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SEARCHING FOR THE CREATOR

THROUGH THE STUDY OF

A BACTERIUM

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"Until a man has found God and been found by God, he begins at no beginning, he works to no end. He may have his friendships, his partial loyalties, his scraps of honor. But all these fall into place, and life falls into place, only with God." H. G. Wells.

Introduction:

The heart of every human being, whether aware of it or not, continually searches for God. The search takes many forms and goes in many directions. Happy are those who recognize the nature of their restlessness and orient their search toward God. The answer to the question " Can you by searching find God?" (Job 11:7), through God's grace, is yes (Deut. 4:29). And finding God is not the end but the beginning of a fulfilled life.

Finding God is a very personal matter, which cannot be accomplished for someone else. But the fruits of one's search may be shared. Seeking for God may begin with Bible study, but it does not have to end there. The signature of the Lord is present in many places, unobtrusively, like an artist's autograph on a painting. The object of this essay is to study one such signature. The thesis is, that teachers may look for the Creator's signature in their fields of study for the purpose of personal satisfaction and for sharing their findings with their students.

Underlying this exercise is the conviction that we are endowed with the capacity both to comprehend the physical realities of our world and to seek for deep meaning in them. The most profound meaning that may be culled from the study of nature is to gain insights into the character of the Maker of the Universe.

Of one of the wisest man, this was written: "Solomon took an especial interest in natural history, but his researches were not confined to any one branch of learning. Through a diligent study of all created things, both animate and inanimate, he gained a clear conception of the Creator. In the forces of nature, in the mineral and the animal world, and in every tree and shrub and flower, he saw a revelation of God's wisdom; and as he sought to learn more and more, his knowledge of God and his love for Him constantly increased" (Prophets and Kings, p 33).

In this essay it will be a given, that the Universe and our world are God's creation, as described in the Bible. This is stated at the outset, because today's academia is largely in the evolutionist camp. As a scientist, I frequently find myself taking a polemic stance in defense of creationism. In doing this, I easily lose sight of nature as a revealer of its Creator. It is a pleasant change to contemplate my field of scientific interest, looking for insights about the Creator.

The act of creation.

"In the beginning God created the heaven and the earth" (Genesis 1:1). Adventist understand this verse to refer to the creation of the earth and of its immediate surroundings, including perhaps the solar system. We were not the first world or beings created. When our planet was born, "the sons of God shouted with joy" (Job 38:7). As astronomers began examining our cosmic neighborhood, they discovered that the solar system is part of a galaxy of

perhaps as many as one hundred billions stars, each at least the size of our own Sun.

The Milky Way, in turn, is part of a group of galaxies called the "local group". It now appears that the Universe contains maybe a billion galaxies, which are arranged in strings, clusters and superclusters (1). The Creator of the heaven and the earth of Genesis 1:1 is also the Creator of these unnumbered galaxies.

There was a time, back in the distant past, when there was no Universe, only the Triune Godhead. The material Universe came into existence as the result of God's creative action. The Creator was not dependent on pre-existing matter for creation, " For he spake and it was done: he commanded and it stood fast" (Psalm 33:9).

Matter as we know it, is a stable form of energy. All of the matter we now find in the Universe had to come from God. Einstein's famous equation, $E= mc^2$, permits us to estimate the energy cost of creating $2x10^{52}$ g-s of matter, which is an estimate of the total visible mass of the Universe. It is approximately $1x10^{66}$ joules (2). This amount of energy could supply the earth's energy needs for approximately 10^{45} years (3).

Why God created the Universe will be the subject of inquiry for a long time. While the amount of energy invested to produce just the raw materials needed for the Universe is utterly beyond our comprehension, we can appreciate that it was a prodigious cost. One cannot help, but wonder about the connection between the living God and inanimate matter, which came forth from His hand. While we would not want to say that "God is in matter" as the pantheist do, we affirm that all matter belongs to God, by virtue of having proceeded from God. It is a reasonable postulate that the Lord has absolute control over the inanimate world. Perhaps He keeps track of every atom. ("...the very hairs of your head are all numbered." Mathew 10:30). From such a perspective, it does not seem difficult to understand how Jesus could multiply the loaves and fishes, calm the Sea of Galilee or to command Lazarus to walk out of his grave.

Relying on our eyes, we notice objects in our environment ranging in size from 0.0001cm to approximately 10,000 centimeters in size, or 8 orders of magnitude. With the help of the microscope and the telescope we become aware that we are part of a much larger Universe, spanning perhaps 32 orders of magnitude.(4). The Creator is the Designer and the Caretaker of, what is from our perspective, the Very Large and the Very Small. We understand some things about the Very Small, but the reality of the Very Large is puzzling. Existence was much more cozy in a Universe of the Middle Ages, which centered around a flat Earth. What are those billions of galaxies doing out there?

One is tempted to come up with an outrageously egocentric theory, to explain this oversupply of galaxies. Every galaxy could represent a different "order" of existence. Perhaps the Creator experimented over eons of time with creation, not being completely satisfied, until He came to the creation of the Earth. Here he created beings to God's image. Finally an effort, with which the Creator was satisfied. So He pronounced it " very good" (which is what we teachers would call, a B+ grade, "excellent" being the A).

Of course, we don't have any information regarding why there are so many galaxies out there. The Bible text comes to mind: "For as the heavens are higher than the earth, so are my

ways higher than your ways, and my thoughts than your thoughts (Isaiah 55:9).

Why study bacteria?

As a youngster in Hungary, I wanted to become a doctor, but coming to the US, I ended up studying chemistry in college. I was attracted to organic chemistry in particular. In my junior year I took a course in biochemistry, and I realized that this subject combined my interests of chemistry and medicine. So I continued with biochemistry in graduate school.

Biochemistry is a study of the chemistry of life. Paradoxically, in order to study the chemistry of living matter, one has to take the living tissue apart, thereby killing it. As a graduate student, one of my laboratory exercises called for taking apart a white albino rat, removing its liver and study its cholesterol metabolism.

I performed the experiment as required, heart-sickened from the act of killing the cute laboratory rat. I realized that as a biochemist I may have to do this many times during my carrier, and I wasn't sure that I could do that. Fortunately I discovered that not all biochemists worked with animal tissues. There were professors in my department, who worked with bacteria. I arranged to do my thesis work in one such laboratory, and I have continued to work with bacterial cells ever since. To be sure, studying the biochemistry of bacteria also involves killing bacterial cells. However, bacteria belong to a different class of living entities than albino rats. Every time we use mouth wash, we are guilty of killing microorganisms in the oral cavity.

It so happens that the greatest advances in biochemistry in the past 50 years have come from studying the biochemistry of bacteria. Among the many species of bacteria, one organism towers above all others in significance as the best studied model organism, *Escherichia coli.* Some wags have gone as far as to classify all living organisms into just two categories: the "coli" and the "uncoli".

It is now clear that there are overarching similarities in all biological matter, from bacteria to man. These similarities surface when one compares the gross chemical composition of various organisms or the biochemical logic that animates them.

All living matter is composed of cells. Some organisms, such as ourselves, are organized from millions of different cells. We have skin, muscle, bone, liver, brain cells, all different in structure and function, yet retain certain similarities with each other. Other organisms may contain fewer cells, or consist of only a single, self-contained cell. The most fundamental unit of life is the cell. When a cell is taken apart, life disappears. It can be appreciated, therefore, that the in-depth study of *E. coli* could lead to advances in our general knowledge of life.

Escherichia coli is a rod-shaped microorganism. It was first isolated early this century from the stool of a convalescent diphtheria patient by Theodore Escherich, a German physician. It is part of the normal flora of many species of microorganisms, residing in the large intestines of vertebrates. Because of its relative non-virulence and ease of cultivation in the laboratory, it became the organism of choice for experimenters. After nearly a century of research, more is known about *E. coli* than about any other single cell form of life. The study of *E. coli* informs

us about the logic of life in general. One of my teachers in graduate school put it this way: " an elephant is like *E. coli*, only more so".

Of course, this is an exaggeration. Bacteria, which are unicellular, are markedly different life forms than the multicellular, considerably more complex organisms. Moreover, there are considerable variations even among the thousands of different types of microorganisms. Nevertheless the rapid advances in biochemistry over the past 50 years can be partly attributed to the diligent work of thousands of scientists on *E. coli.* Last year a two volume set of articles was published, consisting of 155 chapters on 2800 over-sized pages, which summarized some of our knowledge of this microorganism. (5). This was the second edition of a similar effort, which appeared in 1987. In the second edition essentially all of the articles from the first edition had to be rewritten due to the rapid accumulation of knowledge. It is seen that even this comparatively simple life-form is a very complex organism.

An invisible world.

Mankind existed for more than 5 millennia, without the slightest inkling of the existence of microorganisms. In the instructions to the Israelites, for the practice of personal hygiene and for the isolation of the leper, we now recognize effective preventive measures against the spreading of contagious diseases. Had these rules been followed in the Middle Ages, mankind would have been spared of many epidemics.

Microorganisms are better known in the public as "germs". They definitely have an image problem. Why did the good Creator make bacteria?

The short answer is: life on planet Earth would be impossible without microorganisms. The most vital role they play is the conversion of nitrogen gas of the air to useful nitrates in the soil, without which plants could not grow. In addition, some bacteria participate in the capture of solar energy through photosynthesis and others implement the biodegradation of dead organic matter.

Microorganisms cover our skin, grow in our oral cavities and in our intestines, all of them protecting us from harmful biological agents. *E. coli* helps create an oxygen-free environment in our colons, for the benefit of obligate anaerobic organisms, which aid digestion. *E. coli* also secretes a water soluble B vitamin, choline, for our use. "Germ-free" laboratory animals are much more vulnerable to infection and disease than their germ carrying counterparts.

The biosphere is essentially coated with microorganisms. It is estimated that nowhere can a gram of soil be found on the surface of the Earth, including the Sahara desert, which contains less than 10,000 microorganisms. Bacteria belong to the robotic class of living matter created by the Lord. Other robots include trees, plants and flowers.

Bio-robots are living organisms without nervous systems. Biologists place them in the "vegetable" kingdom. These organisms are unaware of their existence, although they respond to appropriate external stimuli. They perform photosynthesis, and are the ultimate sources of

food on Earth. Microorganisms belong to this kingdom as well.

The vast majority of microorganisms in our environment are harmless, except if they find their way accidentally (such as during surgery) into a nutritionally rich environment within the body. Most disease causing microorganisms, including the pathogenic variety of *E. coli*, have acquired extra pieces of genetic material, called plasmids. These extra-chromosomal pieces contain the disease causing genes.

Among the most dangerous *E. coli* is the strain O157:H7, which causes hemorrhagic colitis. This organism colonizes in the small intestine of the host and secretes large quantities of toxins which damage the lining of the intestine. By acquiring a plasmid with genetic information for these toxins, somewhere in the past a harmless strain of *E. coli* was converted to a dangerous pathogen. Just where these harmful plasmids came from, no one knows. But the Christian suspects: "An enemy hath done this" (Mathew 13:28).

The biochemistry of bacteria.

Like all living matter, bacteria are 70 percent water and 28 to 29 percent biopolymer. The remarkable similarity, but not identity, in composition and in internal workings among all living entities is a fruitful theme for contemplation. Conceptually all organisms may be thought of as variations on one or more themes. *E. coli* is one of about 5,000 different bacteria. Each organism carries within itself a set of biological agents called "restriction enzymes". These enzymes are not only programmed to recognize the host's own genetic material, but at the same time they destroy any foreign genetic substance. These agents guard the genetic uniqueness of each type of microorganism. Interestingly, multicellular organisms do not possess this sort of protection devices, perhaps because they do not need it.

The similarities among living entities ensures that their needs are similar or at least compatible with each other, simplifying the task of supplying nutrition to all. A very large portion of the biosphere utilizes the products of photosynthesis, in the form of plant products. It is also observed that the discarded waste of one organism becomes a useful resource for another. The best known example is the production of carbon dioxide by non-photosynthetic entities, to the delight of photosynthetic organisms. The resources available for all organisms exquisitely match their needs. One hears echoes of Phillipians 4:19: " my God shall supply all your need...".

The molecular structures of the bacterium.

Biopolymers are complex substances, composed of thousands, or in the genetic material, millions of atoms of carbon, hydrogen, oxygen, nitrogen, phosphorous and sulfur. The four classes of biopolymers are proteins, nucleic acids, polysaccharides and lipids. An *E. coli* cell contains millions of polymer molecules. Some polymers are needed in many copies, others in just a few. It is estimated that every cell uses approximately 1500 different kinds of polymers, each with a different structure and a different function.

Bacterial cells have to accomplish four major tasks for their existence: 1) to harness energy from the environment and utilize it for biosynthesis and growth,. 2) to manufacture the building blocks of its biopolymers, 3) to synthesize biopolymers and 4) to break down existing biopolymers for the purpose of continuous renewal.

How energy is harnessed.

Energy is the driving force behind all life. Almost everything connected with living, chemically speaking, is an uphill event. Energy is required for the transport of all nutrients into the cell, for the manufacture of biopolymers and subcellular structures and for the maintenance of the physical integrity of the cell. *E. coli* is able to extract chemical energy from organic substances, such as glucose. Glucose, a product of plant photosynthesis, contains some of the Sun's light energy which was captured by the plant. Thus *E. coli,* just like the rest of us, runs on solar energy.

The solar energy trapped in glucose maybe released by non-biological means. One can burn glucose, for example, to release 4 kcal/g of energy as heat. But such a burst of heat energy is useless to living matter. In the cell glucose is utilized by an ingenious process equivalent to a very slow burning, called glycolysis and the citric acid cycle. These biochemical pathways methodically dismantle the sugar molecule to smaller and smaller substances, which contain less and less energy.

The energy is drained out of glucose in the form of high-energy electrons, which are captured by designated electron-carrier substances. The electron carriers transport the captured electrons into an electron-collecting device called the respiratory chain. Here the electrons flow through the cell's membrane as tiny micro-currents of electricity. This process transfers the electrons' energy into a charge difference on the two sides of the cell membrane. The energy of the charge separation, in turn, pushes the synthesis of ATP molecules to completion. The chemical energy content of ATP molecules, in turn, can be used by most energy requiring process in the cell. In the world of energy transactions, ATP is the common currency. The molecular design of ATP synthesis in bacterium is similar, although not identical to that in all non-photosynthetic organisms, including man.

Thus, one can trace the flow of energy from the sun to the ATP molecules. We feel pretty smug when we are able to operate a device needing 9 volt DC, by plugging it into a 110 volt AC socket through an appropriate adapter. In nature we see the energy of the Sun's nuclear reactor, generating millions of degrees of heat, being transformed to operate bacterial and other metabolisms, running at a fraction of a volt of electricity. Here we observe the Creator smoothly connecting the Very Large with the Very Small.

The manufacturing process.

Chemical factories are designed to produce quantities of substances for sale. Other

enterprises purchase their products and use them for manufacture or for research. Each bacterial cell is a miniature chemical factory, where the manufactured products are used in-house to create more chemical factories. In fact, even during the manufacturing process, the factory is expanding, continually using up the products as they come off the assembly lines.

Compared to the bacterial factory, chemical factories have modest inventories of products. When we consider that bacteria manufacture all their biochemical intermediates, polymer-building subunits and polymers, the number of manufactured products are in the neighborhood of 2,000 different substances. Each of these products have a function in the cell. As soon as they are produced, the products are integrated into their proper place. The assembly lines are also regulated, so that no resource is wasted. The regulation includes an immediate acceleration or slowing down of the manufacturing rate, depending on the needs of the cell, as well as an adjustment in the long term production of the "factory equipment". These factories have no director, foremen or assembly workers, they are 100% automated.

If someone would write a fictional narrative about self-replicating, fully automated, microscopic factories, it would probably be rejected out of hand as completely absurd. But they actually exist! When we wonder about the future marvels of the New Earth, we should remember that we live in a world filled to the brim with miraculous manifestations. Scientists are busy trying to understand the molecular explanations of some of these marvels. Those who dig the deepest into the mysteries of nature are usually the most aware of how little we actually know or understand.

The genetic information of *E. coli.*

The genetic material of *E. coli (DNA)*, consists of 4.6 million pairs of nucleotides. It contains the data for the correct structure of every protein in the cell, and for the regulation of he timing of their production. Indirectly, through the action of proteins, every aspect of the metabolism and the infra-structure of the organism is coded into its genome. In terms of information density, estimates are that 1 cubic micrometer of DNA contains 150 megabytes of information. This is 10 orders of magnitude greater than our current CD-ROM's optical storage capacity. If the complete genetic information of this organism would be printed in a standard book form, it would contain about 3,00 pages.

The turnover phenomenon.

A surprising discovery was that in bacteria (and in all other organisms), biopolymers, which represent the investment of a great deal of energy, are periodically dismantled and replaced by new polymers. Later it was realized that during normal metabolism, polymers are damaged and lose their functions. Therefore, it is now understood that as a "preventive maintenance", the turnover process is essential for all living matter. The Creator is seen here as anticipating problems and instituting steps for their prevention.

Two examples suggest that *E. coli* was designed to be in our colons.

E. coli has three genes which enable it to utilize the "double-sugar" lactose. These genes direct the synthesis of three proteins. One of the proteins carries lactose into the cell. A second protein cleaves lactose into two "single" sugars, glucose and galactose. The third protein converts unusable, potentially harmful, galactose-related sugars for secretion from the cell. Because lactose does not usually reach the colon of humans, ("milk sugar" is usually digested and absorbed before reaching the colon), the three " lactose genes" are ordinarily silent. In fact maybe half to two thirds of *E. coli*'s genes are routinely silent, waiting to be activated only when needed. Apparently a great deal of metabolic flexibility was programmed into this organism.

Until recently, the physiological role of the lactose genes was something of a mystery. Then it was discovered that an indigestible plant product, galactosyl-glycerol, activates the lactose genes extremely well. It seems then, that *E. coli* was designed to take advantage of the plant diet of its host.

There is also evidence, that we were designed to have *E. coli* inhabiting our colons. We have in our liver an enzyme, alcohol dehydrogenase. This bio-catalyst hastens the detoxification of alcohol in our blood. The puzzle is, that alcohol is not produced by any of our body's metabolic reactions. However, we now know that *E. coli* does produce alcohol as one of its normal fermentation product, but our alcohol dehydrogenase nicely neutralizes it.

What is life?

A dictionary definition of life is: " that property of plant and animal which makes it possible for them to take in food, get energy from it, grow, adapt themselves to their surroundings, and reproduce their kind" (6). This is a fine definition of life, but does not state what "that property" is. We have a sense that it is on the tip of our collective tongues, just that we have not been able to capture it in words. Which is a sure sign that, in fact, we do not know what "life" is.

Life is the property of entire cells, cell complexes and organisms. When a cell is taken apart, "life" vanishes. Life is not an independent entity, rather it is a description of the behavior of certain collections of matter. Cells are the fundamental units of life, nothing less than a cell can "live". Living cells are working together to form a living organ. Living organs, functioning harmoniously together produce living organism. We humans, are multicellular organisms with numerous organs, and in the possession of three "layers" of life. "Life" on each level has a somewhat different meaning. In contrast, *E. coli* being a unicellular organism, has only one layer of life.

In living cells, such as in *E. coli*, all of the chemical reactions are in a state of non-equilibrium. This is a remarkable phenomenon, considering that every chemical reaction in the cell is catalyzed by a very efficient biocatalyst (enzyme). The role of an enzyme is to push a

particular chemical reaction to its equilibrium. When a chemical reaction reaches its equilibrium (end) point, no further net chemical conversions take place. If all reactions in a cell reach their end points, the cell dies. "Old chemists never die, they just come to equilibrium".

Here is where the genius of design enters the picture. The chemical reactions in living cells are interconnected to each other. The end product of one reaction becomes the starting material for the next: Reaction #1: A ---> B , reaction #2: B---> C and reaction #3: C--->D etc. A series of chemical conversions in the cell resembles an assembly line. When the final chemical product roles off the "conveyor belt", it is immediately utilized, preventing its accumulation. In this manner no reaction is permitted to reach its equilibrium.

At creation, the Creator ignited these chemical chain reactions in the various organisms, and to this day they are continuing, from generation to generation. Biologists recognize this by their dictum: "life comes from life".

In Isaiah 45:18 we read that the Lord created the Earth to be inhabited. But He could have placed humanity in a sterile, non-living environment. Instead God immersed mankind into a sea of life and gave them the task of managing the biosphere. Did He do it because it would have been too much for the Lord to take care of things on Earth? Not likely. Rather, Adam was asked to provide names for the created organisms, thereby becoming a coworker with God. One wonders if the Lord told Adam about *E. coli* in his colon, or if this was to have been revealed to him at a later time.

Summary.

It is a privilege beyond words to be alive in this amazing world. We are surrounded with innumerable miraculous phenomena. Our very act of probing is amazing: we, a collection of inanimate atoms and molecules put together in such a way as to have the ability and curiosity to probe and judge. Our judgments are often faulty and out of line (Isaiah 29:16) but the great Lord condescends to dialogue with us.

We cannot overstate or exaggerate the greatness of God. The scope of this essay does not permit the consideration of even a small fraction of the amazing features uncovered in the study of the lowly, microscopic, bio-robot *E. coli.* We did not explore its capacity to sense favorable nutritional gradients in its environment, and swim toward it. Neither did we deal with its capacity to withstand nutritional deprivation, or chemical insults from the environment. Nor did we document its nutritional versatility, its capacity to withstand mechanical stresses amounting to thousands of times the force of gravity.

But from a small selection of examples, it is clear that even at this microscopic level, the Creator was fully able to implement a variation on the theme of life, completely appropriate for its intended functions. Hopefully it was shown, that this kind of approach enhances our appreciation of the Great Designer. And although we now only " see through a glass darkly" (1 Cor. 13:12), it is our sense, that we will continue to draw closer to our Maker through eternity, precisely through a diligent study of His works.

NOTES AND REFERENCES.

1) Y.B. Zeldovich et al. (1982) Nature, 300:407.

2) The total mass of the Universe is approximated by assuming that the Earth's mass is $6x10^{21}$ tons, our Sun's mass is $3x10^5$ Earth mass, the Milky way is $1x10^{11}$ Sun mass, and the Universe contains $1x10^9$ galaxies which are of the same size as the Milky Way.

Einstein's equation of $E=mc^2$ was used to calculate the energy equivalent of the estimated Universe's matter. C= $3x10^5$ km/sec. Tons were converted to kg-s, km-s to m-s, and the results for energy were obtained in m x newton=joules.

3) S. Fred Singer, Scientific American, September, 1970, p.175. Here the energy consumption was expressed in BTU -s (British Thermal Units). These were converted to joules by the equation: 1 BTU=1,055 joules.

4) The diameter of the Universe is estimated to be 13 $x10^9$ light years. 1 light year=9.46 x 10^{12} km.

5) Escherichia coli and Salmonella. (1996) F. C. Neidhardt, Editor in Chief. ASM Press, Washington, D. C.

6) Websters New World Dictionary, Second College edition, D. B. Guralnik, Editor in Chief. 1982, p.816. Simon and Schuster.