A Beginner's Guide to the Origin of the Universe

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Whatever gets you through the night 'salright, 'salright…Don't need a clock to waste your time oh no, oh no…Whatever gets you to the light 'salright, 'salright.

–Elton and John

Lunar cycle before last I proposed the diel theory of evolution. The diel hypothesis states that the oscillations produced by the sun and the rotation of the earth, and the slowing of the earth's rotation over time, have played a more central role in our evolutionary history than the absolute passage of time. Here, I review how the diel theory recapitulates and extends previous work of Haldane, Spitzer et al., Rothschild, and others. I propose the strong null hypothesis that maximum-organic-chemical complexity, on earth, was reached around the time of first life. I infer a variety of just-so stories about the evolution of metabolism and the central dogma in an attempt to make this null hypothesis seem viable. A proposed proto-photosynthetic reaction center that existed in the primordial soup, perhaps until the great oxygenation event (GOE), forms the Gaian, central part of these stories. I explore the history of replication and recombination as relatively independent and suggest that it must be so. I try to answer the unsettled question of why meiosis arose in Eukaryotes by highlighting the importance of maternal inheritance and the nucleus, both of which separate plastids from recombination. I also illustrate how diel theory provides a new way of thinking about old biological problems like translation, cancer, and Alzheimer's disease.

I conceive of life, at the species level, as a set of genetically related cellular forms with a full complement of replication and recombination machinery, where replication and recombination in individuals are independent at the molecular level. I consider this, more or less, a molecular restatement of the commonly accepted definition of life as dependent on the appearance of natural selection. I organize around well-known guidelines for abiogenesis research.

FIRST, USE FULL-SPECTRUM SOLAR RADIATION, CYCLED AND WITH A LENGTHENING PERIOD, AS A PART OF PRIMORDIAL-SOUP PROTOCOLS.

Most intuitively understand the importance of light in evolution. Everyone knows about the day-night cycle. Thus, I ask, why has the light-dark cycle been so neglected in favor of wet-dry and temperature fluctuations, whether on a diurnal cycle or mostly otherwise? I make no attempt to review the myriad of lines of evidence for the importance of light in biochemistry; suffice it to say that many researchers have used light radiation as an energy source or catalyst to study the chemistry of life. Haldane recognized the power of UV light to transform simple organic molecules into a complex reaction mixture. The ideas of Oparin and Haldane—that a reductive atmosphere allowed the accumulation of organics, that the atmosphere transitioned from reductive to oxidative due to the evolution of life, that early life used fermentation as a way to get energy in an anaerobic environment, and that first life was quite simple—all still pertain, although I might disagree with the last of these, as have others. Recently, many central metabolic reactions were recreated using light in a plausible prebiotic mixture. Lipids, nucleotides, and amino acids can be formed in one medium with UV radiation. However, the light-dark cycle has found little or no place in abiogenesis research.

Spitzer et al. arrived at the first part of the diel hypothesis, the importance of "solar diurnal disequilibria," almost two years ago, having built on the ideas of Rothschild, Cockell, and others. (I developed the diel theory of evolution without knowledge of the work of Spitzer et al. and was surprised when I stumbled across this paper while looking for critical comment--surprised because I had already read hundreds of papers, albeit on a topic new to me, but had not seen their work mentioned. I also had a draft of the theory posted online. At that point, I got a DOI and published without further changes.) It is notable that we reached many of the same conclusions from very different perspectives, them working primarily forward from evolutionary chemistry and me backwards from biology. Poolman and Spitzer (the paper I saw just before publishing) reviewed the state of the field in a comprehensive way but did not expand on previous ideas about diurnal fluctuations. Because the light-dark cycle itself has not been utilized in abiogenesis research, it was not featured. In the spirit of their review and others, I reprise Dobzhansky as follows: Nothing in biology makes sense except in the strobe light of evolution. Any number of abiogenesis reviews, including those which have appeared in just the past couple of years, neglect the day-night cycle altogether. The potential importance of the lengthening day over time has been ignored more or less entirely. By any measure, the study of the day-night cycle, which goes back to the bible, which got it wrong by separating the light side and the dark side, because they must be considered as one to really grasp the power of the diel hypothesis, has not been sufficiently approached.

If poly-aromatic hydrocarbons (PAHs) slimed earth during the Hadean, then there is good reason to think that the light-dark cycle has been the major driver of chemical evolution since time immemorial. Aromatics can also be made *de novo* from simpler organic molecules and UV light on earth. Research on photochemistry, including prebiotic photochemistry, seems poised for great progress, but even more progress could be made regarding the prebiotic world by serious reconsideration of the day-night cycle as a functional unit. Even far reaching fields, such as the biomimetic capture of solar radiation for solar-electricity generation, may benefit from such reconsideration. Created by UV light in the interstellar medium, PAHs that fell to earth may have experienced their first ever darkness that first night. After that, early aromatics and their derivatives probably stored energy from light, especially UV light, during daylight hours, and released some of that energy at night. That would have made energy available for other reactions, some of which would not occur in the daytime anyway due to interference from light. Thus, it's easy to see how a diurnal rhythm may have been established in the prebiotic medium even in our earliest history.

As a general rule, metabolic pathways may be interpreted as recapitulating prebiotic chemical evolution. If complex molecules were still being synthesized by early-evolved substrates at time of first life, which is not assured, then this line of reasoning should be valid. Some metabolic pathways will better reflect the daytime chemistry of the primordial soup, for example photosynthesis, while others may give us clues about nighttime chemistry, for example degradation and repair of photosynthetic machinery. The cyclic nature of biochemistry must also be taken into consideration. Instead of end products, all biomolecules must be considered as both substrate and product. Nevertheless, it should be possible to determine which steps in a metabolic cycle evolved first, and in what order, based on a combination of sequence data and the thermodynamic logic of prebiotic and post-biotic-but-still-rich-soup chemistry.

SECOND, CONSIDER THE STRONG NULL HYPOTHESES THAT COMPLEXITY CAME BEFORE NATURAL SELECTION, THAT THE SOUP REMAINED COMPLEX THROUGH THE GOE, AND THAT MODERN LIFE EVOLVED FROM NUMEROUS ANCESTORS.

If catalysis by modern enzymes reflects catalysis that was occurring by other means in the prebiotic soup, then catalysis by modern cofactors and coenzymes may reflect prebiotic catalysis by light, minerals, organic molecules, and mixtures of these. For example, the apparent necessity of chemicals like porphyrins, chlorins, and quinones in photosynthesis indicates that they were lead actors in the prebiotic medium. These molecules can capture energy from UV light, can transport individual molecules of gas, and can pass electrons around in redox reactions. Many cofactors serve as antennae for gathering light and/or for resonance transfer of electrons. They tend to consist of a somewhat-variable lipid anchor attached to a light gather, although cofactors that also function as primary energy-sharing molecules, such as ATP and NAD, do not have anchors. If there was a pre-lipid soup where molecules like protochlorophyllide passed around electrons in a less orderly fashion than in modern photosystems, then a maximal level of chemical complexity may well have been reached before any cell membranes appeared, much less any life.

Lipids must have been a prebiotic innovation if life has always been cellular in nature. It seems safe to assume that membranes existed prebiotically--undergoing complex self-assembly--something like cell division works in modern forms. Because modern fatty acid biosynthesis requires an array of precursors, energy molecules, and catalysts, this alone suggests a rich prebiotic medium: This same set of precursors, energy molecules, and catalysts also participate in many other metabolic reactions in modern forms, including plastids. Genes for cell assembly appear to be as ancient as they get, though that may also be said for all metabolic genes, including many of those used for oxidative metabolism.

Beyond cellular compartments, there is not a consensus on what did or did not self-assemble directly out of the soup in the earliest proto-cells. An early, mostly RNA proto-cell seems to have the most proponents. However, a pathway from RNA-polypeptide hybrids and then to separate RNA and protein function and on to central dogma also seems to be making a comeback. So far this bottom-up approach has not explained anything about modern biology or much about evolution that we know of for sure. Why and when did replicating proto-organisms or organisms begin using information contained in RNA or DNA molecules instead of relying on self-assembly for perpetuating their line? Were there information molecules before nucleic acids, for example the order of molecules in an electron transport chain? How many hundreds of millions of years of day-night cycles passed during a time when cellular compartments and proto-organisms existed, but before there was life, as defined here and elsewhere? Is translation a part of the central dogma because polypeptides were common prebiotically, or is it because amino acids were plentiful, and peptides turned out later to be stable and useful?

As a general rule, if metabolic genes have a common ancestor that seems to reach back to the beginning, then I propose that the metabolic reactions effected by those genes' enzymes occurred in the soup before first life. If common ancestors cannot be found, I consider the possibility that the same biological reaction was still present in the soup until at least the last time in history it evolved. Considering the seemingly ancient origins of all biochemistry in all organisms, apparently including oxidative metabolism, then this leads quickly to a strong null hypothesis that the prebiotic soup may have contained the sum total of all biochemistry in all of life's forms, and perhaps more. The most complex prebiotic mixture imaginable, based primarily on the biological data, but also on chemical theory, makes the strongest possible null hypothesis for the complexity of the prebiotic soup. While I make no attempt at a statistical model here, intuitively, it should be easier to prove that any one of two reactions was not happening in the soup, compared to trying to prove either one of the two was not present. That should be true whether being studied backwards from biology or forward from prebiotic chemistry.

The first organisms may have gotten by with a reduced genetic code, which is consistent with a rich prebiotic soup and conventional models of the evolution of the central dogma. However, why not posit that the first Darwinian organisms had the full central-dogma and metabolism package, since most modern organisms do? The genetic code itself had to evolve prebiotically, since it did not spring forth in its final form. Many believe the more complex parts of the code were shaped by natural selection after the formation of simple organisms. That stems mainly from the intuition that it would be difficult to self-assemble an organism with twenty codons.

A self-replicating photosystem in the soup, eventually based on DNA, but still not subject to natural selection explains the data in a more straightforward way. Much of the logic regarding the chemistry of the prebiotic world, as studied so far, for example the RNA vs RNA-peptide hybrid debate, would still apply in this scenario, but in a prebiotic way. Recombination, by and large, has been considered to have arisen from an error-prone replication process, not unlike what takes place in a cancer cell. I will suggest recombination had a very different evolutionary history--more nocturnal, more vesicular, and less dependent on energy—than replication.

Short intervals of life, say one lasting several hundred-million years or so, could have increased the overall chemical complexity of the soup, at least in theory. Even the ancestors of modern organisms may have increased the complexity of the soup, especially by colonizing niches outside the sphere of the self-replicating photosystem. However, with the exception of photosynthetic anabolism, metabolism tends to turn higher-energy, more complex molecules, into lower-energy, less complex molecules. Even mitochondria take in more complex products than they secrete, although the importance of ATP production as a creative force in evolution cannot be overstated. Thus, if photogenesis was taking place in the soup, it's difficult to see how adding organisms to the mix would increase the complexity of that soup. I have not seen much evidence that metabolic DNA or proteins have gotten more complex or added features during evolution by natural selection. For example, a new kind of biological photosystem has appeared multiple times within the last 100 million years as the days have gotten longer, but it depends on new kinds of engineering rather than any new chemistry.

I would guess that life must have been created and gone extinct multiple times before any individual became the long-sought-after-but-as-yet-unfound common ancestor (LUCA; see also adapted animals in the evolution of eukaryotes or ADAM and EVE). It even seems plausible that we are related to previous generations of life in the following way: If life shared DNA with the primordial photosystem and then went extinct, and if that DNA was preserved in the self-replicating photosystem, then the next time life evolved, species may have used DNA from earlier false starts.

Neither the lack of oxygen in the geo-atmospheric record, nor the lack of oxidative metabolism in the earliest organisms, if the latter turns out to be the case, necessarily means that the soup itself did not have an oxidative side. Indeed, it's possible to imagine that any molecular oxygen produced would be so useful in a largely reductive soup that none would escape. Perhaps oxygen only began to accumulate in the atmosphere and undersea when oxidative organisms began to use oxidative-photosynthetic machinery for their own ends, perhaps to avoid the formation of reactive oxygen species. Although this seems kind of unlikely, even to me, it should be testable in the laboratory. It does seem that, at least, there should be more oxidized organics in the geological record from prebiotic times if this were the case. If the self-replicating photosystem in the soup came into its own 3.8Bya and life did not form for another billion years or more, then stromolites may need careful reconsideration.

Even now, or today, which is the same in diel time, and in English often enough, as much carbon can be found in dissolved organic matter (DOM) as in atmospheric CO_2, perhaps a fifth of the total organic carbon. Subsurface UV breakdown (SUB) still plays a major role in degradation, and this relationship between DOM and SUB remains a vital part of the complex community of modern organisms. The DOM controversy, as revealed by the DOC (dissolved organic carbon) and the DON (nitrogen) seems particularly salty. The interaction between DOM, SUB and the community also fascinates. Perhaps the very best way to study the prebiotic chemistry of the soup would be to examine, in detail, the continuing role of the soup in modern biochemistry.

Just-so stories about human evolution tend to describe increasing biological complexity over time. Indeed, natural selection turns out to have been a great engineer especially considering eukaryotic forms. However, after the GOE, if not before, the need for energy and energy storage, especially in non-photoautotrophs, must have put a premium on chemical simplicity. Before the GOE, species could apparently pick up or drop metabolic cycles by natural selection or other means. Since the GOE, natural selection would appear to have primarily simplified metabolism and even genomes. For example, animals spend much of their time finding and eating specific organisms for their vitamins and amino acids, molecules synthesized by many protists. Exceptions may be found where species have regained a lost reaction, which would not seem to change the overall tendency to lose function over time.

In the evolution of life's chemical complexity, light provided the energy, and the rotating earth and the lengthening day were the tinkerers. Natural selection came later but did not replace light, which may still act as the primary mutagen in many organisms.

THIRD, THE MORE DERIVED, COMPLEX PARTS OF THE SOUP WOULD HAVE PROVIDED THE SELECTIVE FORCE DRIVING COMPETITIVE ORGANISMS.

The null hypothesis in any inheritance study under the rubric of Darwinian natural selection must always be "no common ancestor." Speculation about lost genes, lost ancestors back through time immemorial, convergent evolution, and massive horizontal gene transfer all may be warranted as an alternative hypothesis. However, it should always be stated that when no common ancestor can be found, the study does not disprove the null hypothesis of no common ancestor. The complexity-first hypothesis provides a molecular motivation for this null hypothesis: It is easy to see how a metabolic trait may be adopted multiple times if organismal metabolism reflects ongoing chemical reactions in the primordial soup.

For example, Cardona et al. state, "Light-driven water oxidation by Photosystem II evolved only once in an ancestor or the phylum Cyanobacteria." That's a good restatement of the consensus opinion but ignores the null hypothesis altogether. They conclude, "We suggest each one of these forms of D1 originated from transitional forms at different stages toward the innovation and optimization of water oxidation before the last common ancestor of all known cyanobacteria." Note that if more than one part of a genome have no known common ancestor, the holy grail of a common ancestor gets pushed even further back in time since natural selection works sequentially. Do we even have definitive evidence that oxidative metabolism postdates anaerobic versions from the genetic inheritance data?

There are other explanations for the data consistent with the null hypothesis. For example, a fully formed photosystem, nearly identical in many ways to modern photosystems, may have been present in the prebiotic medium, perhaps right up until the GOE. Until the GOE, it would have been possible to evolve a photosystem simply by adopting a stretch of DNA out of the soup. Before the GOE, photosynthesis appears to have evolved and been lost dozens of times. After the GOE, existing photosystems have been shaped by natural selection in the context of a lengthening day and in a soup not unlike the one that exists today. Consider that much of the data can be explained by the *de novo* formation of a photosynthetic *organism* just before the GOE, which, as a null hypothesis, should provide an easy target for rejection by inheritance studies.

I further suggest that the photosystem in the soup was self-replicating somewhat like modern chloroplasts and mitochondria. Nearly all of the energy and organic substrates, especially complex organic substrates, driving the chemistry of the prebiotic medium would eventually come from this source, just as photosynthesis ultimately provides the energy for all life today. Such a photosystem would have combined the functions of mitochondria and chloroplasts, whose DNA sequences seem to date back to the beginning of life. Perhaps it grew and budded off more like a cloud than a bunch of little organelles. However, an interior compartment, such as the interior lumen in modern plastids, would have been vital for energy storage in the form of a proton gradient.

Note that these forms, the proto-chloroplasts and proto-mitochondria, may have used RNA and other substrates in the soup to self-assemble early in evolution. However, these forms were not subject to natural selection because, while they could replicate, and anything with DNA will undergo at least some recombination, they could also be created *de novo*. Here is where the genetic code started to be written, before life formed. As self-replication of the photosystem became more information-dependent due to its reliance on more and more complicated RNA and/or DNA molecules, the ability to form *de novo*, would have been lost.

As soon as compartments seem feasible, it becomes tempting to talk aboutcompetition between these compartments. Moreover, if membranous compartments absorbed anything from the soup after forming, a sort of *de facto* kind of competition would have occurred. However, if these compartments formed and lysed in the service of a larger autocatalytic cycle, then it would not be analogous to competition between individuals. The soup, in its entirety, may be compared to an organism who lives it up during the day, then has sex and dies at night. Concepts such as competition and cooperation should be left to describe the behavior Darwinian forms or redefined carefully.

There had to be a driving force, or reason why the first organisms evolved. For example, note that there is no trophic level specified in my definition for life even though early life must have required at least some energy. If ATP and expensive biomolecules were plentiful in the soup, then a species may not prosper trying to spend limited resources on their production. Perhaps the biggest challenge for early forms was not competition among individuals or between species, but rather avoiding being sucked back into the diurnal soup by proto-viruses, especially at night, and light-driven-prebiotic degradation pathways, especially during the day. Eventually, somehow, cellular compartments managed to escape not only the viruses at night but also the ongoing cycle of photogenesis in the primordial soup during the day, and life begun.

Even the driving force behind prebiotic evolution may be considered based on metaphors like novelty or rarity, although it must also be a thermodynamic argument at heart. For example, much has been made about the possibility of membranes recapitulating a pH gradient available for biosynthesis in the soup. However, what is the driving force for forming a pH gradient if one is already available?

After the formation of first life in this context, it becomes easy to see why organismal metabolism would probably evolve by picking up the more complex or rare reactions in the soup first. Only some parts of modern metabolic pathways, if considered in individual steps, would have provided an advantage to an organism. These always seem to be the more chemically complex parts of any given cycle. For example, the step in the Calvin cycle that would provide an obvious advantage to an organism converts carbon dioxide into fixed carbon. Something like this step was probably first to be internalized during evolution. RBP may have been relatively rare and packaging the carbon fixation step provided a big advantage. Furthermore, four back-to-back steps in the Calvin cycle, including the carbon fixation step, form the backbone of this pathway, and these were probably the first four steps internalized. The other steps in the cycle may have had antecedents in the evolution of metabolism or were added later out of the soup. The idea in biology that evolution by natural selection can be traced forward along a metabolic pathway would seem to be exactly wrong. Organisms could only evolve the important parts first, because without the important parts, the subsidiary parts provide no advantage. Of course metabolism does not occur in individual cycles or pathways but in interdependent loops, so subsidiary parts of new--from the perspective of the species evolving--metabolic reactions would have been present often enough anyway.

If organisms could derive energy directly and easily from their environment, then perhaps organismal complexity was selected by other factors, at least initially. One possibility would be to fill niches outside the sphere of the posited photosystem that may have been dominating the primordial soup. For example, developing an anaerobic lifestyle in near-shore mudflats, where oxidized organics were plentiful, seems like a possibility. The intertidal is another. Perhaps the most logical place would be the aqueous layer just below the soupy, organic layer on top. My best guess would be all of the above.

FOURTH, WORK BACKWARD FROM BIOLOGY AT LEAST AS OFTEN AS FORWARD FROM THE BIG BANG AND ACCRETION.

Evolution must account for the 12 billion years of history including especially the last 4.5 billion on earth. The diel theory of evolution places particular importance on early earth history when there were more days per year, when those days were probably increasing in length at a more rapid rate, and when there may have been UV-C light in the mix. However, it must also be admitted that the more distant the history, the more difficult to reveal.

Diel time counts the passing of days rather than the absolute passage of time, suggesting that biology should tell us more about life's beginnings than we may have expected previously. That beginning happened more recently in diel time than in absolute time. For example, if the diurnal metabolism inside of cells recapitulates a diurnal rhythm from the prebiotic medium, then it may be possible to infer what was in the prebiotic mixture, in part, by studying the diurnal rhythms of chemistry in modern organisms. For example, melatonin circulation at night seems to be a universal trait in animals. Furthermore, the pattern of release does not vary between species. If the pattern in the prebiotic soup mirrored our modern pattern, then it suggests melatonin was created or released during the first half of the night, and consumed or degraded during the second. Many plants and other organisms release melatonin as a waste product. Other organisms take it up. Further study of this diversity should provide more clues as to what was happening in the primordial soup.

FIFTH, LOOK FOR LIFE IN THE TRANSITION OF PREBIOTIC METABOLISM FROM DAY TO NIGHT.

Recombination is usually conceived of as having arisen from errors in replicative machinery. However, consider that recombination is, in some ways, the opposite of replication. When a species recombines its genome, individual identities are lost, not reproduced. When a species evolves enough, a new species may be formed that will outcompete and extinguish the former species. It becomes difficult to conceptualize how either replication or recombination could arise or evolve one from the other in this context.

If first life underwent natural selection, then both replication and recombination mechanisms must have been present, and therefore must have evolved prebiotically. It also seems possible that they evolved relatively independently, because biological recombination and replication of DNA at the molecular level never occur together in healthy organisms. Both replication and recombination imply multiple individuals, and therefore must be considered at the species level and as such, not themselves subject to natural selection. They cause natural selection. The number of individuals in a population and the amount of variability in a population are clearly population parameters. Nevertheless, it must be noted that both replication and recombination are dependent on sets of genes, each one of which must be subject to natural selection. They are interdependent on the molecular level down to relying on the same strands of DNA. DNA seems to provide a stable way to balance the two, but as my definition of life suggests, they must also be in many ways independent.

Cancer, most often described as cells where replication has gone haywire, may be better conceived of as cells where the wall between replication and recombination has been breached. Cancer does not evolve much like a Darwinian organism. Meiosis genes important in cancer etiology have already been identified. It would be of interest to know what suppressing a gene likeMAX would do to a cancer cell line in culture, perhaps with a normally sub-lethal dose of radiation.

[Besides the interest from an evolutionary standpoint, ramping up meiosis might be a way to bury cancer in its own grave. This may be how radiation treatment kills cancer cells anyway. I also think therapy based on this idea could be very dangerous in terms of metastasis and the testicular cancer. Testicular cancer is one of the few types of cancer that afflicts younger men so that it would seem to be induced rather than suppressed by meiosis. In general, cancer strikes those in their old age and often enough during childhood but only rarely during the primary reproductive years. Infertile women are more likely than others to get several types of cancer.

Something as simple as taking fertility drugs before/between radiation therapy treatments might make a good first clinical trial. It might also make a good adjunct to ongoing trials of lower-level, maintenance doses of radiation therapy. Advanced-stage ovarian cancer patients would seem to be an attractive group for at least three reasons. First, the prognosis does not get any worse. Second, treatment with fertility drugs on their own have very few serious side effects. Third, they would not be at risk of testicular cancer. Of course ovarian cancer, like most other types of cancer, usually strikes after fertility has ended.

The diel theory of evolution also suggests that lots of sex should be good for preventing and even curing cancer, especially if sexually-transmitted diseases can be avoided, and hey, what if it is wrong? I am happy to report that there are cancer researchers in the world taking this idea seriously.]

One way replication and recombination could have arisen relatively independently is diel variation. In the daytime, a self-replicating photosystem evolved all of life's metabolism and much more. In the evening, cells assembled to protect the replicating DNA from degradation and recombination overnight. Nonetheless, DNA finds ways to recombine. In the long-run, this made the replicating photosystem stronger, that is, even though it tries to prevent recombination. In this way, replication and recombination may have always been at odds but were also always interdependent. Again, this balance of replication and recombination seems to be the reason DNA found a stable place as an information molecule.

Disregarding the apparent need for a cellular compartment, the soup itself may be viewed as one big organism where replication happened during the day, and recombination occurred at night. Considering the apparent requirement for Darwinian evolution in all definitions of life, the idea that life evolved from a soup that resembled a Darwinian organism seems reasonable. Again, I would guess that as more and more life evolved, the self-replicating photosystem in the soup began to lose steam. Because the soup could adapt by the same basic molecular mechanisms as a Darwinian organism, the temptation arises to think of the soup as competing with life in a struggle for survival, and I like this interpretation, despite my exhortations above.

Earlier in time, *the switch from self-assembling complexes of molecules over to informational molecules may have been energetically favorable due to the ability to preserve data, rather than structure, overnight*. RNA viruses may reflect this transition period during (what I still consider) prebiotic evolution. Cellular compartments must have been handy for storing energy overnight. Indeed, building a cell membrane full of pigments and minerals seems a bit like moving from day to night anyway. Many anthropomorphized functions of metabolism, such as heat-shock protein function, may be better viewed as nighttime chemistry, for example after the drop in temperature that occurs each night.

Recently, it was shown that sleep helps repair double-strand breaks (DSBs) in humans. Humans lack a photolyase gene, which most other organisms have, that repairs DSBs in low light. In this context, cryptochromes that function as an endogenous diel timer for many eukaryotes probably evolved from photolyases active in the evening, and especially in the morning.

SIXTH, ANTENNAE.

Photosynthesis has evolved and devolved at least dozens of times. Although the basic photosynthetic reaction center has not been changed by natural selection, innovations have appeared, for example in light-gathering antennae at the macro-molecular level. I consider that the evolution of translation also seems like antennae design. The original starting amino acid for translation, N-formylmethionine, looks for all the world like a cross linker that would allow attachment to a lipid membrane. Of course starting cytosolic translation in eukaryotes involves methionine, a simpler molecule, which may have arisen by natural selection. Furthermore, its position in the codon table makes the tryptophan triplet seem like the original stop codon. In some organisms, more than one of the eukaryotic stop codons, code for tryptophan. The original peptides may have been made from the simpler amino acids as most models suggest, however proteins seem to have come into their own as antennae: Start with an anchor, add a chain (perhaps random in number at first) of glycines and similar molecules, and top it off with a good light gatherer. Next you would need good electron transport, which would mean picking up cofactors and evolving mechanisms like pi stacking using the whole suite of amino acids.

It also seems possible that tryptophan, being a lot like a stop codon, and among the rarest of the amino acids in modern proteins, may be the least necessary of all the amino acids, added last by natural selection, and so forth. However, as usual, I strive to make this story easily disprovable. I suggest translation evolved, at least in some large measure, to position tryptophan as a light gatherer. Furthermore, I will bet on the three rarest amino acids--the best light gatherer, the start codon, and the cross linker—as important, early contributors to protein evolution and function.

[In my investigations, I looked at the sequence data of some small unfolded proteins to see if they lacked the more complex amino acids. I did not find much evidence for this, but the lack of tryptophan in human tau genes seems striking. Could absorbing light be so traumatic for neurites that tryptophan has been selected against? In general, is this why tryptophan is so rare? Has UV light been considered seriously in the etiology of neurological disease? Could growing a beard and wearing a hat help prevent Alzheimer's? I remain agnostic about these possibilities but mention them because it suggests how old topics may gain fresh perspective—or a renewed emphasis on a neglected perspective—by applying diel theory.

This line of reasoning leads quickly to the fully-dressed-brain hypothesis to explain nakedity in humans. When humans got smart of enough to wear clothes and live inside, that came into conflict with the need for vitamin D, an essential vitamin, especially for healthy brain function. Making vitamin D locally was not an option for the nervous system because of the damaging effects of solar radiation, especially on fine neurites. Thus, we needed to get our vitamin D quickly if and when our skin was exposed to the sun, and thus the loss of hair on most of the body save head, face in many, and sexual organs.]

Where were we? Oh yes, translation. What came before translated antennae? I would suggest polymers of RNA bound to light-gathering, electron-transporting proto-cofactors, both covalently and non-covalently, or in other words, an antenna, as a leading candidate.

SEVENTH, STUDY ESTABLISHED CELL LINES OUTSIDE.

While diel theory suggests cancer is not alive, it does not immediately resolve whether or not cancer represents a primitive form. One popular scenario has it that a cancer-like cell reproduced itself, and diel theory would say perhaps during the day, and then was degraded at night. Perhaps life came to be when the days got a little longer, and the first organisms were able find a more successful strategy of building a wall between replicative and recombinatorial functions. The simple observation that cancer cell lines are stable in culture medium supports this possibility. This also would not contradict the notion that life came to be when Darwinian evolution was able to act by natural selection on individuals.

Still, my digestive microbiome informing my thoughts and emotions tells me that a cancer-like cell was not a primitive form leading to the evolution of life. It seems more like anti-life, and not because it kills multicellular creatures. In fact, the just-so story presented here, where nighttime recombination evolved in spite of daytime replication, gives physical instantiation to the philosophical truism that death implies life, and life implies death. And also, sex and death are about the same. Grow and multiply during life, recombine and die thereafter. Cancer is just different from life. It mixes life and death functions.

And speaking of sex, I may have figured something out about the most inspirational mystery in all of evolution. If DNA from the self-replicating photosystem was freely available in the soup, then eukaryotes may represent, in some ways, a more primitive form than bacteria, as others have suggested. It seems all species were adopting genes from the soup, but eukaryotes never incorporated all of this DNA into their nuclear genome. Instead, eukaryotes rely on more primitive vestiges of the proposed, self-replicating, primordial photosystem. Maternal inheritance of plastids insures that their DNA will not recombine much with paternal versions. If plastid DNA is meant to replicate and not to recombine, then it must have been important to wall off the recombinatorial functions of the nuclear DNA from the plastid DNA. Et voila, the nucleus. The study of barriers to recombination of all sorts may help us parse sex. However, this wall-around-recombination idea would seem to contradict the pattern of achiasmy and heterochiasmy in many species, where recombination is confined to the maternal line. Haldane suggested achiasmy might function to preserve the sex chromosomes from recombination. In particular, the Y chromosome would seem to be on the same *de facto* evolutionary trajectory as plastid DNA--not much chance to recombine, but a high mutation rate.

FINALLY, GO ONLINE FOR REALITY SAKE.

That the work of Rothschild, Spitzer, Poolman and others has not received merited review suggests a major problem in abiogenesis research, and perhaps research science in general. For example, and I choose this example because there is no dance more relevant to the diel theory of evolution than the one she studies between light and DNA, much of Rothschild's work is not available online. Other work by Rothschild may be had with temporary urls, making it difficult to share with hyperlinks. I am pretty sure my tax money funded this research. How can it be that I have no access?

Information about our shared history has no place locked behind academy doors or publishers' pay walls. The number of important articles to which I have no access is a personal tragedy, but I would suggest greed has also drastically slowed the potential of science. It seems unconscionable to hinder the progress of cancer research in order to make a profit. For example, I would love to read this paper or this paper. The dichotomous view of capitalism versus socialism has already played a role in shaping abiogenesis research. Haldane was a Marixt who fled England, and Oparin a Communist. I am not implying that the hydrothermal-vent hypothesis is a red-baiting conspiracy by bad actors but would rather suggest that organizations such as NASA can reach peculiar stable states for a myriad of reasons. The hive mind on the internet makes it impossible to discuss any other hypothesis besides hydrothermal vents. One has only to look at the laws passed to protect Oparin's fellow Soviet scientist Lysenko to be convinced of anti-scientific (semi) stable states.

Abiogenesis research is, by nature, chemistry but also encompasses all areas of biology and many in astronomy, geology, atmospheric science, and others. Anyone who can keep it all straight based on a piecemeal literature deserves a little statue for that alone. Of course everyone knows this already, which makes it a travesty. Let's change acts. Let's go online. Everyone is interested in their history already, so there would be no lack of interest. We can work as one, in our little competitive drama, and find the answers to unsolved scientific questions about life and beyond. We might even help steer the arc of world history toward cooperation between countries and eventually peace.