bodies, long necks and long tails. They also possess, like snakes, a forked tongue which can protrude a relatively long way beyond the mouth. Like snakes, they are capable of swallowing large prey because of the solid bony sheath around the brain, which helps to protect the brain from pressure as the prey is being swallowed. Another similarity lies in the jaw bones, which are moveable on each other, facilitating a wide opening of the mouth. The ossification of the temporal arch is complete. Thus the two halves of the lower jaw are joined by a ligament. There are also similarities in the structure of the skull itself. Despite all of this, the monitors are not viewed by evolutionists to be ancestors of snakes.

The above evidence, demonstrating the lizards such as the monitors carry many of the features of snakes, shows that a created lizard (a modified one at that, adapted to a meateating diet) could quite easily become the snake we know. This could happen without transgressing the Genesis kind.

Contributed by Colin Brown

Science vs. Humanity (Roche)

"When the men of science have said all their say about the human mind and heart," wrote Albert Jay Nock, "how far they are from accounting for all their phenomena, or from answering the simple, vital questions that one asks them! What is the power by which a certain number and order of air vibrations is translated into processes of great emotional significance? If anyone can answer that question believe me, he is just the man I want to see."

And just the man the world wants to see. Science, for all its brilliance, is blind to the things that matter most to us, in our hearts and minds and souls. Its genius has been our downfall. For two hundred years and more, men have placed their faith and hope in scientific advance, dazzled by its success and certitude. But to do so, we must put aside our very humanity, for that part of us is forever veiled to scientific inquiry. This is the mistake of the anti-hero, seeing the natural side of us that needed no explaining, and ignoring our spiritual side, nay, denying it with scorn. Let it not be said of his doctrine: "It can't all be wrong. It must have some truth to it, to make such an immense impact on the world. Where there's smoke, there's fire." It is all wrong, and its results show it. It got its power from the seeming perfection of natural science in times long gone, science now obsolete. But anti-heroism is not science, it is philosophy built on flawed perceptions of scientific findings, and on some false findings at that. It deals in ideas, not science, and its ideas must be judged by their truth.

In looking at the curious faiths of the anti-hero, we do not see ourselves. We do not see men. We do not see real people trying to live life on a human scale, and get along, and love one another, and care for their families.

We see, rather, grotesque beings, automatons spun by an uncaring goddess called Nature. We see a beast that thinks it thinks, but some of its "most advanced" thinkers say its thought is a meaningless illusion. We see a beast that acts as if it could act, but has no will to do so. We see a beast that aches in its soul to be good, but has no soul and inhabits a place that has no good. We see a beast that cries out in joy when an imaginary dragon is slain, and weeps real tears when an imaginary princess is felled by an imaginary flower; yet one having no imagination or spirit.

There is no such beast. We are human creatures of a loving God, who take joy in life and grow in His spirit, or not at all.

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PREBIOTIC FORMATION OF THE FIRST CELL

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Received 22 December 1988; Revised 9 May 1989

Abstract

While much attention and effort has focused on the prebiotic formation of such molecules as amino and nucleic acids, the formation of a reproducing cellular entity in a prebiotic environment constitutes a gap seldom addressed in the scientific literature. Indeed, the gap between simple organic molecules and a reproducing cell is vastly greater than that envisioned by most researchers in origin of life studies. The nature and complexity of known cells suggests that the simplest conceivable cellular form is far too complex to be a product of known prebiotic mechanisms. From directing metabolic processes to maintaining osmotic stasis, all would be necessary functions for the first cell.

Prebiotic Environment

An almost endless flow of speculation has been presented in recent decades on the origin and chemical composition of the organic soup from which life is claimed to have originated. At stake is the need for an environment in which organic compounds can thrive and spontaneously join together, forming the necessary components leading to the world's first cellular life form. In part, the cause for so much speculation is the large number of problems associated with the spontaneous appearance of organic life from an inorganic source.

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The presence of molecular oxygen (O_2) in the atmosphere would literally "eat up" any primitive organic molecules that spontaneously formed. The prevalent assumption, therefore, has been that the initial atmosphere of the earth was predominantly reducing. However, many researchers have argued against such an initial reducing atmosphere (Brinkmann, 1969; Clemmey and Badham, 1982; Thaxton *et al.,* 1984). Walker (1977) concluded that the strongest evidence for this reducing atmosphere was that such an atmosphere is what is required for the origin of life. A further complication is that a reducing atmosphere would provide

no protective ozone layer, allowing early organic molecules to be destroyed by cosmic rays. An aqueous environment would offer some protection from these rays, but would also prevent needed energy from reaching the molecules—inhibiting further chemical reactions and effectively stopping a cell from forming.

Another difficulty has been determining the mechanism by which biologically active amino acids and sugars sorted themselves from their biologically inactive mirror images. While such mixtures (racemates) occur naturally, the presence of only one biologically inactive molecule will inactivate an entire protein or nucleic acid. Thus, optical purity of these compounds is a biological requirement. Among the number of suggestions that have offered to explain how optically pure proteins formed spontaneously, the most popular appears to be the parity violation model (Mason, 1984). This concept suggests that these violations of parity induce an energy difference in optically active amino acids (L-amino acids) that may favor their formation into peptide chains while discriminating against the addition of D-amino acids into the peptide. Mason (1984) even suggests such a mechanism makes the production of optically pure molecules "fully determinate" rather than just a result of chance.

Mason's observation, however, is somewhat over optimistic. Experimental data is very conflicting, and Pacheco (1987) observed that firm evidence for such a result has not yet been produced. Others have voiced great doubt that this mechanism could ever produce significant levels of optically pure molecules (Broda, 1984; Keszthelyi, 1984; Wilder-Smith, 1981).

Actually, such mechanisms tend to be beside the point. Any force favoring formation of optically pure molecules still could not negate the fact that optical activity will always tend to be lost by spontaneous racemization. Even more, such mechanisms working on inanimate molecules are strictly a nonbiological function. Therefore, the origin of optical purity is strictly incidental, and completely independent of any biological process. This would mean that inanimate organic molecules would also be affected, and optical purity should not be almost exclusively limited to, and intricately associated with living systems. Thus the paradox: without life there is no stereospecificity, yet stereospecificity must exist for there to be life.

However, despite these and other difficulties, the initial events in the theorized "primordial soup" are not the real problem. Even if plausible explanations of the origin of these early molecules were forth coming:

> The most difficult aspect of the origin of life problem lies not in the origin of the soup but in the stages leading from the soup to the cell. Between the basic building block . . . and the simplest known types of living systems there is an immense discontinuity. (Denton, 1986. p. 263).
>
> It follows that the heart of the abiding mystery of the origin of life is not the abiogenic origin of genes and proteins, it is the spontaneous generation of cells. This is hardly a resounding conclusion, but it is at variance with the impression one obtains from the literature of primordial evolution. (Harold, 1986. p. 170).

Transition From Chemical to Biological

All living organisms exhibit purpose in their behavior, which immediately distinguishes the quick from the dead. The ability to respond to environmental changes, regulate internal conditions, and ultimately reproduce is a common feature of all living cells. In fact, Jacques Monod (1971) incorporated the concept of purpose into his definition of living systems. He then assigned the role of executing biological purpose to proteins (enzymes). Enzymes recognize molecules with extreme precision, distinguishing one stereoisomer from the other. Their kinetic parameters enable them to select the proper reactions from all the thousands of thermodynamically possible reactions; thereby directing the course of metabolic activities in the cell. Such is the gulf that separates biological chemistry from organic chemistry.

In 1867 the physicist, James Clerk Maxwell, proposed a physics puzzle involving a hypothetical creature, which had the ability to recognize and manipulate single molecules. This creature, known as Maxwell's demon, was able to decrease the entropy of a system simply by virtue of its cognitive ability. Like Maxwell's demon, the cognitive ability of enzymes impart the cell with self determinancy (i.e., the ability to respond and adapt to environmental changes by processing and applying information). Furthermore, the cell's ability to regulate all of this enzymatic determinancy is the key to making functional sense of its own metabolic machinery.

Views such as Oparin's (1968) coacervate droplet are simply functionally impotent. They do not satisfy the criteria for even a "precellular" form, since they are incapable of informational application. While such models may use an ingenious mechanism to temporarily overcome thermodynamic restrictions, without the cognitive ability of Maxwell's demon the system ultimately suffers a thermodynamic death (i.e., thermodynamic equilibrium). The self determinancy of the living cell enables it to overcome this tendency toward thermodynamic equilibrium, and thereby maintains its biological homeostasis. A model entailing anything short of this is inadequate. Maxwell's demon obtained its self determinancy by violating the second law of thermodynamics (Morowitz, 1978). Without a similar type of violation, where did the self determinancy of the cell originate?

In bridging this gulf between the chemical and biological process, Bhargava and Gambhir (1984) suggest some possible transitional mechanisms. One proposal is that given the presence of all the necessary constituents, accompanied with sufficient time, the original cells ("protocells") would naturally organize themselves into a cellular system by virtue of a stochastic event (random chemical reactions). The writers acknowledge that such a concept requires replenishment of all constituents that are lost prior to the completion of cellular formation. Since all the evidence is against such a stochastic event, they admit the probability would be "extremely small." Even this would seem overly optimistic.

The second transitional mechanism is the result of an event that "for reasons unknown" produced a cellular form. This would be a single event in history, and all life in the universe would be a descendent of such an

event. This unknown mechanism is not a very intuitively satisfying explanation since it depends on naturalistic processes, but cannot be accounted for by those processes. This notion also requires that the three very distinct and diverse cellular forms, eubacteria, archaebacteria, and eucaryotes (Woese, 1987) be the descendants of one "protobiont." While a common origin of cellular forms is the more popular assumption, currently these cellular types "stand equidistant apart, and equidistant from a theoretical common primeval ancestor" (Denton, 1986, p. 288). Also, the peculiarities of the mitochondrial nucleic acids, which appear not to follow the so-called universal genetic code (Anderson *et al.*, 1981), presents another difficulty for a one time event of "protocellular" formation.

Ultimately, and despite the grandiose claims of some, simple stochastic events or "mysterious" natural processes cannot account for the self determinancy of the cell or the intricate complexity that is commonplace in cellular technology. Yockey's (1981) statement that currently "there is no valid scientific scenario for the origin of life" (p. 15) is still accurate, at least as far as a naturalistic scenario is concerned.

Even more, the conviction that "enough time" is all that is necessary for the formation of living cells should no longer be acceptable to the scientific community. Such "infinite escape clauses" (Mora, 1965) serve no purpose other than to divert attention from the real issue; our present understanding of chemistry and biology does not offer a naturalistic mechanism for the formation of the first cell. As Shapiro (1986, p. 128) notes:

> The improbability involved in generating even one bacterium is so large that it reduces all considerations of time and space to nothingness. Given such odds, the time until the black holes evaporate and the space to the ends of the universe would make no difference at all. It we were to wait, we would truly be waiting for a miracle.

Primitive Cells

The primitive cell must have possessed the ability to metabolize, generate and transduce energy, and reproduce. But above all, it had to be able to change, since this is the very essence of cellular evolution. Harold Morowitz (1966, 1967) postulated the minimal requirements for a self-replicating cell. Reasoning, in part, that ubiquity implies antiquity, he determined that constituents such as DNA, tRNA, ATP, NADH, and ribosomes must have formed early. Thus, these molecules set a lower limit to possible size and simplicity of the "protocell." Morowitz (1966 p. 456) suggested a cell with 45 functions and a diameter of about 1000A. As he concedes:

> It is almost certainly a lower limit, since we have allowed no control functions, no vitamin metabolism and extremely limited intermediary metabolism. Such a cell would be vulnerable to environmental fluctuation.

Today the minimal size and postulated number of functions in the "protocell" would most likely be larger since additional functions have been determined that are ubiquitous and logically required. For example, Morowitz's postulations were prior to a more complete understanding of membrane-bound cellular structures. Our current knowledge suggests that functions such as reproduction and energy generation would require a number of distinct chemical entities, perhaps no fewer than the minimum in contemporary cells. Also, such capability can hardly be envisioned apart from some type of cellular membrane (see discussion below). Finally, compartmentation in the soluble phase is necessary to separate synthesis from degradation, and maintain the cyclic asymmetry required for cell division.

Nevertheless, applying Morowitz's cellular model, these early cells would have been some type of anaerobic chemotroph. Precursors for energy biosynthesis would have been obtained from carbon and nitrogen generated by abiogenic processes in the "primordial soup." Energy metabolism would, by necessity, be extremely simple. Probably some type of fermentative process was the most viable option for early "protocells." Fermentative products are normally organic acids that must be disposed before they acidify the cytoplasmic region of the cell. Passive efflux would not be sufficient since phospholipid bilayer membranes are virtually impermeable to protons and even organic acids would generally be retained. Ridding itself of these would require the "protocells" to be equipped with some type of catalytic mechanism that caused the efflux of metabolic wastes as well as an outward-directed proton pump (Figure 1).

A fermentative process, however, would require at least some sequence of enzymatic reactions, much like those involved in the Stickland reaction or the glycolytic pathway. Instead, an alternative pathway such as that employed by methanogens may have been more likely. Methanogens couple the conversion of H_2 to methane with the synthesis of ATP (Figure 2). But what initially appeared to be a simple electron transport chain has been found to involve an elaborate sequence of enzymatic reactions still not totally understood.

Simpler types of metabolic processes become, by necessity, more theoretical and less like those currently utilized by cells. Such models usually involve the flux of an ion, such as Na^+ or H^+ into cell. This influx of ions acts to create an electrochemical gradient, much the same as the sodium or proton motive force currently employed by many cells (Figure 3). However, even "simple" models require some type of ATPase, and compel the cell to accommodate wide fluctuations of cellular pH and ionic concentrations.

As part of their pH homeostasis mechanism, bacteria apparently utilize a proton pump generated pH gradient. In fact, alkalophiles utilize an inverted pH gradient (Booth, 1985). Raven and Smith (1976, 1982) have presented arguments that creating this outward-directed proton pump was the original function of the F_1F_0 ATPase. Evolutionarily, it is remarkable that such a sophisticated enzyme (or a similar one) may exist in all prokaryotes, as well as mitochondria and chloroplasts. This enzyme may become another "universal" cell constituent. In addition, this ATPase is electrogenic and net expulsion of protons requires concurrent movement of other ions, usually an ex-

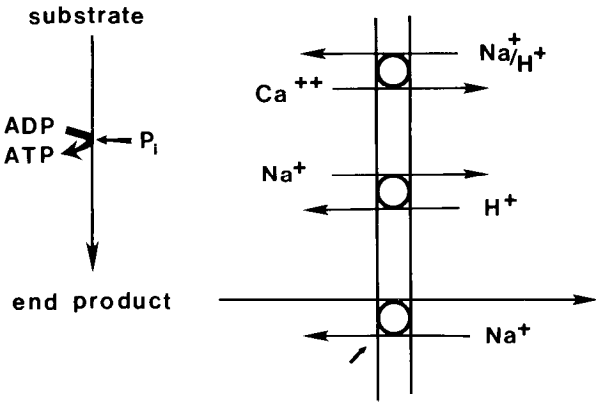

Figure 1. Model for metabolism of the "protocell." Energy (ATP) could be obtained from substrates, such as sugar or amino acids, by fermentative processes. The resulting end product (organic acid) is then pumped across the membrane and out of the cell. This pumping, would probably be coupled with the influx of sodium, and may involve an "early" form of ATPase (denoted by ®). Also shown are processes for transporting calcium, sodium, and protons across the membrane.

change of H^+ for other cations. For this enzyme to be functioning in the "protocell," selective cation permeability must have also been present.

Any "protocellular" organization would also face the problem of osmotic stability. Metabolites and other macromolecules enclosed within the protomembrane would produce osmotic swelling of the "protocell." Cell breakage from such swelling would be a constant threat. In addition, the problem would be enhanced by the proton pump, which generates a negative membrane potential resulting in cation accumulation. Bacteria cope with this by using an external cell wall that restrains such swelling. The "protocell," lacking such a cell wall, would have to achieve stability by mechanisms such as the exclusion of a major medium constituent from the cytoplasm. Since K^+ would have been insufficient, only Na^+ could serve as this constituent, thus regulation of intracellular concentrations of K^+ and Na^+ would be necessary.

Mechanisms for such regulation (i.e., accumulation of K^+ and exclusion of Na^+), by necessity, may have predated the fixation of a ribosomal mechanism of protein synthesis, which requires K^+. In fact, K^+ is the predominant monovalent cation in the cytoplasm of most cells, and it is a critical component in maintenance of cell osmolarity. Therefore, a primary or secondary sodium pump, in addition to some type of proton pump, would probably be needed for cellular stability (Wilson and Lin, 1980). Apparently the "protocell" faced the problem of either immediately possessing the ability to maintain its osmotic pressure or rupture if it failed to do so.

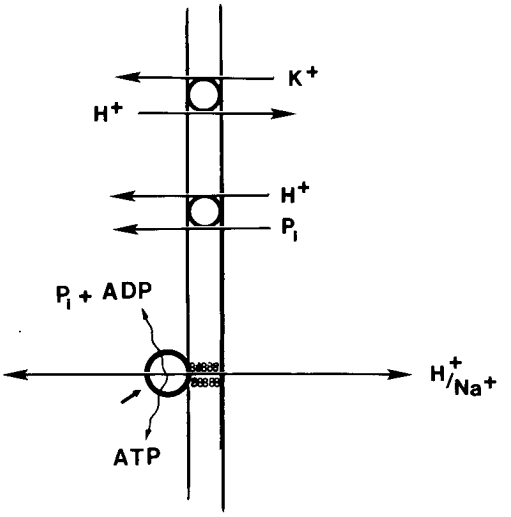

Figure 3. Model for a "simplified" mechanism of energy generation. Protons or sodium ions are pumped through an ATPase (denoted by ®) by which ATP is formed. This ATPase may also have the capability to pump these ions out of the cell. Also shown are processes for transporting potassium and inorganic phosphate across the membrane. Such capability would be crucial for the cell to be able to generate ATP or synthesize proteins.

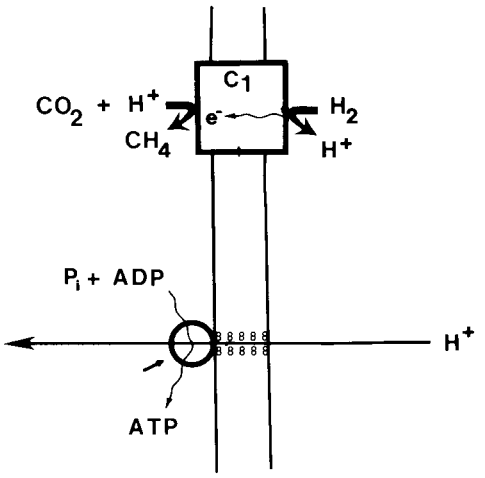

Figure 2. Model for energy production by methanogenic organisms. C_1 denotes the "Wolfe cycle" where electrons (e^-) are transferred from hydrogen to carbon dioxide to produce methane. This cycle, once thought to be a simple transfer of electrons, is now known to involve an elaborate chain of intermediate compounds and enzymatic reactions using cofactors not found in other cells. The protons that result from this electron transfer are pumped through an F_1F_0 ATPase (denoted by ®) to produce ATP.

Another serious problem faced by the "protocell" is that the seclusion of metabolic processes in closed vesicles requires additional transport systems. However, it would be very unlikely that such additional transport systems would be formed in the absence of a reasonably sophisticated level of cellular organization, and the availability of cellular energy (i.e., ATP, GTP, etc.). Inorganic phosphate (Pi) is a major component of ATP, and in nature is usually a growth-limiting nutrient. This is primarily because of the propensity of Pi to form an insoluble precipitate with metals such as ferric iron. This makes any accumulation of Pi by the "protocell" increasingly difficult.

Under natural conditions availability of Pi will depend, not only on total environmental Pi, but also its solubility, which is in turn dictated by the presence of alkaline earth and heavy metal ions, pH, and many other factors. Nonetheless, in terms of quantitative requirements and, disregarding the elements of water, Pi ranks third, after carbon and nitrogen, among nutrients required for bacterial growth (Rosenberg, 1987). Thus, metabolic use of ATP, an early require-

ment for the "protocell," appears to have required the presence of a Pi accumulating transport system.

Compounding this problem of Pi availability is the high tendency of Ca^{++} to precipitate Pi, especially at alkaline pH. This is particularly serious for the "protocell" since Ca^{++} is abundant in natural waters and will accumulate to high levels in any vesicle with a negative membrane potential, regardless of the membrane's impermeability. Therefore, the ability to rid itself of Ca^{++} appears to be another necessity of any "protocell" system.

Because of the growing evidence against the existence of a primordial soup, Woese (1979, 1980) suggests that life developed in the atmosphere. Envisioning a hot dry earth and an atmosphere similar to that of Venus, Woese speculates that there were clouds in the upper atmosphere consisting of droplets of saline. At the surface of these droplets he proposes that the progenitors of life were formed. However, it is doubtful these macromolecules could avoid destruction by oxidation and ultraviolet (UV) radiation. It is also very likely these compounds, once formed, would settle out of the upper atmosphere prior to assembling into some form of "protocell." This becomes even more critical since contact with earth's hot surface would also be a lethal event for the newly formed "protocells." Their only chance of survival would be a reproduction rate greater than their rate of descent. Studies of particle descent in the atmosphere of Jupiter suggests the "protocell" would have only months before it descended to the planet surface (Sagan and Salpeter, 1976).

> . . . a self-reproducible unit would have had to develop during the suspension time interval with a reproduction rate high enough to permit several "cell divisions" (i.e., some sort of infection of other particles, a mechanism for which is difficult to conceive) before the unit reached the hot surface. (Scherer, 1985. p. 93)

Woese's model also is vague as to how these "protocells" were formed or the origin of their genetic information. But such radical departure from standard naturalistic scenarios is refreshing amid the daily barrage of useless and baseless chemical evolutionary literature.

Regardless of the primeval nature of the "protocell," it required some mechanism by which to reproduce. Such ability would not only be necessary for simple survival, it is a prerequisite for mutational evolution and natural selection. Because of the sophistication involved in the formation of cellular organization, many scenarios have attempted to place "reproduction" of the biochemical polymers prior to encapsulation within a crude cellular structure (Argyle, 1977; Eigen and Schuster, 1982). Thus, the formation of cellular structure is viewed as of secondary consideration.

The discovery that RNA can catalyze specific reactions, without enzymatic assistance, has led some to speculate that RNA preceded DNA and even proteins (Gilbert, 1986; Lazcano *et al.*, 1988). RNA is suggested as the agent responsible for catalyzing the initial activities required to form a functional "protocell" system. Since large RNA molecules (several hundred nucleotides) could not be expected to exist in precellular systems, small RNA molecules are assumed to be sufficient (Orgel, 1986).

The absence of cellular compartments would force nucleic acids to survive "unprotected" in the prebiotic environment. More to the point, the survival would have to be long enough to allow the coupling of transcription and translation from which the components for cellular encapsulation would subsequently be produced.

Almost certainly a large number of nucleosides (specifically ribonucleosides) would have to form by precellular mechanisms for any "noncellular" replication to occur. However, as the number of reactive hydroxyl-bearing components increased in the environment, the synthesis rate of these oligo molecules would have dramatically dropped (Shapiro, 1984). For example, ribonucleosides would have been swamped by high proportions of closely related molecules such as adenosine analogs.

> Adenine can react at positions other than N-9. There are two other monoaminopurines, three diaminopurines, and one triaminopurine. Eight straight chain aldopentoses exist, and sixteen aldohexoses; each of the 24 has 4 different ring forms. By selecting one sugar and one base from the above, we can generate 2,640 nucleosides. Much larger numbers would be obtained by including branched chain sugars, amino sugars, ketoses, reduced sugars, as well as ketopurines, methylpurines, and derivatives of hundreds of other heterocyclic systems. (Shapiro, 1984. p. 569)

Such a prebiotic "soup" would also have contained alcohols, hydroxyethers, hydroxyacids, and millions of other compounds capable of polymerizing the nucleosides. In fact, nucleosides have a higher affinity for these compounds than for other nucleosides, thus effectively stopping RNA and DNA formation altogether.

Many other synthetic difficulties existed for the prebiotic formation of RNA. For example, the postulated pH of the prebiotic soup is 8-9. However, at this pH amino acids react freely with carbohydrates and other compounds containing ketone and aldehyde groups. This reaction results in the degradation of both molecules. Abelson (1966) states that these reactions would have depleted virtually all the free glucose, ribose, and deoxyribose. Lacking these carbohydrates, synthesis of RNA, DNA, AMP, etc. would not be possible. Nucleic acids also have a high affinity for UV light, and are consequently particularly subject to UV-induced damage. Without the protection of a membrane, UV light would effectively destroy any precellular system attempting to develop a primitive genetic apparatus. In fact, the prebiotic availability of even ribose, a necessary component of RNA, is extremely questionable (Shapiro, 1988).

Harold (1986) perceives that life processes and cellular organization are intricately related. He concludes (p. 171) that the concept of precellular reproduction

> . . . is flawed in principle: cellular organization, far from an after thought, must have been from the beginning part and parcel of the origin of life. The vital force, that *vis vitae* which will not be ex-

> orcised without proper explanation, has its roots in the astonishing degree of organization that pervades the living world from the molecular level to the organismic and societal. Biological order must be maintained by a continuous flux of energy. Therefore a believable biopoietic scheme is one that creates mounting levels of biological order naturally, by providing the means to convert the flux of energy into the organization of matter. This seems to me inconceivable without compartments.

The coupling of an energy liberating reaction to synthesis of macromolecules (energy requiring) can hardly be rationalized without the existence of some type of cellular membrane.

A final difficulty existed for the metabolic and genetic apparatus of the first cell. By definition, the cellular systems of the "protocell" would have been less efficient than its present day descendant. Woese (1965) acknowledges that such early systems would be much more likely to make an error, to the point that error-free gene translation could not have been done. However, an inaccurate translation does not lead to a more accurate translational system. An excellent summary of this difficulty is provided by Denton (1986, pp. 266-68)

> It is difficult enough to see how an imperfect translational system could ever have existed . . . That such a cell might undergo further evolution, improving itself by "selecting" advantageous changes which would be inevitably lost in the next cycle of replication, seems contradictory in the extreme . . . That an error-prone translational system would lead inevitably to self-destruction is not only a theoretical prediction but also a well-established empirical observation . . .

Summary

Our current understanding of the cell forces the conclusion that the first cell possessed mechanisms, not only for reproduction, but for internal regulation of organic and inorganic molecules. Such regulation was required since systems that cannot maintain biological homeostasis are unable to prevent a thermodynamic death. Therefore, no model of the formation of the first cell can be considered valid that does not account for formation of the elaborate mechanisms and regulations that were a necessary component. The only primafacie conclusion possible is that the first cell would have been far too complex to be a product of known prebiotic mechanisms. It would seem that a naturalistic explanation for the origin of the first cell cannot yet be offered.

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KEY WORD INDEX TO VOLUME 25

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For multi-page articles, the reference is to the first page only.

QUOTE

But neither millenarianism nor rationalism would, by itself, have been able to sustain the utopian temper had it not been for the advent of modern technology, with its large promise of human control over human destiny. There is nothing dreamlike about technology: it works—and because it works, it gives plausibility to the notion that modern man is uniquely in the position of being able to convert his idealized dreams into tangible reality. It also gives plausibility to the notion that, because the development of technology—of man's control over both nature and man—is progressive, therefore human history itself can be defined as progressive, as leading us from an imperfect human condition to a perfected one. The ancient Hebrews, the Greeks, the Christians all felt that there was a diabolical aspect to the power of technology; they saw no reason to think that men would always use this power wisely, and thought it quite probable that we would use it for destructive ends. But modern technology, emerging in a context of millenarian aspirations and rationalist metaphysics, was not bothered—at least not until recently—by such doubts. Francis Bacon's *New Atlantis* is the first truly modern utopia—a society governed by scientists and technologists which, it is clear, Bacon thought could easily exist in fact, and which he proposed as a very possible and completely desirable future.

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