presumed eruption age; and decrease with distance away from the central area.⁶ These unique features indicate that terrestrial helium comes from different sources, each with a distinct characteristic isotope ratio.

SOURCES OF HELIUM

Helium has three basic sources: primordial (initial creation), radiogenic (a product of radioactive decay), and cosmogenic (a product of nuclear reactions initiated by cosmic radiation). Elements that exist as a direct consequence of initial creation would be expected to have characteristic isotope ratios, with due allowance for minor changes that could have occurred since creation due to the slight changes that may have developed in some samples as the result of the dependence of diffusion rate and chemical reaction rate on atomic mass. The primordial He-3/He-4 ratio may be designated as R_p . Unfortunately, no sample of helium has become available that can with 100% confidence be considered as primordial.

On the basis of geological considerations an estimate of $(R_p/R_A) \approx 73$ has been suggested.³³ Excluding the items that may represent cosmogenic

TABLE 1. He-3/He-4 RATIO, R/R_A
in Proportion to $R_A = 1.37 \times 10^{-6}$ for Earth Atmosphere

Source	R/R_A
<i>Earth Reference</i>	
Earth atmosphere ⁷	1
Groundwater ⁸	0.003-0.83
Crust average ⁹	<0.015
<i>Extraterrestrial</i>	
Solar wind ¹⁰	314
Solar helium ¹¹	280
Average star ¹²	146
Interstellar helium ¹³	157
Interplanetary dust ¹⁴	292
Lunar dust ¹⁵	270
Meteorites ¹⁶	175
<i>Igneous</i>	
Mantle magma ¹⁷	2.9-7.3
Carbonatite, Koala, Russia, "380 Myr old" ¹⁸	4.9-19.1
Upper mantle ¹⁹	8.5
Lohi seamount ²⁰	11.5-25.3
Mid-Ocean-Ridge basalt (MORB) ²¹	8±1
Ocean Island basalt ²²	6-35
Andean lava ²³	0.18-6.9
Flood basalt, Ethiopia (Oligocene) ²⁴	0.035-19.6
<i>Sediment</i>	
Deep ocean sediment ²⁵	0.007-226
Terrigenous sediment ²⁶	0.001-0.34
Marine limestone, Sweden, "480 Myr old" ²⁷	0.22-22.7
<i>Gas</i>	
Yellowstone Park gas ²⁸	16.6
North Sea oilfields gas ²⁹	0.28-0.38
Texas helium wells ³⁰	0.150
<i>Diamonds</i>	
Industrial diamonds ³¹	0.0507-176
North Kazakhstan diamonds ³²	0.007

helium, the data in Table 1 indicate that $(R_p/R_A) \geq 25$. A theoretical estimate from Hot Big Bang cosmology suggests primordial (He-3/He-4) $\approx 10^{-4}$, about 73 times R_A .³⁴ Since He-3 is in a higher energy state than He-4 (14.9 vs 2.3 MeV Mass Excess), matter that is the result of a supernova might have a lower (He-3/He-4) ratio (available energy is reduced in natural processes). We must keep in mind that Big Bang cosmology and the role of supernovae are highly speculative, and their specifications do not necessarily describe matter that appeared in an *ex nihilo* creation.

Analysis of the isotope abundances of the light elements may provide a clue concerning a probable value for R_p . None of the first 21 elements in the periodic table, hydrogen through scandium, for which the most abundant isotope is even-numbered has an isotope of lower odd number, with the exception of helium.³⁵ He-3 is the only stable isotope with more protons than neutrons. These relationships strongly support a speculation that primordial helium did not initially contain He-3.

One source of radiogenic He-3 is the daughter-product of radioactive H-3 (tritium). Since tritium has a 12.33 year half-life, 50 years after the instant of primary primordial creation 94% of the H-3 created would have converted to He-3. Consequently He-3 produced from primordial H-3 may be considered as primordial helium. Hydrogen is 0.015% H-2. Since odd-numbered isotopes tend to be lower in abundance than associated even-numbered isotopes, it is reasonable to presume that in an instant of primordial creation any H-3 created was with abundance $< 0.015\%$. If the present cosmic-ray ratio of H/He, which is at least four,³⁶ represents the primordial H/He ratio, 70 years after Creation the He-3/He-4 ratio probably would have been less than 0.0006 ($4 \times 0.015\%$), and less than $430R_A$.

RADIOGENIC HELIUM

The major source of terrestrial helium appears to be from the ongoing transformation of heavy elements into lead. For every atom of lead derived from Uranium-238, or Uranium-235, or Thorium-232, there is produced 8, or 7, or 6 atoms, respectively, of He-4. A small amount of He-4 is also produced in the relatively rare spontaneous fission of radioactive heavy elements. Radiogenic helium is 100% He-4.

According to the best estimates for the composition of Earth's crust, there is a 1.9×10^{14} kg inventory and a 2.5×10^6 kg annual production of

He-4.³⁷ If there has been no loss to outer space, this inventory corresponds to about 80 million years of radiogenic accumulation. If the mass of planet Earth (the “foundation” of the earth, as the term “earth” is defined in Genesis 1:10) was created less than 10,000 years ago, these considerations together with the terrestrial data in Table 1 require speculation that at least two types of primordial helium were produced in the initial creation: one with $R_p/R_A > 40$, and one with $R_p/R_A < 0.001$.

The data in the *CRC Handbook of Chemistry and Physics* specify Earth’s atmosphere to have 5.136×10^{18} kg total mass, 5.24×10^{-6} volume fraction of helium, and a molecular weight average of 28.57. According to these data the atmosphere contains 3.8×10^{12} kg of helium. To produce this amount of helium by the radioactive decay in the crust would require over 1.5 million years. Additional accumulation time would be required to account for loss from the atmosphere into outer space.

COSMOGENIC HELIUM

Helium produced on Earth by cosmic rays, and helium that comes to Earth from outer space, can be classified together as cosmogenic helium. Helium comes from outer space in the solar wind, and in meteoroids and interplanetary dust. Both He-3 and He-4 are produced in the breakup of atoms struck by cosmic-ray particles, and from nuclear reactions with the neutrons and muons produced by such breakup.³⁸ Production of helium by cosmic radiation is limited to the atmosphere and the top few meters of Earth’s surface.³⁹ Estimates of cosmogenic helium production at Earth’s surface are in the order of 10^4 atoms per cm^2 of Earth surface per year.⁴⁰ Since the estimated production by radioactivity within the crust averages 7.4×10^{13} atoms per cm^2 of surface per year,⁴¹ the quantity of helium produced by cosmic radiation is a relatively negligible consideration. For meteoroids and cosmic dust that have no atmospheric shielding, production by cosmic radiation is a major consideration.

With interplanetary dust accumulating on Earth at the rate of $\sim 4 \times 10^4$ tons/yr,⁴² and an average He-3 content of 6.8×10^{14} atoms/gram,⁴³ the He-3 accumulation to Earth via interplanetary dust (IDP) is 136 g/yr. For an IDP $R/R_A \approx 200$ (see Table 1) this represents about 700 kg/yr of He-4, which is negligible compared with 2.5×10^6 kg/yr from radioactivity in the crust.

Since helium in the solar wind is ionized, Earth’s magnetic field provides a shield that diverts a large portion of the solar wind helium

from striking the surface.⁴⁴ As may be expected, the contribution from solar wind, together with that from IDP and cosmic-ray production is negligible in comparison with the production from radioactivity in the crust.

It is of passing interest to note that if the only sources of atmospheric helium had been radiogenic and cosmogenic, at present estimated rates, the atmospheric He-3/He-4 ratio would be in the vicinity of only 5% of the presently observed value.⁴⁵

HELIUM-3 CONSTRAINTS ON GEOLOGICAL AGE

Since helium forms chemical bonds only in rare cases, and since it has only two orbital electrons; it diffuses relatively rapidly through a host mineral, and concentrations of He-3 above that in the surrounding medium should dissipate rapidly. The dissipation of a localized high R helium is analogous to the dissipation of a drop of dye on a large surface of water that has been tinted lightly with the same color. The concentration of He-3 atoms becomes distributed among an increasingly larger number of He-4 atoms, as the concentration of dye molecules become distributed in an increasingly larger number of water molecules. Any radioactive material that might be in the sediment would contribute only He-4, and increase the rate at which R is reduced.

In a report on He-3/He-4 ratios in Central North Pacific pelagic clay sediment, K.A. Farley (1995) noted that “Laboratory diffusion measurements extrapolated to sea-floor temperatures predict complete diffusive loss of ³He from IDP magnetite grains in <10⁷ years after fallout.”⁴⁶ The extraterrestrial data in Table 1 establish an upper boundary for R from which diffusion to an indistinguishable background level would be expected in <10⁷ years. Yet the 1360-1365 cm interval of sediment core LL-44-GPC-3 has R/R_A = 150, and an assigned geologic age of 45.18 Myr.

Farley’s resolution of the dilemma is in proposing that the natural diffusivity in IDP is several orders-of-magnitude less than indicated by laboratory determinations. A simpler, more reasonable conclusion is that conventional geological age dating is incorrect — that Core LL-44-GPC-3 is a sample of post-biblical-Flood sediment that accumulated <5500 years ago.⁴⁷ Farley’s treatment of the data indicates that during the Quaternary, ocean sediment accumulated in the order of ten times faster than throughout the preceding 65 millions years of the

Tertiary. Restricting “Tertiary” to the early portion of post-Flood time produces a more reasonable pattern of sediment accumulation rate. The 150 value for R/R_A in the 1362 cm vicinity of Core LL-44-GPC-3 may indicate sediment deposit associated with passage of Earth through a region of interplanetary dust and meteoroid concentration.

Another indication that geological age assignments are grossly inflated is provided by helium in diamonds. In reporting their investigations of helium in diamonds, R.C. Wiens et al. (1994) note that “Measured and extrapolated effective ^4He diffusivities at 1200°C are...much higher [5-10 orders of magnitude] than...required for quantitative helium retention over diamond ages”; “Bulk retention of trapped mantle helium over the age of most diamonds (>1 Ga) would require effective diffusion coefficients at least several orders of magnitude lower than that inferred for the cosmogenic helium component at 1200°C , typical of mantle temperatures.”⁴⁸

The remarkable similarity of helium isotope ratios ($R/R_A = 6.1 \pm 0.7$ to 6.65 ± 0.25) of volcanics in the Massif Central (France), the Eifel (Germany), the Spitsbergen (Arctic Ocean), and the Kapfenstein (Austria) Cenozoic volcanic provinces of Europe, regardless of geologic age assignments ranging from 3.5 thousand to ten million years,⁴⁹ taken together with the high diffusivity of He-3 , is further indication that conventional geological age assignments are vastly inflated. Any mineral for which the $\text{He-3}/\text{He-4}$ ratio is markedly greater than that for the surrounding area, and that has a geologic age assignment in the millions-of-years range, is evidence for orders-of-magnitude discrepancy between real time and the conventional age assignment. As was already noted above, due to the high diffusivity of helium a concentration of relatively high R will blend together with a lower concentration in the surrounding area. The higher diffusivity of He-3 with respect to He-4 will augment the rate at which this blending occurs.

An analysis of olivine and clinopyroxene surface samples from the Bismarck Archipelago of Papua, New Guinea, gave cosmogenic He-3 concentrations that could be generated in 2.5-16 thousand years at an estimated present cosmogenic He-3 production rate (63 atoms per gram per year at sea-level on the equator).⁵⁰ An estimate that is uncertain within the range 2.5-16 kyr is in satisfactory agreement with formation of these islands since the Genesis Flood.⁵¹

According to Farley (1995),⁵² He-4 concentrations in a 23 m length of central North Pacific pelagic clay core presumed to extend to ~ 72 Ma

ago, are up to two orders-of-magnitude *below* predictions based on geological age assignments. The He-4 concentrations in this core *decrease* with depth, rather than increasing as would be expected on the basis of helium production and diffusion over the assigned age of core segments. Uranium concentration values reported in the source of the data on this core⁵³ also decrease with depth, exhibiting minor variations about a representative constant He/U ratio. From my perspective, the data are most readily explained by deposition over a few thousand years with sediment that has a U-He age characteristic which does not relate to the time of deposition.

Authors and editors are naturally inclined to, and are under pressure to, publish material that is readily understandable from the perspective of the prevailing concepts that presume geological features represent gradual overall development over millions of years. The appearance in the professional literature of the examples cited in this section indicates that there is a solid scientific basis for reconsidering the prevailing concepts related to geologic time.

LOSS OF HELIUM TO OUTER SPACE

An understanding of the helium content of the atmosphere must take into consideration the processes by which helium is lost to outer space. Representing the flux of the i^{th} sort of atoms to outer space per unit area of surface by ${}^i\mathbf{F}$,

$${}^i\mathbf{F} = {}^i\mathbf{n} \times {}^i\mathbf{f}, \quad (1)$$

with ${}^i\mathbf{n}$ the number of the i^{th} sort of atoms per unit volume at the elevation for which determination is made, and ${}^i\mathbf{f}$ a factor with units of velocity that specifies the portion of these atoms that have an outward component of velocity equal to or greater than the escape speed \mathbf{v}_{esc} .

$$\mathbf{v}_{\text{esc}} = [2GM/r]^{1/2}, \quad (2)$$

with G the universal constant of gravitation, M the mass of Earth, and r the distance from Earth-center for which \mathbf{v}_{esc} is specified.

There are three types of process by which an atom may acquire sufficient speed to escape Earth's gravitation: (1) ionization and subsequent acceleration in electric fields, particularly in the regions around the magnetic poles⁵⁴; (2) collisions that transfer energy from ions in the solar wind, or atoms that have been ionized by ultraviolet light; and (3) the high-energy portion of the thermal energy distribution (Jeans

escape).⁵⁵ Jeans flux has been estimated to account for only about 1/6 of the helium loss from Earth's atmosphere.⁵⁶ Such estimates should be accepted with caution, since they may be derived from an assumption of helium equilibrium in the atmosphere, rather than actual physical measurements.

Since a quantitative estimate can be made readily for proposed Jeans flux, and even crude direct estimates have not been available for loss by ion acceleration and non-thermal collision interactions, treatment of atmospheric helium dynamics has usually featured Jeans flux.⁵⁷ For Jeans flux the appropriate $i\mathbf{f}$ factor in Equ. (1) above, $i\mathbf{f}_{th}$, is

$$i\mathbf{f}_{th} = (2\pi^{1/2})^{-1} v_{esc} [(1+\lambda)/\lambda^{1/2}] e^{-\lambda}, \quad (3)$$

in which $\lambda = (v_{esc}/v_{mp})^2$ (4)

$$v_{mp} = (2\kappa T/m)^{1/2} \quad (5)$$

with v_{mp} = most probable velocity, κ = Boltzman's gas constant, T = absolute temperature in °K, and m = mass of the molecule.⁵⁸

The concentration in the region from which escape to space is evaluated, $i\mathbf{n}$, may be a more significant factor in Equation (1) than $i\mathbf{f}$, the fraction of atoms that escape from that region. With a concentration gradient from Earth's surface to outer space, diffusion considerations would be the dominant factor in the establishment of $i\mathbf{n}$. The Jeans flux for the portion of $i\mathbf{n}$ that have sufficient energy to escape the gravitational field is based on the Maxwell-Boltzman energy distribution function which is strictly valid only for an equilibrium state within a confined region, regardless of whether that region is defined by physical boundaries. Thus if there is escape, the Jeans flux provides at best only a first approximation to the actual portion of $i\mathbf{n}$ that flow outward per unit of time as a consequence of energy acquired through thermal interaction.⁵⁹

Table 2 is a tabulation of Jeans flux parameters for atmospheric helium at 800 km altitude (radius 7171 km from the center of Earth) and 1000°K. These temperature and altitude values were chosen from Figures 4 and 5 of the Astronomical Constants section of the *CRC Handbook of Chemistry and Physics*.⁶⁰ Values estimated or calculated from estimated values are shown in italics. Values measured or calculated from measured values are in bold face. All other values are from Jeans thermal flux escape calculations. The surface area of a sphere of 7171 km radius is 6.46×10^{18} cm². For the production, P , of He-4 at

TABLE 2. THERMAL ESCAPE FLUX DATA

Parameter	He-3	He-4
n	1.4 atoms/cm ³	10 ⁶ atoms/cm ³
v _{mp} (at 1000 °K)	2.35 km/sec	2.04 km/sec
v _{esc} (at 800 km alt.)	10.54 km/sec	10.54 km/sec
* f _{th}	2.6 x 10 ⁻³ cm/sec	4.0 x 10 ⁻⁶ cm/sec
F_{th} = n x f_{th}	3.6 x 10 ⁻³ atoms/cm ² /sec	4.0 atoms/cm ² /sec
L_{th} = F_{th} x Area	2.3 x 10 ¹⁶ atoms/sec	2.61 x 10 ¹⁹ atoms/sec
Q	7.8 x 10³² atoms	5.7 x 10³⁸ atoms
R_{th} = L_{th}/Q	2.9 x 10 ⁻¹⁷ sec ⁻¹	4.6 x 10 ⁻²⁰ sec ⁻¹
Q_{max} = P/R_{th}	5.6 x 10 ³⁵ atoms	2.6 x 10 ⁴⁴ atoms
P	1.6 x 10 ¹⁹ atoms/sec	1.2 x 10 ²⁵ atoms/sec

*f as defined for Equ (1), f_{th} indicating thermal escape

equilibrium concentration, Q_{max}, the value 1.2 x 10²⁵ atoms/sec for radiogenic production in the crust is used.

An estimation of the equilibrium concentration, Q_{max}, for He-3 may be obtained from noting that for both He-3 and He-4

$$Q = Q_{\max} (1 - e^{-R_{\text{th}}t}). \quad (6)$$

He-4 Q_{max} may be determined using for P the He-4 production in the crust, assuming that at equilibrium thermal escape from the atmosphere will equal diffusion from the crust into the atmosphere, and diffusion from the crust is equal to production in the crust. The 2.6 x 10⁴⁴ atoms value in Table 2 was calculated on this basis. Simultaneous equations may be obtained from Equ. (6), using the present inventory for Q, the appropriate respective values for R_{th}, and an unspecified time t_p (present) for t. Eliminating t_p between the two equations produces an equation that may be solved for He-3 Q_{max} to obtain the 5.6 x 10³⁵ atoms value in Table 2.

The reciprocal of R_{th} as defined in Table 2 is the exponential relaxation time, T_r — the time in which an exponential term multiplies or divides e-fold (2.718 times). Table 3 lists significant time intervals for evaluation of the thermal escape model. The reader should keep in mind that these time intervals are hypothetical, and are based on the assumption that the atmosphere at one time did not contain any helium.

**TABLE 3. CHARACTERISTIC TIME INTERVALS
FOR THERMAL ESCAPE**

Interval	He-3	He-4
Relaxation Time, T_r	1.1 billion years	690 billion years
Time to reach present Q	1.5 million years	1.5 million years
Time for 98% equilibrium	4 billion years	2.7 trillion years

For a crustal production rate 1/10 as great as that based on uniform distribution of U and Th (3.75×10^{31} atoms He-4 per year), Q_{\max} would be 2.6×10^{43} atoms for He-4, and 5.6×10^{34} atoms for He-3; and the time for reaching the present Q would increase from 1.5 million years to 15 million years.

In the same way that Q_{\max} for He-4 was derived from a value for the production rate, the production rate for He-3 may be derived from a value for its Q_{\max} . The time-projection of He-3/He-4 ratio in the atmosphere, according to the thermal escape model, indicates relatively rapid (i.e., compared with He-4) accumulation of He-3 to an equilibrium level which is about 1/450 of that which would be expected if the two isotopes had equal probability for loss to outer space (quotient of Equilibrium and "Time-Zero" ratios of Table 4). The "Time-Zero" value is obtained

TABLE 4. TIME-PROJECTION OF ATMOSPHERIC He-3/He-4 RATIO

"Time-Zero" Ratio	1.0×10^{-6}
Present Concentration Ratio	1.4×10^{-6}
Equilibrium Ratio	2.2×10^{-9}

from recognition that in a backward approach to the limit of time-zero, the concentration ratio approaches the production ratio. It must be kept in mind that these considerations assume constant annual diffusion into the atmosphere of the amount of He-4 that has been estimated for the present yearly radiogenic production of helium in Earth's crust. In 10 billion years the He-4 production in the crust is projected to be about half its present rate. Consequently, conclusions from the foregoing analysis should not be extended beyond a range of about two billion years.

BOUNDARY-LIMITED THERMAL MODEL FOR ATMOSPHERIC HELIUM

The extreme disequilibrium, and the unrealistic time-interval projections of the Jeans escape model as developed in the foregoing paragraphs, make the usefulness of this model highly questionable. Before discarding it, the possibility for modifying basic assumptions sufficiently to make the model more attractive should be investigated. Modification of these assumptions to the extreme extent I think might be justified yields what may be designated as the Boundary-Limited Thermal Model. For this model, He-4 production is presumed to be 1/10 of the value obtained from assumed uniform distribution of thorium and uranium from the surface to the base of Earth's crust. And the kinetic temperature of the escape region is presumed to be 1500°K, the upper extreme of a range of uncertainty that may be inferred from Figure 4 in the *CRC Handbook of Chemistry and Physics*.⁶¹ The Jeans escape function is so sensitive to temperature that this 500° increase produces an increase of about 5400-fold in the thermal escape flux. The specifications of this model are given in Table 5, with presumed values in italics, and measured values in bold-face.

Although the time values of the Boundary-Limited Thermal Model are all within the usually accepted 4.6 billion years for the age of Earth,

**TABLE 5. BOUNDARY-LIMITED MODEL
FOR ATMOSPHERIC HELIUM**

Parameter	He-3	He-4
v_{esc} (at 800 km)	<i>10.54 km/sec</i>	<i>10.54 km/sec</i>
v_{mp} (1500 °K)	<i>2.88 km/sec</i>	<i>2.49 km/sec</i>
L_{th}	<i>1.6 x 10¹⁹ atoms/sec</i> <i>5.0 x 10²⁶ atoms/yr</i>	<i>1.4 x 10²³ atoms/sec</i> <i>4.4 x 10³⁰ atoms/yr</i>
Q_p	7.8 x 10³² atoms	5.7 x 10³⁸ atoms
$R_{th} = L_{th}/Q_p$	<i>2.1 x 10⁻¹⁴ sec⁻¹</i> <i>6.6 x 10⁻⁷ yr⁻¹</i>	<i>2.5 x 10⁻¹⁶ sec⁻¹</i> <i>7.8 x 10⁻⁹ yr⁻¹</i>
P	<i>2.6 x 10¹⁹ atoms/sec</i>	<i>1.2 x 10²⁴ atoms/sec</i>
$Q_{max} = P/R_{th}$	<i>1.2 x 10³³ atoms</i>	<i>4.8 x 10³⁹ atoms</i>
t_p	<i>16 million years</i>	<i>16 million years</i>
$t_r = 1/R_{th}$	<i>16 million years</i>	<i>128 million years</i>
Time to 98% Q_{max}	<i>6 million years</i>	<i>501 million years</i>

the extreme assumptions that are necessary to accomplish this make the best accomplishment of Jeans escape modeling to be inducement to search for non-thermal mechanisms by which helium might escape Earth's atmosphere.

NONTHERMAL ESCAPE

Before space exploration provided direct measurements of the gases in the exospheres (regions from which escaping particles originate) of Earth and the other inner planets of the Solar System, treatment of escape from the upper levels of an atmosphere seemed fairly straightforward.⁶² In the data that became available from space missions were surprises that have considerably altered our understanding of atmospheric stability.⁶³ It is now recognized that there are probably seven nonthermal processes⁶⁴ by which gases may escape a planetary atmosphere (see Table 6). Five of these seven involve atoms in an ionized state to which

TABLE 6. NONTHERMAL ESCAPE MECHANISMS⁶⁵

1. Charge exchange collisions: high kinetic energy ion becomes a neutral atom.
2. Dissociative recombination: ionized molecule breaks up and gives kinetic energy to a component.
3. Impact or photo dissociation: molecule breakup into two high kinetic energy components.
4. Ion-neutral reaction: ionization energy converted to kinetic energy.
5. Sputtering or knock-on: backward "splash" from atoms or ions impacting Earth's outer atmosphere.⁶⁶
6. Solar-wind pickup: entrapment in the solar wind.
7. Polar region ion escape: acceleration in electric fields and escape along open geomagnetic field lines.

the Jeans escape does not apply. Ion escape at the magnetic poles where there is no transverse acceleration of a moving charged particle is considered by Chamberlain and Hunten⁶⁷ to be the principal means by which helium escapes from Earth. A recent issue of *Physics Today*⁶⁸ has a space-vehicle photograph of the solar ultraviolet light scattered

by the ionized helium surrounding Earth. This photo indicates that a distinct concentration of helium extends over a region about three times the diameter of Earth (elevation about 8000 miles, or 13,000 km, above Earth surface).

There is need for a quantitative model that enables determination of the extent to which the rate of helium loss to outer space is limited by diffusion, rather than by the processes for attaining escape velocity. According to one estimate, the loss of hydrogen to outer space is determined by the diffusion to the exosphere.⁶⁹ If all the atoms of a specific type in a layer of the exosphere are eventually lost to outer space, the population gradient of that type in the underlying layers will adjust to a level that supports a loss rate to outer space that is equal to the rate of input by diffusion, making diffusion the limiting factor in the establishment of a loss rate.

CONCLUSIONS

One firm conclusion which can be made is that the dynamics of helium isotope concentrations in Earth's crust and atmosphere are highly complex, and beyond adequate treatment with a simple model. Treatment of helium in the atmosphere as if thermal considerations (Jeans escape) account for the major loss to outer space produces a model that specifies a high degree of disequilibrium, and indicates an equilibration time within a range between half a billion years and greater than the half-life of uranium, even greater than the proposed age of the Solar System. It is evident that Jeans escape modeling does not relate adequately to physical reality; and that, contrary to claims frequently made in creationist literature, it does not provide significant evidence in support of (or contradictory to) a young-earth viewpoint.

There is ample evidence that consideration must be given: (a) to diffusion flow of helium to the region from which loss to outer space occurs; (b) to loss from ion acceleration in the regions around the magnetic poles; (c) and to loss from energy gain in collision with solar wind atoms and atmosphere atoms that have been elevated to a high energy state by ultraviolet radiation.

There is an option of considering the primordial creation of the matter in Earth's crust and atmosphere to have been coincident (within one week) with the placement of organic life on the planet. In this option the helium isotope distribution in the crust, the atmosphere, and

areas of volcanic activity on the surface should be recognized as requiring the creation of at least two types of helium, each with a distinct primordial He-3/He-4 ratio, differing by several orders-of-magnitude. This seems unlikely. There is no evidence for the creation of any other element in this manner, and no evidence of need for helium to be so different from all other elements. The present helium content of Earth's atmosphere may not be any more explainable than is the present nitrogen and oxygen content.

With the data at hand we should at least be able to predict trends in atmospheric helium abundance and isotope ratio. An unexpected conclusion from this study is the low rates that may be anticipated for these trends, if thermal escape is a dominant factor. According to the "Boundary-Limited Thermal Model" He-4 will not reach equilibrium level in the atmosphere until around 400 million years in the future! The simplistic assumptions on which the model is based may not be expected to be applicable over so long a time period. The question of the rate of loss of helium to outer space remains an enigma. Several alternatives are possible.

One clear implication of the helium isotope data in the professional literature is that conventional geologic age assignments may be grossly inflated. The implications of laboratory-determined He-3 diffusion rates are persistently ignored in favor of conventional geologic age assumptions. Any mineral for which the He-3/He-4 ratio is conspicuously higher than for the surrounding minerals or area, is prime evidence that the host igneous or sedimentary formation was emplaced *within* the last few million years. On the basis of helium isotope ratio data, there is better scientific foundation for placing the formation of the Phanerozoic portion of the geologic column within the past 10,000 years than to extend it over 500 million years.

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ENDNOTES

1. (a) Isotope data in this paper are taken from: Tuli JK. 1995. Nuclear Wallet Cards, 5th edition. Upton, NY: National Nuclear Data Center, Brookhaven National Laboratory; (b) also see Table of the Isotopes in: Lide DR, editor. 1994. Handbook of chemistry and physics. 75th edition. Boca Raton, FL: CRC Press.
2. See Note 1. U-234 is radioactive (unstable) with a 2.455×10^5 year half-life. The 0.0055% abundance of U-234 is equal to the equilibrium ratio of U-234 to its parent U-238. Ninety-eight percent of this ratio would be attained by one million years after an isolated sample of U-238 was created.
3. Small variations may occur in samples that have experienced thermal diffusion or chemical reaction, since the lighter isotopes move slightly faster in these processes. Such variations are usually expressed in parts per thousand (per mil, or ‰). An isotope may be in excess of its standard value if it is a daughter of a radioactive parent and there has been a previous association with the parent element. E.g., primordial lead that has been associated with uranium will have enhanced ratios of the lead isotopes that are daughters of uranium.
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35. For Li, Be, B, F, Na, Al, P, Cl, K, and Sc the most abundant isotope is odd-numbered. Of these, Be, F, Na, Al, P, and Sc are monoisotopic. For Li and B the second-most abundant isotope is even-numbered, and lower — Li-6 at 7.5% vs Li-7 at 92.5%; B-10 at 19.9% vs B-11 at 88.1%. For Cl and K the second-most abundant isotope is odd-numbered and higher — Cl-37 at 24.23% vs Cl-35 at 75.77%; K-41 at 6.7302% vs K-39 at 93.2581%.
36. Lide 1994, "Cosmic Radiation", Section 11: Nuclear and Particle Physics, p 155 (see Note 1b).
37. Lide 1994, "Astronomical Constants," Section 14 (see Note 1b), provides the following data for Earth's crust: Total Mass 2.36×10^{22} kg; 8×10^{-3} mg/kg He; 9.6 mg/kg Th; 2.7 mg/kg U.

- Th-232 has a 1.405×10^{10} yr half-life, and produces 6 He-4 atoms per Th decay. U-238 has a 4.468×10^9 yr half-life, and produces 8 He-4 atoms per U-238 decay. U-235 is 0.720% of uranium, has a 0.7038×10^9 yr half-life, and produces 7 He-4 atoms per U-235 decay. The U-235 contribution brings the total He-4 atoms per U-238 decay to 8.04. The combined production from Th and U is 1.6×10^{10} He-4 atoms/yr kg, or 1.1×10^{-13} grams of helium per year per kilogram of crust. If the 9.6 and 2.7 mg/kg concentration estimates correctly represent the entire crust, the total He-4 production is 2.5×10^6 kg/yr, or 7.38×10^{13} atoms/yr per cm^2 of surface.
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 46. Farley 1995 (see Note 9).
 47. Placing the date of the Flood at about 3400 B.C., according to 1 Kings 6:1; Exodus 12:40,41; Genesis 47:9; 25:26; 21:5; 11:10-26; with construction of Solomon's Temple in 970 B.C., and chronological data as specified in the Septuagint text. This limit would be extended from 5500 to between 10 and 15 thousand years with the interpretation proposed by Gerald Aardsma [1993. A new approach to the chronology of biblical history from Abraham to Samuel. El Cajon, CA: Institute for Creation Research. For a critique, see: Wood BG. 1993. *Bible and Spade* 6(4):97-114].
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ANNOTATIONS FROM THE LITERATURE

ARCHAEOLOGY: SHIP-BUILDING ERECTINES

Morwood MJ, O'Sullivan PB, Aziz F, Raza A. 1998. Fission-track ages of stone tools and fossils on the east Indonesian island of Flores. *Nature* 392:173-176.

Summary. Many southeastern Asian islands, such as Java, Sumatra and Borneo, lie in shallow waters, and were once connected to the Asian mainland during low sea level. Other islands, including Flores, lie in deeper water, and are believed to have been always isolated. Stone tools have been found associated with fossils of *Stegodon* pygmy elephants and *Geochelone* tortoises, indicating the activities of humans in the area. Fission track dating of volcanic tuffs adjacent to the fossils produced ages of about 800,000 to 880,000 years. *Homo erectus* was the only known hominid in the area at the time. This indicates that *Homo erectus* must have had the ability to build boats and cross short stretches of ocean, an ability not generally attributed to the erectines.

Comment. If erectines could build boats and use them to migrate to new regions, it seems likely they must have had language. They may well have been intellectually much more similar to modern humans than previously thought. Arguments that *Homo erectus* should be interpreted as within the normal range of humans have been offered by Lubenow (1992, *Bones of Contention*, Grand Rapids, MI: Baker) and Morton (1997, *Adam, Apes and Anthropology*, Dallas: DMD Publishing).

BIOGEOGRAPHY: DISPERSAL OR VICARIANCE?

Baum DA, Small RL, Wendel JF. 1998. Biogeography and floral evolution of baobabs (*Adansonia*, Bombaceae) as inferred from multiple data sets. *Systematic Biology* 47:181-207.

Summary. Baobabs are often-photographed trees with distinctive shapes. One species is found in Africa, six in Madagascar and one in northwestern Australia. At least three explanations might be offered for this unusual distribution. It might be produced by fragmentation of

a continuous distribution as a consequence of the breakup of Pangaea, or it might be the result of overwater dispersal. A third possibility, that the trees are not truly related, seems unlikely. Relationships among the eight baobab species were estimated from morphology and from three different molecular sequences. Morphologically, four of the Madagascan species are more similar to the Australian species than to the African species. Internal transcribed sequences from nuclear ribosomal DNA showed the Madagascan species to be more similar to the African species. Comparisons of a chloroplast intron showed two of the Madagascan species to be most similar to the African species, but the other four Madagascan species equally similar to the African and Australian species. Restriction site analysis showed the Australian species to be most similar to the African species. All the molecular differences among the species were small in magnitude. This fact, coupled with the discordance among the gene phylogenies and the lack of *Adansonia* pollen in Mesozoic rocks, led the investigators to conclude that the present distribution of baobabs is the result of overwater dispersal. This is made more plausible by the tough water-resistant seeds.

Comment. Vicariance biogeographers have sometimes been quick to assume that distributions restricted to southern continents must be the result of fragmentation of Pangaea. This example shows that there may be other interpretations of the data. Dispersal should not be ruled out *a priori*, even when vicariance appears probable.

BIOGEOGRAPHY: HURRICANES AS DISPERSAL AGENTS

Censky EJ, Hodge K, Dudley J. 1998. Over-water dispersal of lizards due to hurricanes. *Nature* 395:556.

Summary. The Caribbean island of Anguilla lacked green iguanas until 4 October 1995, when at least 15 of the lizards washed up on the shore on a floating mat of logs and trees. This event was preceded by two large hurricanes in the month of September, and it is postulated that the lizards were washed away from their original home by the winds and rain of one or both of these hurricanes. The most likely source of the iguanas is thought to be the island of Guadeloupe, at a distance greater than 250 km. The group of lizards included both males and females, and this observation confirms that overwater dispersal and successful colonization can occur.

Comment. Dispersal has fallen out of favor among some biogeographers who prefer more testable hypotheses, comparing distribution patterns with movements of tectonic plates. Examples such as this show that overwater dispersal due to catastrophic conditions such as hurricanes may be an important factor in the distributions of species.

DESIGN: THE GENETIC CODE

Freeland SJ, Hurst LD. 1998. The genetic code is one in a million. *Journal of Molecular Evolution* 47:218-248.

Summary. The genetic code consists of 64 codons (groups of 3 bases), each of which codes for a specific amino acid or a reading signal. Similar codons generally code for the same or similar amino acids, which means that a point mutation (change of a single nucleotide) is likely to result in replacement of an amino acid by the same or a similar amino acid. Considering that transition mutations (purine to purine, or pyrimidine to pyrimidine) are more frequent than transversion mutations (purine to pyrimidine, or pyrimidine to purine), what is the probability that a code assembled at random would be as efficient as the existing code? Calculations indicate that the probability is only one in a million, indicating that the genetic code is non-random in arrangement, as expected if it were produced by selection.

Comment. The efficiency of the genetic code is best explained as a striking example of design. It seems implausible to propose that a randomly generated genetic code could be so significantly improved through natural selection, since changing the meanings of the codons would disrupt the process of natural selection of the protein products.

DESIGN: MOLECULAR MACHINES

Alberts B. 1998. The cell as a collection of protein machines: preparing the next generation of molecular biologists. *Cell* 92:291-294.

Summary. This is the introductory article to a collection of articles describing molecular machines in cells. The author no longer views cellular processes as driven by random collisions of proteins, colliding two at a time in an undirected sequence. He now believes that virtually every major cellular process involves assemblies of 10 or more protein molecules, each of which is interacting with other molecular assemblies. Each of these assemblies function as machines, with highly coordinated

moving parts. The author then discusses whether one should have expected such well-engineered protein machines as are found, and to appeal to university science departments to consider how better to prepare the next generation of molecular biologists. They will need to have a good knowledge of mathematics and the physical sciences in order to unravel the mysteries of how these machines operate.

Baker TA, Bell SP. 1998. Polymerases and the replisome: machines within machines. *Cell* 92:295-305.

Summary. Replication of DNA involves an interacting complex of several molecular machines. These include the primases and polymerases that copy the DNA, the exonucleases that correct copying mistakes, the clamping proteins that attach the polymerases to the DNA, and the helicases that separate the DNA strands so they can be copied. The clamping proteins provide an example of mechanical action. A sliding clamp protein forms a ring around the DNA strand at the appropriate location, and attaches the polymerase unit. A clamp loader protein opens the ring-shaped sliding clamp protein, moves it to the correct location, and closes it around the DNA strand. This requires specific recognition sites for DNA initiation sites, the sliding clamp protein, and ATP, along with specific structural features that facilitate appropriate configurational changes to open and close the sliding clamp protein at the proper times.

Bukau B, Horwich AL. 1998. The Hsp70 and Hsp60 chaperone machines. *Cell* 92:351-366.

Summary. Molecular chaperones are molecules that cause conformational changes in other molecules, converting them into active forms. For example, an inactive protein may be converted into an active enzyme by a molecular chaperone that causes an appropriate change in the folding of the protein. In some cases, proper folding may be achieved by a series of molecular chaperones. Chaparonins consist of double-ring assemblies with a central cavity that can attach to proteins that are not properly folded. Attachment of the protein molecule triggers conformational changes in the chaparonin that result in proper folding of the protein. The chaparonin's function is made possible by its three-part, hinged structure, its inner hydrophobic recognition site, an ATP recognition site, and by its specific shape that facilitates appropriate conformational changes.

DeRosier DJ. 1998. The turn of the screw: the bacterial flagellar motor. *Cell* 93:17-20.

Summary. The mechanism for movement of the bacterial flagellar motor is unknown, but much has been learned of the structure. The flagellum “resembles a machine designed by a human...” It consists of a rigid filament connected to a curved piece by two junction proteins. The flagellum is set into a socket in the inner cell membrane, and rotates within two bushing-like rings embedded in the outer cell membrane. Three other rings are also present. About 50 genes are involved in flagellar structure and sensitivity to chemicals.

Kinosita K, Yasuda R, Noji H, Ishiwata S, Yoshida M. 1998. F_1 -ATPase: a rotary motor made of a single molecule. *Cell* 93:21-24.

Summary. ATP, the major energy carrier molecule for living cells, is constructed with the aid of an enzyme, ATP synthase. The ATP synthase molecule includes a rotary motor only 10 nm in size. The motor has a central shaft that rotates inside a hexagonal structure of six subunits. Rotation of the central shaft has been confirmed by observing movement of a larger molecule attached to the shaft. When ATP is added to the medium, the central shaft rotates counterclockwise, hydrolyzing the ATP, probably with an efficiency near 100%. If the shaft is turned clockwise, as by passage of a proton, ATP is produced.

Comment. The articles in these issues of *Cell* provide an impressive reminder of the complexity of cellular processes, and the extraordinary amount of information in their sequences. If, as seems probable, each molecular machine is irreducibly complex, creation by direct agency seems the best explanation for the origins of these molecular machines.

EVOLUTION: THE HOMOLGY PROBLEM

Tautz D. 1998. Debatable homologies. *Nature* 395:17-18.

Summary. The concept of homology is foundational for evolutionary theory, but extremely difficult to define. Further, “homology concepts tend to fail when it comes to tracing evolutionary novelties.” Studies of developmental genes have complicated the issue by showing that genes with similar sequences may produce similar structures, such as eyes or legs, in different phyla, when such structures are believed absent from their common ancestors. The potential for gene

duplications, losses and re-duplications means that sequence similarities are not, of themselves, sufficient to establish homology. Studies of sea urchin hybrids may provide increased understanding of development, but it appears that their regulatory modules may be composed of subunits that can be combined in different ways. If homology must be identified through similarities in complex regulatory modules, the term “homology” would indeed be “ripe for burning,” as suggested by evolutionist J. Maynard Smith.

Comment. Morphological evolution can be divided into two aspects: variation/modification, and addition/subtraction. Homology is certainly a useful concept in the studies of variation/modification that can be observed experimentally, which all creationists accept. Homology’s most difficult problems occur when attempting to explain differences in species with different body plans. At the same point, problems occur in explaining the origin of the genetic information responsible for the differences in body plans. Rather than trying to force a concept on a situation where it doesn’t work, it would seem better to use differences in body plans as a useful starting point for proposing independent ancestries.

EVOLUTION: IS THE PRESENT THE KEY TO THE PAST?

Thompson JN. 1998. Rapid evolution as an ecological process. *Trends in Ecology and Evolution* 13:329-332.

Summary. The importance of rapid changes in species has been overlooked, but greater recognition of such change rates would increase the importance of the field of evolutionary ecology. Introduced species provide many examples of rapid changes, perhaps because they are more likely to undergo directional selection rather than fluctuating selection. Rates of proportional change over time are measured in units known as “darwins.” Calculated rates of change are inversely proportional to the estimated time. Rates over short time scales, as measured in real time, tend to be relatively very high. Rates of change over long time scales, as calibrated against the geological time scale, tend to be relatively very low.

Comment. The inverse relationship between rates of change and time is exactly what would be predicted by creationists. Relatively high rates of change observed over short periods of time are real.

Relatively low rates of change extrapolated from the geological time scale may be an artifact of the inflated time scale.

EVOLUTION: NATURAL SELECTION AND LIZARDS

Losos JB, Jackman TR, Larson A, de Queiroz K, Rodriguez-Schettino L. 1998. Contingency and determinism in replicated adaptive radiations of island lizards. *Science* 279:2115-2118.

Summary. Lizards of the genus *Anolis* are abundant on Caribbean islands. Especially on the larger islands, these lizards have diversified into different “ecomorphs” — differing in size and habitat preference. The question is whether similar ecomorphs on different islands are most closely related to each other or if the different ecomorphs of an island are most closely related to each other. Phylogenetic relationships among *Anolis* lizards of the four Greater Antilles (Cuba, Hispaniola, Jamaica and Puerto Rico) were determined using mitochondrial DNA sequences. Results indicate that the different ecomorphs of an island are closely related to each other, and that similar ecomorphs from different islands have independent origins. This example shows that natural selection is more important than chance in modifying body form in these lizards.

Comment. This is a nice illustration of the power of natural selection to modify morphological characters such as body shape and limb proportions. Creationist theory postulates extremely large changes in environmental conditions since the creation, making significant variation, often accompanied by speciation, necessary for survival.

EVOLUTION: A NATURAL SELECTION AND PEPPERED MOTHS

Coyne JA. 1998. Not black and white. (Review of) *Melanism: evolution in action*, by M.E.N. Majerus, Oxford University Press. *Nature* 396:35-36.

Summary. The peppered moth has been the centerpiece in the story of the power of natural selection. Moths resting on lichen-colored tree trunks were camouflaged if white but conspicuous to predators if black. Accordingly, most moths in pre-industrial England were white. As soot darkened the tree trunks, black moths were better camouflaged, and the white forms were selectively removed. As pollution came under better control after 1950, the white forms again became common.

The story has lost much of its punch by the realization that the moths do not normally rest on tree trunks during the day, do not choose matching backgrounds in controlled studies, and the white form increased in areas where there was no change in the abundance of lichens on the tree trunks. According to Coyne, we must now abandon the claim that we understand how natural selection has caused shifts in the proportions of white and black peppered moths. Especially notable is his comment:

It is also worth pondering why there has been general and unquestioned acceptance of Kettlewell's work. Perhaps such powerful stories discourage close scrutiny. Moreover, in evolutionary biology there is little payoff in repeating other people's experiments, and unlike molecular biology, our field is not self-correcting because few studies depend on the accuracy of earlier ones.

Comment. The above quote should provide a sobering reminder to all involved in discussions of creation and evolution that the nature of historical science simply does not justify the degree of confidence seen in more experimental science, despite the reassurances of some of the discussants.

GENETICS: MOBILE GENES IN VERTEBRATES

Kordis D, Gubensek F. 1998. Unusual horizontal transfer of a long interspersed nuclear element between distant vertebrate classes. *Proceedings of the National Academy of Sciences (USA)* 95:10704-10709.

Summary. LINEs, or long interspersed nuclear elements, are segments of DNA found repeated in many copies in a genome. One particular LINE, called ART-2 retroposon, was previously found first in cattle, then throughout the ruminants. It was thought to be specific to the ruminants until it was discovered also in vipers. This appeared to be a case of horizontal genetic transfer, perhaps by a common parasite. This possibility was tested by surveying 22 species of snakes, 17 species of lizards, 2 crocodylians, and 2 turtles. ART-2 retroposons were discovered in all the snake species and a majority of the lizard species, but not in the crocodylians or turtles. Horizontal transfer appears to be the best explanation for this pattern.

Comment. Horizontal transfer is common among bacteria, but it is thought to be rare among multicellular organisms. If horizontal transfer is much more common among multicellular organisms than currently believed, inferences from similarities in molecular sequences might be greatly weakened.

MOLECULAR EVOLUTION: STRONG OR RELAXED SELECTION?

Bargelloni L, Marcato S, Patarnello T. 1998. Antarctic fish hemoglobins: Evidence for adaptive evolution at subzero temperature. *Proceedings of the National Academy of Sciences (USA)* 95:8670-8675.

Summary. The Antarctic fish fauna is dominated by a group known as notothenioids, which have some exceptional physiological features. Notothenioids include the icefish, famous as the only vertebrate lacking hemoglobin. Icefish are believed able to survive without hemoglobin because of the high oxygen content and reduced metabolic needs in the cold Antarctic waters.

Fish in most environments have multiple forms of hemoglobin, thought to be useful in dealing with changing environments. In contrast, several notothenioid species have reduced levels of hemoglobin, dominated by a single form. In the fish *Gymnodraco acuticeps*, only one form of hemoglobin is present. It has been proposed that there is a simple trend from multiple hemoglobins to a single form of hemoglobin, to loss of hemoglobin as in the icefishes. This hypothesis was tested by comparing hemoglobin DNA sequences in several notothenioid species, including *G. acuticeps*. Results showed that *G. acuticeps* hemoglobin has an unusually large number of amino acid differences, which appear to be the result of strong directional selection, rather than relaxed or weak selection. This is interpreted as not supporting the hypothesis of a simple trend toward loss of hemoglobin in these fishes.

Comment. This conclusion would be strengthened if an improvement in function can be discovered for the *G. acuticeps* hemoglobin. If not, the high number of amino acid differences in *G. acuticeps* may be just as easily explained as due to relaxed selection, potentially leading to loss of hemoglobin function.

MOLECULAR PHYLOGENY: WOOLY MAMMOTH DNA

Noro M, Masuda R, Dubrovo IA, Yoshida MC, Kato M. 1998. Molecular phylogenetic inference of the woolly mammoth *Mammuthus primigenius*, based on complete sequences of mitochondrial cytochrome *b* and 12S ribosomal RNA genes. *Journal of Molecular Evolution* 46:314-326.

Summary. The elephant family, Elephantidae, includes both types of living elephants and the extinct mammoths. Controversy has surrounded the question as to which two types are the more closely related. Immunological and hair comparisons showed the three genera to be equally distant from each other. Dental studies suggested mammoths and Asian elephants to be more closely related. Previous molecular studies suggested mammoths and African elephants to be more closely related. This study is the first to use the complete sequences of two mitochondrial genes. This study agrees with previous molecular studies that the mammoth is slightly more closely related to African elephants than to Asian elephants.

Osawa T, Hayashi S, Mikhelson VM. 1998. Phylogenetic position of mammoth and Steller's sea cow within Tethytheria demonstrated by mitochondrial DNA sequences. *Journal of Molecular Evolution* 44:406-413.

Summary. Mitochondrial DNA sequences were compared for African elephants, Asian elephants, extinct woolly mammoths, and several other species. Results show that the woolly mammoth was more closely related to the Asian elephant than to the African elephant. This is consistent with the fossil record, where the African elephant appears before the Asian elephant.

Comment. The relationships of the three genera of elephants remain ambiguous, despite a good fossil record, availability of molecular sequences, and accessibility of specimens for morphological comparison. In this example, it is doubtful that one can infer phylogenetic branching sequences based on sequences of first appearances of the species, as attempted by Osawa et al. The Asian elephant, African elephant, and woolly mammoth are each in a separate genus, and all three genera have first appearances close together in the fossil record. A common ancestry of the three genera of elephants seems plausible to many creationists, and the lack of resolution may be due to a recent, near-simultaneous geographic isolation and genetic divergence.

ORIGIN OF LIFE: CHIRALITY

Clery D, Bradley D. 1994. Underhanded “breakthrough” revealed. *Science* 265:21.

Comment. A previous report of separation of chiral molecules in a strong magnetic field has been retracted. The report was discussed in *Origins* 24:94 without knowledge of the problem. It turns out that the experiment had been manipulated by one member of the investigating team. Regrettably, fraud occasionally shows up in science, and we apologize for not correcting our report sooner. We thank the *Origins* reader who informed us of the error.

ORIGIN OF LIFE: LIFE ON MARS PUT TO REST

Bada JL, Glavin DP, McDonald GD, Becker L. 1998. A search for endogenous amino acids in Martian meteorite ALH84001. *Science* 279:362-365.

Summary. Meteorite ALH84001 was discovered in Antarctica, and identified as having come from Mars, presumably as the result of an asteroidal impact on that planet. Certain features of the meteorite were interpreted as probable evidence of life on Mars, a claim that was eventually abandoned. This paper reports that amino acids extracted from the meteorite had an excess of L-enantiomers, indicating contamination by terrestrial sources, rather than being carried from an extraterrestrial source.

Jull AJT, Courtney C, Jeffrey DA, Beck JW. 1998. Isotopic evidence for a terrestrial source of organic compounds found in Martian meteorites Alan Hills 84001 and Elephant Moraine 79001. *Science* 279:366-370.

Summary. Possible traces of life were previously reported from meteorites believed to have been ejected from Mars. This possibility was tested by analyzing both the carbon-14 and carbon-13 contents of the meteorites. Carbon-14 is produced by interaction of nitrogen and cosmic rays, and is not expected to be present in significant quantities in the Martian meteorites, since nitrogen is much less abundant on Mars than on Earth. The level of carbon-14 in the meteorites was determined to be about half that of modern terrestrial carbon. This is much greater than expected if the meteorites were from Mars, and strongly indicates that the meteorites have been

contaminated by terrestrial carbon. Carbon from living organisms tends to be low in carbon-13 as compared to carbon from inorganic sources. The proportion of carbon-13 in the Martian meteorites was reduced, indicating that the meteorites have been contaminated by organic carbon from terrestrial organisms. It seems that the organic compounds found in the Martian meteorites did not originate on Mars, but were added to the meteorite after it fell to the Earth.

Comment. These results confirm that the Martian meteorites do not provide evidence for life on Mars.

ORIGIN OF LIFE: PROTEINS PRODUCED IN WATER?

Huber C, Wachtershauser G. 1998. Peptides by activation of amino acids with CO on (Ni,Fe)S surfaces: implications for the origin of life. *Science* 281:670-672.

Summary. Origin of life experiments have shown that amino acids can be produced abiotically, but no way is known for combining the amino acids into proteins. Water tends to hydrolyze the peptide bonds of proteins rather than facilitating their bonding. In this experiment, peptide bonds were formed in hot aqueous solution. Peptide bonding required the presence of carbon monoxide, nickel and/or iron sulfide, hydrogen sulfide, methanethiol, and a pH of 7-10. Amino acids tested include L-phenylalanine, L-tyrosine, and L-glycine. Products were racemic dipeptides. Dipeptides hydrolyzed rapidly in separate experiments using the same conditions. The authors claim these results support the hypothesis of a thermophilic origin of life.

Comment. Major problems in the production of proteins from amino acids include at least: sources of a variety of amino acids; protection from interference by chemical contaminants; formation of peptide bonds; preservation of peptide bonds as the protein is being produced; appropriate sequence of amino acids for biological function. This experiment shows that peptide bonds can be formed in hot aqueous solutions, but that they break down rapidly. The claim that this experiment supports the origin of life in hydrothermal vent environments seems greatly exaggerated.

PALEONTOLOGICAL PATTERNS: DIVERSITY

Adrain JM, Fortey RA, Westrop SR. 1998. Post-Cambrian trilobite diversity and evolutionary faunas. *Science* 280:1922-1925.

Summary. Ordovician rocks are noted for two notable diversity trends: 1) a rapid increase in diversity as compared to Cambrian rocks; and 2) an abrupt turnover in the types of fossils at the top of the Ordovician. This paper is an attempt to better understand the details of the patterns as they apply to trilobites, which are one of the major components of Ordovician fossils. The authors were able to identify two faunal components among Ordovician trilobites. (One family did not fit in either component.) One group, called the IbeX Fauna, dominates the lowest Ordovician layers, but declines through the Ordovician, disappearing from the record at the top of the Ordovician. The other group, called the Whiterock Fauna, increases through the Ordovician and on into the Silurian rocks. The two groups differ in geographic range and in depositional environment. The declining group is found mainly in Gondwana and Baltica, and in a variety of depositional environments, while the expanding group is found mainly in Laurentian regions, and in depositional environments interpreted as platform-margins. Many of the Whiterock families first appear without obvious relationships, while many IbeX families are known also from Cambrian rocks.

Thus, one group of trilobites participated in the “End-Ordovician mass extinction” while the other group did not. The families that did not disappear at the top of the Ordovician had more genera per family, and were more likely to have first appearances in tropical Laurentian platform-margin depositional environments.

Comment. Many creationists have predicted that the fossil sequence should be strongly influenced by geographical and ecological factors. It is interesting to note that these factors have been proposed as important in producing Ordovician diversity patterns among trilobites.

Jablonski D. 1998. Geographic variation in the molluscan recovery from the end-Cretaceous extinction. *Science* 279:1327-1330.

Summary. The Cretaceous-Tertiary boundary is characterized by a major change in fossil types, commonly called a “mass extinction.” A previous study of North American Gulf Coast fossil faunas showed

that certain molluscan families abruptly become abundant above the boundary. This has been interpreted as a population explosion among groups who took advantage of new ecological opportunities following the “mass extinction” (so-called “bloom taxa”). The pattern of sudden expansion of ecological opportunists after a “mass extinction” has been accepted as the normal pattern of recovery after a geological catastrophe. However, the pattern is different in northern Europe, northern Africa and Pakistan-northern India, where the abundance of so-called “bloom taxa” remains relatively steady through Paleocene sediments, or even increases at the top of the Paleocene. These observations are problematic in view of the similar extent of end-Cretaceous taxonomic turnover in all four regions.

Comment. Fossil trends are an important aid in interpreting earth history, but they may be misleading. Global summaries hide regional differences and give equal weight to rare taxa and abundant taxa. Regional studies such as this one may provide the best picture of earth history, including the effects of global catastrophe.

DeHaan RF. 1998. Do phyletic lineages evolve from the bottom up or develop from the top down? *Perspectives on Science and Christian Faith* 50:260-271.

Summary. The received view of evolution is that it branches from the bottom up, so that new higher taxa originate through accumulation of small changes over long ages. But this view is refuted by two observations. First, living species change at rates much greater than those inferred from the fossil record. Furthermore, the changes are minor, and variable rather than cumulative. Second, the pattern of diversity in the fossil record is inconsistent with the bottom-up hypothesis. The major taxa appear first, followed by diversity at lower taxonomic levels. This second fact, especially, points toward a top-down development of diversity. The Cambrian Explosion involved numerous distinct phyla, the highest taxonomic category. The eleven phyla of fossil marine invertebrates can be divided into 62 classes, the next-lower category. The stratigraphic midpoint of first appearances for Classes occurs in the Ordovician, above the Cambrian. (Half of all classes appear before the midpoint, and half after the midpoint.) The midpoint of the 307 orders occurs in the Devonian, well above the Ordovician. The greatest number of fossil species is in the upper layers,

deposited after virtually all the higher taxa. The view of top-down evolution is reinforced by the stability of body plans, and the top-down direction of development.

Comment. The implication of this paper is that biodiversity is polyphyletic rather than monophyletic. This conclusion is supported by the actual arrangement of fossils, even when the geologic record is viewed as a record of history rather than a record of catastrophe. This is opposite to the conventional view of evolution as monophyletic.

Miller AI. 1998. Biotic transition in global marine diversity. *Science* 281:1157-1169.

Summary. Three types of global diversity patterns are easily observable in the fossil record: expansion (e.g., Cambrian, post-Paleozoic); abrupt turnover (e.g., end-Permian, end-Cretaceous), and gradual transitions in dominance among higher taxa. "Mass extinctions" seem to occur abruptly, while expansions are more gradual. However, combining all data into a single global pattern may mask smaller-scale patterns. Ordovician sediments display a major expansion (Ordovician radiation), followed by a major turnover (end-Ordovician extinction). Major faunal transitions generally appear abrupt locally or regionally, but differences in stratigraphic position cause global patterns to appear more gradual. The fossil record is determined by local and regional processes, so that mass extinction events are not fundamentally different from those operating during background times.

Comment. It is interesting to note that mass extinctions appear more abrupt locally and regionally than globally. This suggests that regional catastrophic activity in the history of the geologic column may be more informative than that which is deduced strictly from global patterns. This should stimulate creationists to search for regional patterns of depositional conditions and fossil trends.

Rampino MR, Adler AC. 1998. Evidence for abrupt latest Permian mass extinction of foraminifera: Results of tests for the Signor-Lipps effect. *Geology* 26:415-418.

Summary. The end-Permian mass extinction was the largest in the fossil record, but controversy continues over whether it was abrupt or gradual. One difficulty is that extinctions are difficult to estimate for species with an incomplete fossil record. This results in a "smearing"

of apparent extinctions (last appearances) when real extinctions are simultaneous. This is known as the Signor-Lipps effect. Stratigraphic analysis of forams in an end-Permian section in Italy are consistent with an abrupt mass extinction rather than a gradual, stepped extinction. The mass extinction appears to coincide with a negative carbon-13 anomaly probably caused by a global ecological stress event.

Comment. Many workers regard the end-Permian “mass extinction” as a gradual process. This paper suggests a more catastrophic process. If an extraterrestrial impact crater is found (a South African impact site has been suggested), the catastrophic view would be more persuasive. In the meantime, the cause of the end-Permian “mass extinction” remains unresolved.

PALEONTOLOGICAL PATTERNS: DEPOSITIONAL

Taylor PD, Allison PA. 1998. Bryozoan carbonates through time and space. *Geology* 26:459-462.

Summary. Bryozoans are invertebrate animals, usually with a calcareous skeleton, found commonly as fossils from the Ordovician onward. Paleozoic and post-Paleozoic bryozoans are mostly classified in different taxonomic orders. Living bryozoans leave significant sedimentary remains in temperate zones, but not in the tropics. This paper reports a test of whether bryozoan-rich limestones have a similar distribution pattern in the fossil record. The study included 176 bryozoan-rich Paleozoic and Jurassic to Pleistocene stratigraphical units. (No bryozoan limestones have yet been found in Triassic or Lower Jurassic rocks.) Results show that the present extra-tropical distribution pattern goes back only to the Jurassic. Paleozoic bryozoan-rich deposits are mostly from regions thought to have been tropical, based on plate reconstructions. One explanation for the difference in patterns is that predators were less common in Paleozoic tropical habitats, permitting greater bryozoan growth than in Mesozoic tropical habitats.

Comment. This study provides information on bryozoan fossil distributions that might be useful in modeling global processes in earth history. The contrast between Paleozoic and post-Paleozoic taxonomic and distributional patterns is particularly enigmatic.

PALEONTOLOGICAL PATTERNS: ECOLOGY AND BEHAVIOR

Labandeira CC. 1998. Plant-insect associations from the fossil record. *Geotimes* 43(9):18-24.

Summary. Herbivorous insects produce tell-tale effects of their mode of feeding. These effects may be preserved in the fossil record, and provide evidence concerning the diversity of feeding strategies in the fossil groups being studied. Evidence of Paleozoic insect diversity is seen in the diversity of insect damage seen in fossil plants from the upper Pennsylvanian of Illinois and the lower Permian of Texas. Most groups of Paleozoic insects are not found in Mesozoic sediments, but are replaced by insects more similar to those living today. A large majority of modern insect families with a fossil record are found in sediments below the mid-Cretaceous, which is the point at which angiosperm diversity begins to expand. Lower and middle Mesozoic plant fossils show evidence of feeding strategies matching virtually any seen at present. Insect diversity does not appear to be dependent on angiosperm diversity.

Comment. Diversification of angiosperms and insects are often linked. However, the patterns of insect and angiosperm fossil diversities suggest neither is dependent on the other.

Lockley MG. 1998. The vertebrate track record. *Nature* 396:429-432.

Summary. Vertebrate trackways are much more common than thought only a few decades ago. To illustrate, the number of Jurassic dinosaur trackways in the western United States is estimated to be equal to the total number of identifiable dinosaur skeletal remains for the entire world (about 2000). Fossil footprints are abundant in terrestrial sediments from the Carboniferous to Holocene. Fossil tracks have also been used to infer gait and posture, social behavior, to establish stratigraphic correlations, and to fill in gaps in distributions of taxa. Tracks may appear lower in the fossil record than any evidence from body fossils, as is the case for shorebirds, and perhaps for tetrapods. The study of fossil trackways has the potential to greatly enhance our understanding of the fossil record.

Comment. Lockley's systematic studies of fossil footprints are highly informative. Such data may be useful in estimating minimum depositional time, since formation of identifiable footprints probably requires damp surfaces and their preservation requires rapid but limited-

energy sedimentation. The abundance of vertebrate trackways from the Carboniferous onward suggests that some vertebrates were alive and moving about throughout the period of deposition. Studies of regional and stratigraphic distributions of identified trackways could contribute significantly toward improving our understanding of Earth history.

PALEONTOLOGICAL PATTERNS: MORPHOLOGY

Alroy J. 1998. Cope's Rule and the dynamics of body mass evolution in North American fossil mammals. *Science* 280:731-734.

Summary. The author reports the results of comparing body sizes of fossil mammal species from the same genus but from different stratigraphic levels. His study covers essentially the entire North American mammal fossil record, from the Upper Cretaceous (Campanian) to the Upper Pleistocene. His results show that species found higher in the stratigraphic record are larger than those from the same genus found lower in the stratigraphic record. The difference averages 9.1%, and is greater for large than for small species. A stratigraphic trend toward increasing body size has been called "Cope's Rule" in honor of the paleontologist who first proposed the trend. Although Cope's Rule has sometimes been found not to apply, this study shows that it does generally apply to species within the same genus of mammals.

Comment. Creationists have wondered whether Cope's Rule might be an effect of differential survival, with the largest and strongest individuals surviving longer and being buried higher in the geologic column. Such a possibility would be negated if Cope's Rule is invalid. This study helps affirm that the Rule is valid within limits. One important limit is that this trend is seen within single groups, such as genera. Any single stratigraphic unit may contain individuals of different sizes.

PALEONTOLOGY: FOSSIL INVERTEBRATES

Li C-W, Chen J-Y, Hua T-E. 1998. Precambrian sponges with cellular structures. *Science* 279:879-882.

Summary. Fossil sponge spicules have been identified in Precambrian phosphatic sediments significantly lower than any previously known sponges. The spicules are derived from the Class Demospongiae, which is the most abundant group of living sponges.

A fossil embryo appears to be from a different Class, the calcareous sponges. The sponges are thought to have been buried catastrophically. The Demospongiae have been thought to have evolved from the glass sponges, Class Hexactinellida, but these fossils appear lower than any glass sponges. This may indicate a need for revising sponge phylogeny.

Comment. If this report stands, sponges must be removed from the list of groups first appearing in the “Cambrian Explosion.” However, the new discovery raises additional questions. Can the absence of connecting links in the Precambrian be plausibly attributed to the poor quality of the fossil record when microscopic fossil embryos have been found? Perhaps further discoveries in the phosphate deposits will reveal fossils from other groups. If the calcareous sponge embryo is correctly identified, we have two Classes of sponges appearing together, and in lower strata than their putative ancestors. Surely the fossil record has a lot of reinterpretation ahead of it.

Moldowan JM, Talyzina NM. 1998. Biogeochemical evidence for dinoflagellate ancestors in the Early Cambrian. *Science* 281:1168-1170.

Summary. Dinoflagellates are abundant single-celled organisms in aquatic environments. Their known fossil record extends only down to the Middle Triassic, and their apparent absence from Paleozoic strata is puzzling. Dinoflagellates produce certain chemicals not found in other taxa. The presence of dinosterane and 4-alpha-methyl-24-ethyl-cholestane is considered to be indicative of dinoflagellates. Examination of Cambrian sediments in Estonia revealed the presence of these dinoflagellate-specific compounds. This indicates that dinoflagellates or their ancestors were incorporated in Cambrian sediments, despite the difficulties in identifying their cysts. It appears that many acritarchs (fossil cysts of uncertain affinity) may actually be fossil dinoflagellates or their ancestors.

Comment. Dinoflagellate systematics are not well understood, but this report suggests that the dinoflagellate fossil record might be much more extensive than believed. Perhaps dinoflagellates were actually present during Paleozoic sedimentation, but were not preserved.

PALEONTOLOGY: FOSSIL PLANTS

Gandolfo MA, Nixon KC, Crepet WL, Stevenson DW, Friis EM. 1998. Oldest known fossils of monocotyledons. *Nature* 394:532-533.

Summary. Monocot fossils have a meager fossil record, and fossil flowers are especially rare. Tiny fossil flowers representing at least 100 species have recently been identified from Turonian sediments (lower Cretaceous) in New Jersey. Among them are the geologically oldest known monocot flowers. The fossil flowers have features that indicate a close relationship to the family Triuridaceae, a group of tropical saprophytic plants lacking chlorophyll. This discovery suggests the need for new hypotheses of monocot origins and diversification.

Comment. The discovery of these fossil flowers significantly expands the Mesozoic fossil record for flowering plants. The new data appear to be consistent with creationist expectations that monocots have separate origins from dicots; but the fossil record of angiosperms in general poses significant challenges regardless of one's frame of interpretation.

Sun G, Dilcher DD, Zheng S, Zhou Z. 1998. In search of the first flower: a Jurassic angiosperm, *Archaeofructus*, from Northeast China. *Science* 282:1692-1695.

Summary. The Yixian Formation of China has yielded many well-preserved fossils, representing both freshwater and terrestrial habitats. Among these is a plant fossil with a fruit containing seeds, a defining characteristic of angiosperms. The surrounding sediments are classified as Upper Jurassic. This is the most plausible claim for a fossil angiosperm in sediments below the Cretaceous. The fossil has a unique combination of characters, leading the discoverers to propose a new subclass to contain it. Currently dominant hypotheses of angiosperm origins are inconsistent with the newly discovered fossil.

Comment. The origin of angiosperms has puzzled evolutionary biologists since Darwin, and the angiosperm fossil record has puzzled creationists as well. The new fossil does not solve the problems of either group, but does remind us of the challenges contained in the fossil record.

PALEONTOLOGY: TAPHONOMY

Davis PG, Briggs DEG. 1998. The impact of decay and disarticulation on the preservation of fossil birds. *Palaios* 13:3-13.

Summary. The condition of a fossil can provide important clues to the circumstances under which it was fossilized. This study identified five stages in the decomposition of bird carcasses, one of which was disarticulation of the skeleton in seven steps. Disarticulation typically began after about 4 days, and was complete by about 52 days in protected specimens. Scavengers greatly hastened the process of disarticulation of unprotected specimens. It was noted that decomposition occurs much more rapidly in the subtropical waters of Florida than in previous experiments performed in cooler latitudes. The results were compared to the preservational condition of fossil birds from some famous fossil localities. These include the Jurassic Solnhofen Limestone in Germany (the source of *Archaeopteryx*), the Eocene Messel shale from Germany (124 specimens from 18 families of birds), the Eocene Green River Formation of Wyoming (42 specimens from 5 families), and the Eocene La Meseta shoreline deposit of Antarctica (1243 specimens, mostly penguins). The Solnhofen specimens show the least decomposition. The Messel and Green River specimens show a moderate amount of disarticulation, while the La Meseta specimens are preserved as isolated bones, many of them broken. The authors conclude that experiments such as this can aid in interpreting fossil deposits.

Hof CHJ, Briggs DEG. 1997. Decay and mineralization of mantis shrimps (Stomatopoda: Crustacea) — a key to their fossil record. *Palaios* 12:420-438.

Summary. Mantis shrimps are active predators common on tropical and subtropical seafloors. Their fossils first appear in the upper Jurassic Solnhofen limestone, and are also known from several widely scattered localities throughout the world. However, their relatively scanty fossil record contrasts with their present abundance. Experiments were conducted to study the processes of decomposition of stomatopod bodies as a means of interpreting the conditions under which fossil stomatopods were preserved. Three stages of decomposition were identified: swollen but complete; ruptured (by 1 week); and partially decomposed to fragmentary (by 4 weeks). Mineralization occurred

through precipitation of calcium carbonate and replacement of soft tissue by calcium phosphate. All known Mesozoic and Tertiary fossil stomatopods were assigned to one of the three preservation states. About 40% are complete (probably buried alive), 40% ruptured, and 20% fragmentary. Stomatopods exhibit a high potential for fossilization, and their poor record must be due to causes other than decay.

Comment. The presence of fossils is often an indicator of catastrophic conditions, but more quantitative data are often needed. The quantitative studies reported in these papers might provide a way to test the hypothesis that catastrophic depositional conditions dominate the fossil record.

PALEONTOLOGY: VERTEBRATE FOSSIL DISCOVERIES

Loope DB, Dingus L, Swisher CC, Minjin C. 1998. Life and death in a Cretaceous dune field, Nemegt basin, Mongolia. *Geology* 26:27-30.

Summary. The Gobi Desert of Mongolia continues to be an important source of dinosaur fossils. The Upper Cretaceous Ukhaa Tolgod fossil locality is especially rich, with more than 100 dinosaur skeletons and more than 500 mammalian and reptilian skulls recovered. The sediments are largely sandstone, with some siltstones and conglomerates. They have been interpreted as wind-blown, with animals overcome and buried by sand storms, but this hypothesis has problems. Present-day windstorms are not known to be able to overcome and bury live animals, and it seems highly unlikely that live dinosaurs would permit themselves to be buried by blowing sand. Closer analysis shows three different sandstone facies, two of which are eolian (wind-blown) and lack fossils. If sandstorms were responsible, more fossils should be found in the eolian sands. The fossiliferous layer lacks sedimentary structure, and might be interpreted as a gradual accumulation of wind-blown sand, except for the presence of articulated skeletons. The articulated skeletons indicate rapid deposition, probably by landslides from surrounding hills.

Comment. The new interpretation of catastrophic burial by wet sediments seems more reasonable than the previous interpretation of burial of living animals by wind-blown sand. Articulated skeletons might be used as indicators of rapid deposition in other deposits.

Thewissen JGM, Madar SI, Hussain ST. 1998. Whale ankles and evolutionary relationships. *Nature* 395:452.

Summary. Whales are an order of mammals with obvious similarities to each other, but with major differences from any other mammals. Their relationships to other mammals are controversial. Molecular sequences have been used to argue that the hippopotamus is the closest living relative of the whales. Hippos are artiodactyls, which are distinguished by a particular morphology of their ankle bones. Fossil evidence has been used to argue that whales are most closely related to a group of extinct terrestrial mammals known as mesonychians. A fossil ankle bone from a “walking whale” found in Pakistan was compared with ankle bones from artiodactyls and mesonychians. The “whale” ankle bone has features that seem to exclude it from the artiodactyls, and also argue against a close relationship between whales and mesonychians. Extensive convergence or reversals must have occurred in these groups.

Comment. This report suggests that whales, mesonychians and artiodactyls are not directly related, based on their ankle bones. Whales and hippos do share some distinct molecular sequence similarities, but this might be due to convergence (designed similarities), or to horizontal transfer. Fossils with whale-like traits and short limbs might be extinct types of animals rather than evolutionary intermediates. Whale-hippo relationships are enthusiastically defended by some evolutionists, but results such as this remind us that such enthusiasm is sometimes not strictly a matter of data.

SCIENCE AND RELIGION: IMPLICATIONS OF SCIENTIFIC THEORIES

Lubenow ML. 1998. Pre-Adamites, sin, death and the human fossils. *Creation Ex Nihilo Technical Journal* 12:222-232.

Summary. The idea that some humans may have existed before Adam is advocated by some Christians today. The concept of pre-Adamites is used to explain the existence of fossil humans with dates much older than 10,000 years. Almost all who hold a pre-Adamite view maintain that Adam was a Neolithic human who lived about 10,000 years ago. This raises a major theological question — how can death be the result of Adam’s sin, if pre-Adamites were dying before Adam

existed? This proposal removes the basis for Christ's physical death in our place, thus endangering the doctrine of salvation which is the heart of Christianity. The human fossil record shows evidence of premature death, periodic starvation, cannibalism, violence, and disease in fossils dated at over 10,000 years. This is inconsistent with the biblical description of a creation that was "very good," and with Romans 5:12-21, which states that death came to all because of Adam's sin. The solution to these theological problems is to interpret all human fossils as having lived after the fall of Adam.

Comment. The issues raised by Lubenow are critical for Christians, but seems to be avoided by many who advocate acceptance of long ages in the fossil record. At the present time, there is no theory that does a better job of explaining the totality of human experience, including God's continuing providence in human lives, His direct revelation in Scripture, and His indirect revelation in nature, than the straightforward reading of a six-day creation and global catastrophe as described in Genesis.

SCIENCE AND RELIGION: WHICH IS THE ULTIMATE AUTHORITY?

Day AJ. 1998. Adam, anthropology and the Genesis record. *Science and Christian Belief* 10:115-143.

Summary. According to this article, the perceived conflict between science and Scripture is not intrinsic to the two disciplines, but is due principally to emerging scientific theories conflicting with static interpretations of Scripture. We need to be open to reinterpret Scripture if that seems necessary. "Taking the Bible seriously" seems to mean that Scripture teaches some truths, but not necessarily about the material world. "Taking science seriously" seems to mean that Scriptural interpretation should be determined by science. Two key issues for Christians are the method by which the "image of God" was installed into humans, and how the Fall occurred. The text permits the interpretation that both processes could have occurred gradually, and science confirms the need for this interpretation. Adam need not have been an individual, but a term to symbolize humanity. The Fall need not have been an individual act, but a developing separation from God. The "soul" need not be a separate entity, but a reference to the whole person. Insistence on God's intervention in the special creation of humans requires a series of miracles, making science irrelevant.

Comment. This approach as presented in the article purports to take Scripture seriously, but actually seems limited to seeking some spiritual truth, reducing the claims of Scripture to only those that cannot be empirically tested. Day is probably right in identifying the “soul” as the whole person rather than a separate entity, but a gradual appearance of humans, and a gradual Fall do not fit with the basic motif of Scripture — salvation history.

Day seems to claim that interpretations of the acts of God must be subjected to science, and appears to reject the possibility of miracles. This seems to limit God to activity that is scientifically accessible, rendering Scripture superfluous. If science is to have the final word, who needs Scripture? Why postulate the existence of a God whose activities are restricted to “natural” processes? The view presented here seems very much like a god-of-the-gaps approach — invoking God’s activity only until some more natural explanation can be developed.

LITERATURE REVIEWS

Readers are invited to submit reviews of current literature relating to origins. Mailing address: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA. The Institute does not distribute the publications reviewed; please contact the publisher directly.

A BALANCED VIEW OF SCIENCE AND FAITH

*Reviewed by Clyde L. Webster
Geoscience Research Institute*

SCIENCE, LIFE, AND CHRISTIAN BELIEF: A SURVEY OF CONTEMPORARY ISSUES. Malcolm A. Jeeves and R.J. Berry. 1998. Grand Rapids, MI: Baker Books. 305 p. Paper, \$19.99.

This book is a revised and updated version of an earlier volume written by Jeeves in 1969 (*The Scientific Enterprise and Christian Faith*) following a small conference of 36 scientists in Oxford, England. Both authors are recognized working scientists and do not claim to be philosophers, historians of science, or theologians. It is their desire to address the contemporary issues at the science-and-faith interface in a manner that is aimed at both the scientifically and nonscientifically trained reader. Another important feature of this book is that the authors are also writing for students, and it is therefore well-referenced to source materials and includes numerous quotations. The book is divided into thirteen chapters which take the reader through the early history of the conflict between religion and science, and ends with the implications of modern science on the Christian thought-and-belief system.

In Chapter 1, Jeeves and Berry set out to examine the Hebrew-Christian and Greek influences on the rise of modern science. In this chapter the authors explore how the various philosophies and attitudes of the Greeks and Christians molded the nature and direction of scientific inquiry. In a well-balanced review of the arising conflict, the authors conclude this chapter with the following statement:

Despite the still too popular conflict metaphor beloved of the media, we nevertheless believe that a biblically based theology is not only plausible, but, on the evidence, remains a key feature in the development of science (p 31).

In Chapter 2, Jeeves and Berry not only examine the laws of nature, but proceed to take on one of the most — if not the most — controversial conflicts between science and religion: miracles. This topic is not approached head-on, but rather from a perspective of the following questions: what are the natural laws of nature? how do these laws function? and how do they relate to one’s understanding of reality? From this perspective of natural laws, miracles are then examined as to type, nature, cause and purpose. The authors then conclude their discussion of miracles with the following statement:

*A ‘law of Parliament’ concept of a law of nature tends to suggest that the uniformity of nature ought to be defined in such a way as to exclude the possibility of miracles. In contrast, the Christian viewpoint is less restrictive; it agrees that it is perfectly legitimate to assume uniformity in nature, but is willing to entertain the possibility of non-uniformity (or miracle), if there are good grounds for doing so. In other words, our conception of natural laws acknowledges that they are based on a finite number of observations or experiments, and that they must always **remain subservient to**, rather than **normative over**, any further observation [p 46; emphasis mine].*

Chapters 3-5 present a concise, informative description of the “scientific method” and its relationship to worldviews, reality, and God’s hand in the universe. Chapters 6-8 address the concepts of Creation, Evolution, and the biblical concept of human nature. For the first time the authors reveal their position on human origins in their support of “theistic creationism” and the belief that “*in God’s Image*” refers to relational and representational aspects rather than genetical or anatomical aspects, implying the mechanisms of evolution and natural selection. Chapters 9-12 examine the nature of sociobiological aspects of modern science, along with the ideas of modern psychology and ecology. Jeeves and Berry conclude their book with a healthy balanced view of science and Christian faith. They further go on to challenge the Christian scientist to nurture and expound his or her faith in a reasonable, balanced manner because of his or her unique insights into the two books of God’s revelation. However, the authors specifically state that they are not promoting some type of “natural theology” but rather a concept of the positive aspect of God’s interactive nature within the

natural world. Jeeves and Berry conclude their treatise with the following thoughts:

*God points us to himself. Science points us beyond its limits. Reason can answer only some of our questions. Our need is not more science, better reason or great faith; it is **faith in a great God*** [p. 254; emphasis mine].

It is this reviewer's opinion that Jeeves and Berry have presented a fresh, invigorating look at the science-and-faith interface — a look that is well-rounded, not attempting to prove or push one theory in favor of another. While I personally do not accept their position on the origins and development of life, humans in particular, I still find myself in a very supportive role of their overall positions on science and faith. I would recommend this book for classroom use whenever the issues of science and religion are considered, as well as to the individual who is seeking a balanced understanding of the interrelational workings of science and Christian faith in a modern setting.

LITERATURE REVIEWS

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INTELLIGENT DESIGN COMES OF AGE

*Reviewed by L. James Gibson
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MERE CREATION: SCIENCE, FAITH & INTELLIGENT DESIGN. William A Dembski (ed.) 1998. Downer's Grove, IL: InterVarsity Press. 475 p. Paper, \$24.99.

A landmark conference of intelligent design advocates, and some critics, met at Biola College near Los Angeles, California in November, 1996. The Conference was titled "Mere Creation" and this book is one of its results. Contributors to the book include the founders of the "Intelligent Design Movement": William Dembski, Steven Meyer, Jonathan Wells, Paul Nelson, Michael Behe, John Mark Reynolds, and Phillip Johnson. They are joined by an impressive list of scholars for whom "intelligent design" is a key to understanding nature.

The book is divided into 18 chapters, arranged into five sections. Topics range from J.P. Moreland's "The Explanatory Relevance of Libertarian Agency as a Model of Theistic Design"; to "Intelligent Design Theory as a Tool for Analyzing Biochemical Systems" by Michael Behe; to "Big Bang Model Refined by Fire" by Hugh Ross. To keep this review to a readable length, I will select one chapter from each section. This should give an idea of the range of topics, and allow me to point out some of the ideas I found particularly interesting.

Jonathan Wells addresses the issue of similarities in development in his chapter "Unseating Naturalism: Recent Insights from Developmental Biology." All animals appear to have similar genes, known as homeotic genes, controlling major aspects of embryological development. The similarities among these genes from different types of organisms has been used as an argument for common ancestry. For

example, the Pax-6 gene is important in development of the compound eye of insects and also the camera-like eye of vertebrates. However, it is widely believed that the evolutionary common ancestor of insects and vertebrates did not have an eye. How then did the Pax-6 gene become linked to development of eyes with completely different structures in vertebrates and insects? If evolutionary theory is correct, that insects and vertebrates share a common ancestor lacking eyes, then at least the function of Pax-6, and perhaps the gene itself, must have arisen independently in the two groups. And how does one account for the occurrence of a gene before the existence of its major function? Is this not more easily explained as the result of intelligent design? Other topics addressed by Wells include the significant differences in development in different vertebrate classes, and the importance of biomolecules other than DNA in development. Paul Nelson's chapter, "Applying Design within Biology," presents additional arguments concerning the evidence for design in embryological development.

William Dembski's chapter, "Redesigning Science," discusses some of the changes that might come should Intelligent Design be accepted. But the chief contribution of the chapter is his "explanatory filter" for identifying design. Dembski proposes an algorithm of three steps. The first step is to ask whether a phenomenon can be explained as the result of natural law. If so, there is no need to invoke design. If not, the second step is to ask whether the phenomenon is plausibly explained by chance. If so, there is no need to invoke design, although design cannot be ruled out, because it can mimic chance. If chance is implausible, the remaining explanation is design. While it may not be possible to mathematically prove design, yet one can reasonably invoke design as the best inference to the evidence. The explanatory filter provides an objective method to examine the problem of identifying design. The sticky point, however, is the plausibility criterion. People differ in their judgment of what is plausible. Furthermore, philosophical preferences may strongly disincite one to accept an interpretation at variance with one's chosen paradigm. Nevertheless, I found the explanatory filter to be a useful tool to identify the degree of improbability one must accept in order to avoid the conclusion of design.

The relationships among australopithecines and humans are discussed by Sigrid Hartwig-Scherer in her chapter "Apes or Ancestors?" Scherer identifies several unanswered questions in hominoid

evolution, and proposes that hominoids occur in a series of separate types. These include the cercopithecine monkeys, with differences among the genera possibly due to minor genetic modifications of developmental growth parameters. A second type is the gibbon apes, and orangs make a third type. Humans are a fourth type, with a single living species. The African apes comprise the fifth type. When fossils are added, *Homo erectus* and Neanderthals are added to the human type. "*Homo habilis*" is regarded as an unreliable taxon, probably including material from more than one species. Certain fossil apes, such as *Sivapithecus*, can be added to the orang type. Australopithecines are a different type of ape, not related to any member of the living fauna. The African ape type (gorillas and chimps) is not known from the fossil record.

Some critics of intelligent design have accused the movement of resorting to "God-of-the-gaps" arguments. John Mark Reynolds responds to this charge in his chapter "God of the Gaps." As knowledge of nature increased, phenomena previously attributed to God's direct action became explained through "natural" causes. As this trend progressed, God's acknowledged role in the cosmos nearly disappeared. Religious thinkers responded to this in four ways, according to Reynolds. Some retreated from making any historical claims, leaving only moral and ethical concerns as the domain of religion. Others attempted to harmonize science and Scripture, pointing out that scientific claims were inadequate, and supernatural activity should be acknowledged. A third reaction was to seek to interpret the Scripture in cultural terms, not denying some factual basis for some of its statements, but not insisting that all statements be factual. A fourth reaction is the intelligent design response, which insists that failure of scientists to recognize God's hand in nature is due to philosophical biases rather than empirical data. Intelligent design functions in historical science better than in experimental science. The chapter further describes and analyzes examples of god-of-the-gap arguments and criticisms made of them.

Robert Kaita's chapter is entitled "Design in Physics and Biology: Cosmological Principle and Cosmic Imperative?" Kaita points out that inference to design was not problematic before the seventeenth century, and need not be a problem today. Kepler, for example, was a pious Christian and a great scientist. Today, two principles are used in attempts

to expunge the idea of design in nature. One principle is the “cosmic imperative” championed by Christian de Duve. This is, in essence, the belief that life in our universe is somehow inevitable. It is inevitable because that is the only explanation for an event that appears too highly improbable to be attributed to chance. Kaita points out that this principle is actually an *a priori* philosophical presupposition, not empirically based. The second “principle” is the cosmic anthropic principle, promoted by physicists such as Stephen Hawking. This “principle” is that we see the universe as it is because if it were any other way, we would not exist to see it. Clearly, this “principle” does not explain either the existence of the universe or the existence of the human observer — it merely points out that the universe appears remarkably suitable for human existence. Design theorists would agree on that point, but come to a completely different conclusion regarding the reason for it.

This is a sampler of the material in this book. Although it may seem heavy in places, those with an interest in the question of design should find the book to be an intellectual treat.

LITERATURE REVIEWS

Readers are invited to submit reviews of current literature relating to origins. Mailing address: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA. The Institute does not distribute the publications reviewed; please contact the publisher directly.

ARE RADIOISOTOPE DATING METHODS RELIABLE?

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THE MYTHOLOGY OF MODERN DATING METHODS. John Woodmorappe. 1999. El Cajon, CA: Institute for Creation Research. 118 p. Paper, \$16.00.

When two individuals have distinct disagreement regarding the interpretation of significant data, it is apparent that at least one of them is in error. Age determinations based on radioisotope data are commonly considered to be in substantive agreement with geological age criteria. The massive literature survey made by John Woodmorappe demonstrates that in actuality there is often major disagreement, and that the presumed mutually supportive relationship can be demonstrated only with carefully selected data. His compilation of 494 references, mostly from recent professional geologic publications, is a major contribution to an understanding of the relationships between real time and radioisotope ratios.

One of the principal values of this book is the impressive examples in Chapter 3 of disagreement between radioisotope age and corresponding geological age assignment. The following chapters contain additional examples. The reader should keep in mind that such a list, however long, is not proof that daughter/parent isotope ratios are *never* time significant. The statement made on page v in the Foreword by Henry M. Morris that “the various assumptions on which radioactive dating techniques are based are *all* wrong” (emphasis mine) is apt to cause many potential readers who have a foundation knowledge in physics or geochemistry to lay aside the book without discovering its many significant contributions. In stating that “John Woodmorappe is

very positive (and sometimes rather abrasive ...)" (p vi), Dr. Morris gently prepares the reader for a feature of the book that diminishes the quality of recognition it would receive otherwise.

In his Introduction the author unfortunately makes what may be taken as a clearly false statement: "no one has performed an overall review of isotope dating" (p vii). Actually, several excellent treatments are available.¹ Evidently he intended to say "no one [from the viewpoint of biblical chronology]."

Another statement that may foster an initial prejudicial attitude toward the book is located on the first page of Chapter 1: "... very little isotopic-dating work is experimental in nature." It is unfortunate that a more appropriate wording was not used, such as: "Any radioisotope age/date is derived from a theoretical interpretation, as well as the basic experimental data."

The book fully develops the insight expressed on p 83b, "Uniformitarian geochronology is indefinitely adaptable to every conceivable possibility!"; and on p 85a, "... the uniformitarian geochronologist cannot lose, no matter what turns up." A radioisotope age that agrees with geological expectations is readily accepted as confirmation and quantification of the designated age. Radioisotope ages that are significantly greater (or less) than conformable with geological assignment are reasonably explainable on the basis of postulated parent loss and/or daughter gain (or parent gain and/or daughter loss), as a result of solution penetration and/or heating in one or more episodes since the initial formation of the mineral.

The author does not call attention to the equal capability of a biblically compatible geochronology. Radioisotope ages may be reasonably explained on the basis of either uniformitarian geology or young-earth biblical geology. The chemical and thermal modifications of isotope ratios necessary for a reasonable explanation of the data may be postulated as having occurred during an unspecified time between primordial creation of matter and creation of organic life on planet Earth, as allowed by the definition for *earth* given in Genesis 1:10; during, the third day of Creation Week; and during, as well as subsequent to, the Flood episode of Genesis 6-8. A choice between an "old-earth" concept and a "young-earth" concept must be made on a basis other than success in the development of a reasonable explanation for radioisotope daughter/parent ratios.

When the physical measurement of a radioisotope half-life (disintegration rate) has a large range of uncertainty, it is only reasonable for geochronologists to use the boundary value that produces radioisotope ages most closely in accord with expectations based on geologic criteria. The relatively few cases in which the investigator has a significant option for selection of a half-life value do not justify a categorical statement such as found on p 95a: “the decay constants used in isotopic-dating systems are tainted by past and present practice which raise questions about their objectivity.” A statement such as this unfortunately raises a question concerning the objectivity of the author. We should recognize that significant results are often obtained from nonobjective research.

Figure 30 on p 82 presents 96 age determinations for the three U-Pb methods on 32 individual zircon grains from the same igneous rock. There is no specification as to whether these data are taken from the geochemical literature, or are hypothetical values chosen to illustrate the concepts of concordance and open-system resetting. The unlikelihood of 96 radiometric age determinations on one rock sample indicates that the data probably are fictitious. This consideration does not diminish the tutorial value of Figure 30.

Chapter 9 contains many problems for comprehension by the readership to whom the book is directed. There is need for an explanation of what the author intends by a “lack of regional standardization of isotope dates” (p 87a). Lack of a standardized radioisotope age to represent each geologic region? Diversity rather than uniformity of the radioisotope age determinations for samples from a geologic region? The data base for Figure 33 should be specified. *All* published dates? What basis for selection of the dates represented? And what are “lists (D) and (H)”, and “lists (B) and (C)”? Figure 33 has little meaning if these terms are not readily understandable from the text. Why is Figure 33(a) described as log-normal, while 33(b) is represented as log-linear, and the associated text indicates log-linear?

According to the estimates presented in Chapter 9, randomly selected radioisotope ages will be in agreement within precision of measurement in 2.1% of pair selections, and 0.03% of triplet selections. These estimates indicate the significance of agreement between two or more methods of radioisotope age determination on the same sample. For their derivation to be understandable to the target readers, this section must be extensively revised and elaborated.

The present (first) edition of *The Mythology of Modern Dating Methods* will appeal mostly to individuals who are seeking assurance for a previous commitment to a biblical young-earth viewpoint. Several features will impede due recognition by the scientific community-at-large of the significant contributions to radioisotope science that are presented in this book. In addition to the problems with Chapter 9 noted above, the myth versus reality/fact format used throughout the book will inhibit its consideration as a scientific treatise. The range of potential readers who might respond favorably would be increased by using a simple statement of topic as an introduction to each section.

Derogatory categorization of individuals who do not have the same viewpoint as does the author diminish the quality and effectiveness the book should have. For example: on p 96b, “Torture the data long enough, and it will say whatever you want. And if one ‘torture technique’ does not produce the desired result, try another”; and on p 35b,

Having been exposed in their earlier-made blustery claims about the wonderful reliability of isotopic dating, [apologists for isotope dating] now give us a song and dance about the fact that they are the ones who have discovered the flaws in these dating methods.

Who else would have obtained the data necessary for more detailed understanding? It is highly important for biblical creationists to recognize that individuals who hold diverse viewpoints may be just as honest and professional in reaching their conclusions as we consider ourselves to be.

At the beginning of this review it was noted that where substantive conflict exists between viewpoints/conclusions A and B, one of them must be incorrect. Woodmorappe has amply demonstrated that geologic age assignments are often in conflict with corresponding radiometric age determinations. In such cases one or the other must be incorrect. A second possibility is that *both* are incorrect. Woodmorappe concludes Chapter 10 with a call to disregard both fossil sequence and radioisotope age as having extended time significance (p 94b). The book of Genesis provides a basis for a third explanation which allows basic geological principles for interpretation of sequence and circumstances of fossil deposit, and also allows radioisotope data to indicate source material characteristics and circumstances for open-system modification since initial creation.

I urge every reader of this review to check my comments against his/her own reading of the full 96 pages of text. For a broad-based perspective on the book, I highly recommend the excellent review by Michael J. Oard on p 19-22 in Vol. 14 (no. 1, 2000) of *Creation Ex Nihilo Technical Journal* (tjeditors@AnswersinGenesis.com).

ENDNOTES

1. For example: (a) Geyh MA, Schleicher H. 1990. Absolute age determination. NY: Springer Verlag; (b) Fauré G. 1986. Principles of isotope geology. 2nd ed. NY: John Wiley & Sons.