Vol. 1. No. 1 Life 1
What's Wrong with Evolution
(revised)
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Foreword

Current discussion about evolution indicates four different points of view: There are those who don't believe in it; there are those who have limited to no opinions about it; there are those who accept what is basically the Darwinian position of a gradualist evolution driven by natural selection; and there are those who believe that some missing ingredient is still necessary to account for a more precipitant character for evolutionary steps at the species level and above. The author belongs to the fourth class. In this brief essay, I propose a hypothesis based on physical theory to account for both the process of initial evolution and its subsequent history.

Evolution theory – the emergence of species -- currently enjoys more frictional heat of controversy than intellectual light of resolution.[1-15] It would seem clear that some major ingredient is missing. This essay offers a physical theory as the missing ingredient for abrupt or precipitant evolution, for both startup and subsequent speciation.

Introduction

Underlying a scientific theory of living species and their evolution are the following concepts:

1. the cell theory of organisms (a cellular constitution wherein cell begets cell)
2. organic chemical organization and operation of the cell
3. codification of morphological organization of cells by gene units capable of chemical reproduction
4. mutation of the chemical gene by a cosmic radiation background and by occasional imperfect chemical transcription
5. selection pressure from the environment to determine numerically most successful local gene pool (so-called fitness), and
6. symbiotic association of cells or of cellular components into unicellular-multicellular organismic complexes.

These six elements have provided a powerful buttress for the notion of a large gene pool of individual selectable elements from which a gradualist evolution of easily demonstrable organismic breeding changes, observed and selected for thousands of years, can be shown to be emergent from those existing gene pools, as well as the occasional finding of small, e.g., point mutations, of new selectable elements within that gene pool. An extensive literature from the beginning of the 19th century to the present exists for the philosophic-scientific co-evolution of these ideas about biological evolution. Obviously, observation, conjecture, and intuition led that process, and its formal scientific construct, probably quite aptly, is attributed to Darwin[15].

However, as Eldredge and Gould have called attention[11], those mechanisms -- the core of the Darwinist mechanistic explanations -- do not account for their so-called "punctateness" of evolution at the phylogenetic level of species and above. It is the lack of offering a strong enough mechanism for that precipitant process of appreciable biological change which -- in my opinion -- bedevils all discussion of evolution and makes it sound like philosophic mush regardless of any sham use of rigorous mathematics. Mathematical logic can be used to test various questions of self-consistency. It cannot be counted on to furnish a missing physical theory.

The base for a physical theory

My proposal will be based primarily on the observation that the biologist -- even though properly pursuing his function -- has dwelt too much on the organism and not on the dynamic vulnerability and mutability of the hierarchical chemistry of the organism. A physical mechanism will be offered in a unitary geophysical model for the process of evolutionary change as a more direct attack on the biochemistry of the encoding of the organism. It will only look at the organism and its morphology and functional operation in a very shadowy form (see (16), for example). After all, life's processes are basically limited, in the sense of its organizing and operational forces, to electrochemical ionic and covalent bonds. Such a unitary geophysical-geochemical mechanism, therefore, will be discussed because it can account for both life's original evolution and its continuing evolutionary process.

A geophysical model for life's origins

To expect life's origins from modern biochemical mechanisms -- DNA and its capability to produce modern rate governing enzymes, or even from RNA capable of performing various precursor functions including more primitive catalysis -- is naive. We have to turn to Earth's startup, 4.56 Gya (billion years ago) and the processes available at life's startup, 3.8 Gya. Its schematic history[17, 18] is based on the following elements:

- A singular astrophysical event in our Galaxy producing a nebular isolation and condensation 4.56 Gya.
- Formation of a suite of planetesimals that separated materials and led to a middling sized star, our Sun, and its system of planets.
- As an introductory outline of the rest of my theses, I argue in a very closely connected chain that from initial material ingredients and processes, specialized in their startup on Earth, thermal rolls and plumes will develop in a thick lighter material mantle to conduct internal radioactive heat to the surface; cooled there by a layer of condensed water, the resulting balance of solar flux from outside and heat conducted from the interior, conditions on the surface will form a surface elastic skin on the mantle material; the underlying rolls will develop asymmetric shearing forces on the surface layer, cracking and driving them into shifting plate segments, rocking, shearing, and upthrusting above the water layer of oceans; a hydrological cycle of evaporation of water into the atmosphere and recondensation on the upthrusting continental plates will erode and sedimentize them; within those sedimentary beds, reaction chemistry will be catalytically encouraged to produce both a geochemical and organic-biochemical-menu of processes; the isostatic imbalance of those plates, because of differential densities and promoted by the shearing forces below and the shifting sediments, will cause subduction (downward movement) of these plates, creating new continental arrangements; the continuation of these sedimentary processes will then encourage further and faster evolution of the same kinds of processes that were initially capable of producing life. This chain of processes is responsible for both gradual and precipitant transformation, appearance and disappearance of species.
- Sequestering of galactically and cosmologically abundant atomic materials, produced by an earlier, first generation of stars, commonly organized about the mid-family atomic donor-acceptor "hermaphrodites" of H, C, Si, leading then to molecularly abundant materials like water bearing (HOH), carbonaceous (COHN), and silicic compounds (SiO), and of metals up through the fourth family of the Periodic Table and mid-range around Fe among these planetary bodies. (Disregarding the primordial more abundant H and He, the high abundance atoms listed with their numerical abundance relative to Si, are C-12, N-2.5, O-20, Ne-3.8, Na-0.06, Mg-1.1, Al-0.08, Si-1, P-0.01, S-0.5, Ar-0.1, Ca-0.06, Cr-0.01, Fe-0.9, Ni-0.05. Other elements are of lesser abundance[19]).
- A fortunate mid-distance range from the Sun for Venus, Earth, Mars - whose solar flux fits the liquid-vapor range of compounds such as H_20, CO_2, NH_3 (e.g. -100° to +100°C) that exist in three phases of surface matter - gas (e.g., H_2, O_2, CO_2, NH_3, H_2O), liquid (CO_2, H_2O, NH_3), and solid (SiO_2, MgO, $A1_2O_3$, FeO, CaO). On Earth, such a three-phase configuration involves a gaseous atmosphere (N_2, O_2, CO_2), a significant unstable gas-liquid fluctuating phase (H_2O), e.g., in a surface range -70°C to +70°C, as well as various light, solid complexes (Mg, AI, Fe, Ca, Si, O).
- Among the small concentration higher atomic species, Earth also has sequestered a significant fraction of radioactive material (Th, U, K) responsible currently for a large fraction of the heat flow reaching the surface.[19]

Starting from a nebular condensation about 4.5S Gya, nebular disc and droplet dynamics, an attendant sequestering of atomic materials, outgassing of volatiles, loss of low atomic mass volatiles, energy gain from gravitational infall of material, all of these processes serve as an initial transient determinant of the boundary conditions governing these planets as of 3.9 Gya, the nominal terminus of any appreciable early material infall. Given some size and material parameters, one can then start to characterize a thermodynamic near equilibrium model of specific planets.

The transient geophysics-geochemistry on Earth, 4.56-3.9 Gya, likely developed a reducing gaseous atmosphere of CO_2, a solid elastic crust and a thick mantle of SiO_2 with a light fraction of Mg, Al, Fe, Ca oxides and silicates, a segregated heavy core of molten or nearly molten Fe, a thermostatting surface layer of H_2O in liquid (lakes, rivers, and oceans) and in vapor form (clouds), a surface temperature within or related to the range from the triple point O°C to the boiling point 100°C of water, and a thermally driven hydrological cycle. The salient nominal material densities in gr/cm^3 are: 0.0012-surface density in a gaseous atmosphere, 1.0-liquid hydrosphere, five nominal solid mantle constituents of SiO_2-2.65 [48 wt.%], MgO-3.58 [34 wt.%], Al_2O_3-3.97 [5wt.%], FeO-5.7 [8 wt.%], CaO-3.3 [4 wt.%]; a differentiation as oceanic crust composition [in wt.%] - [48] SiO_2, [18] MgO, [12] Al_2O_3, [11] CaO, [9] FeO; as continental crust composition [in wt.%]- [60] SiO_2, [17] Al_2O_3, [6] FeO, [6] CaO, and as core of Fe [12]. (Mars a sister planet, would not have been much different except for the fact that because of smaller size, its atmosphere was blown away by the last extensive incidents of gravitational infall. The remainder of its hydrological story then remains juvenile).

Up to this point. the story is purely materially underpinned until we add one critical ingredient. The radioactive materials sequestered within the Earth's mantle augments the initial infall energy and creates a very significant heat flux through the mantle that tends to govern the parabolically-increasing temperature throughout the mantle (e.g., currently from surface temperature of 10°C average, climbing to quite a few thousands of °C in the mantle).

Geophysicists, as a whole community, have long hesitated to draw a proper conclusion from that fact, which is that the heat flux through the Earth's mantle has to produce rolling cells and plumes. Loosely speaking half accept the convective rolls with the number growing; others still reject them. I will offer a comment on the problem.

Geophysicists tend to judge the material properties of the mantle (at assigned T and ρ) from the "high frequency" seismic propagation properties, which characterizes the mantle as elastic, except perhaps for a thin asthenospheric layer below the Earth's elastic surface. A missing piece of rheological theory, easily seen in latex rubber (a rubber response is given by Nolle[20]), is that its very low frequency response is near liquid, e.g., a Poisson's ratio of 0.498+ and Young's modulus of 3 atm, but a high frequency response of a Poisson's ratio of about 0.3 and a Young's modulus comparable to its bulk modulus of 15,000 atm, a very respectable stretchy solid value. It is not commonly realized that this difference in response is characteristic of all plastic materials as an increase of the unidirectional "tensile" stress with strain from a zero frequency to a very high frequency value, e.g., as exhibited by change in the effective Young's (stretch) modulus. The rheological geophysics of the mantle exhibits that property. What is missing to make the model comprehensible is the time scale of the nonlinear stress, strain, and strain rate in the mantle.

Empirically, the rollover time assignable to the Earth's mantle is about 600 My (million years). The rest of the modeling comes apart with that single observation. It is equivalent to assigning an effective viscosity to the mantle. Before justifying this as a roll process, I will first indicate its consequences.

If thermal rolls or plumes began in the Earth, say some brief time before 3.9 Gya, then they put considerable shearing stress on the elastic skin of plates when they formed; at some point they put those plates into asymmetric in place motions, such as rocking vertical wave motions and - in more extreme cases – anelastically deforming, cracking, shearing, and upthrusting lateral motions. That is, some form of three-dimensional plate tectonics would have begun.

The alternative thermal model to rolls which has recently come into favor[21, 22] involves thermal plumes in the mantle. I have no objection to their possibility, and in fact to carry that argument to a fuller possible extent, I will use the case of Mars[17]. I am prepared to believe that a first asymmetric heating result might have been a plume, as perhaps illustrated by Mars. Such a single asymmetry could have been responsible for the almost singular event of the Tharsis bulge on Mars and little else, on that smaller sized planet. Similarly, with regard to an anelastic processes, deforming the elastic skin of these planets, I would have no objection to consider that elastic plates cracking and rocking vertically in place could have also served as a precursor to a more fully developed motion of also moving horizontally in place, e.g., shearing and overthrusting.

But, however such first elastic-anelastic asymmetries occur in the surface shell from mechanically and thermally generated stresses, the stress field will deform the thermal plume in the mantle. Like a flickering flame column, the plume would be made unsymmetrical and forced at sufficient magnitude toward a roll. Thus if a heating underplay continued on the elastic plate above, the rocking of the plates and the thermally and viscously convective mantle flows would break into rolls in the mantle, and because of the continued asymmetry of the heat-conducting layer, the mantle convection on Earth would break up into a number of rolls. The convective relief of the heating instability would take the form of Bénard cell rolls that fill the mantle space. Since no commensurate number of rolls can be expected, one has to estimate how many rolls the viscous layer might break into. Inspection of any estimated temperature regime and the thickness of the mantle zone suggests that the entire thick mantle will be filled with rolls, so that the number of rolls is neither one nor many but more like a few handfuls, e.g., somewhat irregular. It is no surprise, using Mars and Earth as prototypes, that the numbers that emerge are either one or a few handfuls (a very great amount of forcing heat from below with a thin elastic surface and a relatively thin "mantle" could eventually create a great number or surface cracks and subsurface rolls, but that solution, I believe, does not conform to the internal structure of these planets). On Earth, with no perfectly stable configuration, the result of such physical modeling suggests the closest to stability might be a handful of clockwise-counterclockwise pairs of rolls, very roughly comparable to the number of plates found on Earth.

But the more final near equilibrium result is not clear until one takes into account what the plates do. Driven by shear, as an elastic skin, into rocking-in-place and horizontally moving - in shear, in bowing, folding, cracking, and overthrust movements, they subduct and go back into hotter regions of the mantle. The materials mix. At that point, the differential densities - of water, of continental and ocean plate materials, come into play and begin to affect the isostatic gravitational balance of these floating plates, e.g., who does what to whom. The net effect, as we know it, is to create upwelling volcanic rings of fire around plates, with thin spreading plates under heat-quenching watery oceans, and compression and shear zones near subductions. Thus, thin ocean plates and thick continent bearing plates emerge. The net effect of that further split in formation is to increase the number of rolls and plate regions more nearly to the two handfuls of the number of plates observed. This represents, as a continuing approximation for long term, e.g., for the past 2.5 Gy, the closest approach to near stability for the surface processes.

Current state of modeling of mantle convection may be found in a review[23] and its references. Illustratively, the modeling work of Glatzmeier and Schubert is highlighted. A rather complex mixture of rolls and plume-like structures in the mantle seem the likely result.

As far as we can tell now, the first such settled out plate formation may have taken place in the rather narrow range 4.0-3.9 Gya (geophysicists may have mechanisms to further refine my estimate). But before pursuing the history of such events, I turn briefly to the effect of the appearance of such plates on Earth.

With its persistent gaseous atmosphere (e.g., of magnitude 1 normal atmosphere) and a hydrological cycle of water, that cycle erodes the protruding plates, e.g., in the order of 100 My, by sedimentizing the protruding continental plates. Again as an additional unstable process, driven horizontally and vertically by shear and upthrust by plumed rolls (one does not expect perfect Bénard cells) with unequal heating from below, and their isostatic imbalance by the redistribution of sediment carried by the hydrological cycle, these continental plates unbalance in a somewhat randomly fluctuation fraction of that 100 My, typically perhaps 1/3-2/3rds (30-60 My) and thus reform the plates anew. This process thus both promotes continued volcanism, involving igneous material from below, surrounding plate margins, sedimentization of surface materials, and subsequent metamorphism of the plates at their subducting margins.

Accounting for the grand 600 My cycle

I obtained my first clue to this 600 My cycle from Beloussov[24] whose more recent writings to date indicate that he still doesn't believe in horizontal plate-tectonic movements. Nevertheless, he stated: "Precambrian metamorphism was preferentially confined to certain intervals of time. These time intervals are [in Gya]: 3.0-2.8; 2.6-2.5; 2.2-2.0; 1.8-1.6; around 1.2; 1.0-0.9; and 0.6-0.5. These figures show that Precambrian metamorphism recurred at discrete intervals of [0.3 to 0.6 Gy] ... Each cycle begins with subsidence of the crust and ends in uplift of the crust, thus giving rise to marine transgressions and regressions .. ." The apparent average from these data is about 450 My (see, also, (25)).

With a little more detail, it has been fairly established that sea-level regulation has occurred for the past 2.5 Gy[26] and that most of the crustal material is just continually overturned past the early transients[27].

The actual details of the grand cycle are made clear by the impressive data set of Vail et al.[28] Against a background of the paleontological epochs of the Cambrian epoch, admittedly only for one grand cycle of 600 My, Vail et al. present world-wide data on the rise and fall of sea level. The data indicate sharp rises in sea level and slow falls, or - complementarily - slow subductions of land due to erosion and rapid unstable upthrusts of new continental plates. If the sharp rises (or unstable upthrusts) are removed, then one finds a smooth 600 My cycle.

To me, this clearly means that the 600 My underlying roll cycle is not tightly coupled to the elastic plates above, but that their motions proceed by shear coupling, cracking, lurching, rifting, with a certain amount of chaotic randomness in the process.

The sedimentizing process then consists of those smooth segments between sharp level changes, after which one or another of the continental plate segments undergo relatively smooth erosion and readjustment of its level relative to sea level. That process of continental transformation is thus scaled at a fraction of complete erosion of its upthrust, namely abut 30-60 My, loosely averaging 50 My. According to this model description, continental reformations has been going on since their earliest appearance, e.g., likely in the 3.8-4.0 Gya slot.

However, there is, in my opinion, a third process within the grand process scale of 600 My. This involves a property attached to those elastic continental plates and their contrast with thinner ocean plates. Their aspect ratio is a number of thousands of miles in extent, and perhaps 20-25 miles thickness on average. Effectively, they are thus thin elastic plates. With such configurations they are not rigid plates (see, (29)); they do not float on fluid mantle as "rigid" plates. Thus, when the process of erosion has taken place, much before the entire continental plate has become isostatically unstable (e.g., 50 My), so much material has been eroded at the margins onto the ocean plates (at the so-called continental shelves) that some portion or portions of the continental plates, as well as the ocean plates, deform and flex. At that point, such margins will undergo considerable sedimentation unloading and rapid flexing movement. I have estimated that process as going on at about a 5-10 My scale, perhaps averaging about 8 My, with the rapid changes taking place in perhaps under one My. Such process changes make up the most rapid component of the Vail et al. data set. Those three or four processes - 600 My, 50 My, 8 My, and very rapid one-million-year unloadings, are salient geophysical processes as far as geophysics- geochemistry is concerned.

Turn now to another grand look at the Earth, given these surface processes. In particular, I wish to inquire as to what zones might be most, or at least highly, active geochemically. I would submit that such a zone is at the triple interface of gas, liquid, and solid. More specifically, I would suggest that at the interface between the atmosphere, sedimentation at plate margins, and the liquid interfaces of rivers, lakes, and oceans, the ingredients are all assembled to create a very lively reaction bed within the porous solid medium. I would also submit that this region can promote more reactions, reaction formation, i.e. catalysis than almost any other region that one can elect. Among other things, it has the vigorous stirrings of wet-dry, warm-cold, flow mixing, stirring and upwelling, high electrical field fluctuations of many magnitudes, e.g., lightning as well as electrochemical flows, redox process conditions, and fluctuating atomic ingredients, all easily centered on a polar water solvent and hydrocarbon-water antagonists.

Further, I would call attention to the fact that ground water drainage and its river runoff from the hydrological cycle establishes a rich supply - first of soluble ingredients and later ion exchange ingredients in intimate contact with a reactor bed which - as the product of erosion - is scaled at every physical size from fractional micrometers to large boulders, and at every time scale from seconds (surface water runoff) to millions of years (deeper ground water). Thus aggregation and exchange reactions of all sorts can be self-scaled.

Another property of that geophysical (silicic) reactor bed is that, besides a capability for sequestering electric charges and potentials (see (17)), its interior surfaces exhibit fractal-like properties because of a sorbed boundary layer. Such clayey surfaces act as if they endowed their liquid contents with a negative surface tension so that flow fingering and creeping processes are possible, rather than balling up forms and processes.

I can add one final related property of liquids in small channels. My colleagues and I have established a new kinetic boundary condition for fluid flow in liquids, similar to slip in gases. The rudimentary flow boundary condition of smooth, vanishing, relative fluid, stream velocity at solid state walls is known not be true in the case of gases; its details were established by the theory developed and extended from Maxwell to Knudsen (see (30)). Even though, finally, the actual gas velocity is zero at the walls, the velocity curves sharply up and appears as if it started from zero at one mean free path into the walls. Thus the flow resembles a jump or "slip." A comparable boundary condition exists for liquids. A liquid molecule acts as if it rolls (or saltates a little) in a one-molecular layer at the walls. Thus the average velocity of that single layer is not zero, but it acts as if it were slipping at one half the adjacent "stream" velocity. Another way to look at the flow is to perceive a missing frictional torque at the walls[31]. This property is of great significance in small channels such as in biological membranes or cells. Specifically what it achieves is that, instead of liquid contact collisional fluctuations on the order of picoseconds (10^{-12} seconds), when molecules arrive in the vicinity of any electrical or catalytic patch (such as a globular enzyme patch in a membrane, or electric centers in an ionophore admitting moieties to a cell), the rolling or saltating boundary condition produces coherent residence times of 10^{-3} seconds or greater. Thus space-time chemical correlations with 10^9 gain are possible at such boundary regions. One can perhaps rip off up to 10^6 aggregation steps in a polymeric process (such as protein formation) rather than a single step per collision that the apparent boundary condition might suggest. I have suggested that this physical resultant contains the organizing force for living systems (see (32)). Making use of these contributing physical processes, I now turn to life's feasible origination.

Implications for life's origination.

Return to the earliest formation of surface skin. The earliest known surface materials on Earth are igneously-formed zircons as of 4.2 Gya. Any scenario for Earth's early process steps can hardly place solid surface activity much earlier. More recent findings have uncovered 3.96 Gya rocks with zircons[33]. Putatively, these findings are the oldest known igneous surface rocks on Earth from Earth. Add to this the knowledge that it is more than likely that meteoric bombardment, keeping the surface hot, existed up until 3.9 Gya. Thus one surmises that it was hardly possible to have started up much of an eroding hydrological cycle at solid skin plates before 3.9 Gya. The low temperature surface chemistry I alluded to had little chance to take place before that time.

The first known metamorphic rock, metamorphosed from earlier sedimentation is Isua at 3.8 Gya in Northern Greenland. It appears to contain life forms (see (17)). I take this to mean that the evolution of life on Earth, if it started in this solar system (a very high probability), had to take place in that 3.9-3.8 Gya slot. There is very little measure extensibility in that time slot. So I accept it as the source period. I therefore have to indicate why life could emerge de novo in that frame.

I cannot assume life starting in a low probability "soup" by homogeneous catalysis. Whether he wanted to or not, this is the main idea from Oparin's brilliant originating conjecture[34], about a purely chemical basis for life's origination, which dominants the thoughts of most investigators. Neither can I accept a rapid formation of modern protein catalysts. None of the gaseous atmosphere production models come anywhere near producing that complexity. Instead what I have available, conceptually, is a time slot of 100 My for a "first" geophysical generation of continental plate-sized sedimentation. But consider the possibility of de novo chemistry dependent on all the mechanisms I have named. Most telling, to me, is reactor bed self-scaling, electrical sequestering in silicic - particularly clayey (sial) - materials, the presence of COHN and metallic ions, low surface tension on small moieties, the variety of stirring and mixing forces, and the boundary amplification in small channels of liquid (to the chemist, I would say that I believe that nature at that time and I at this time are about equally ignorant of any of the detailed chemistry that will become exceptionally useful. But my proposal is that I can figure out what nature then did in much much less that 100 My).

Nature does not perform miracles, but nature is a tinkerer. The advantage of a 10^9 process amplification and 100 My time frame in an incessantly mixing bed with various affordable delay time process scales is that if there is a relatively "faster" chemical process in that mix, only emergent in a hierarchical pyramid of steps, e.g., as fast-slow combinations, it has good probably of occurring. I am not seeking for chemical processes catalyzed by modern fast catalysts. I will accept very slow catalysts in among the delay times of the reactor bed. Thus one only needs a reasonable handful of scenarios that might be arrived at by working backward. I am not looking for big forward jumps. I have outlined one such scenario (see (17)).

If I regard a living cell to be a bounded container which only permits a one-way admission of water as growth, and a continued fission at a critical size into two (cells grow-divide in an indefinitely continuing sequence), I can imagine such a process run by osmosis, perhaps even electro-osmosis. A watery droplet and an oily surface can produce such a candidate. Within a suitably-scaled porous reactor bed, I can imagine that the breakdown of surface tension could permit a growth and evolution of filaments (polymers) and droplets (cell-like units) to continue indefinitely. But that has no persistence.

If it were to take on-board elementary units involving a metal, or say any electron, proton, or ion exchange unit and an organic unit capable of forming a combination, that could then furnish a source for the internalizing, osmotic drive of water. And so forth for additionally needed steps, always supported by the "womb" of the geophysical reactor bed until autonomy - of energy, of reproductivity, of mobility - is achieved (see (17)).

One does not have to be hung up on the specific scenario. One knows the forces available; one needs simply to thread the maze and work out a hierarchical sequence <u>using these sources and within that preferred reactor bed. The geophysical modeling clearly indicates with high probability, that natural processes on Earth evolved a feasible scenario in 100 My</u> in such a reactor bed.

Let us provisionally accept that this thesis is true, and possibly even reproducible in a laboratory. What are the further consequences?

Continuation of life's evolution.

Note, that because life's chemical processes as transformed from a geophysical-geochemical reactor bed requiring some appreciable fraction of 100 My for starting up and continuing to run at some much shorter, e.g., year, season, day scale in a self-generating autonomous biochemical reactor bed (the "body" of the organism), scaled at perhaps the day or fractional day scale (as found in a prokaryote cell today), does not mean that the system and its process has achieved any extraordinary immunity to "outside" forces. Cells still operate at the chemical level of ionic and covalent bonding, and they can easily be penetrated by all forces that can exceed that level, e.g., 13 e.v. for the strongest hydrogen bond. Therefore it is no accident that galactic and cosmic radiation, quickly showed a capability for modifying the relatively fragile chains of such polymeric bonds. In one way or another, life's biochemistry simply found ways to bootstrap a polymeric chemistry, and at each level of bootstrapping put itself at increasing risk to external forces. Obviously, it had acquired regulatory immunity to many of the environmental buffeting forces in its reactor bed home, but not to those higher levels of both planetary, extra-planetary (solar), and extra-solar system sources. Thus, that led to polymeric mutations, involving both breakdown and symbiotic aggregations in gene pool coding material. That one mechanism has been clearly grasped by the biologist, biochemist, and biophysicist. But that mechanism does not go all the way. So where do we find the remaining theme?

Higher-ordered evolution

Note, once again, that because the living organism has achieved some additional biochemical cooperativity in their polymeric encoding chains, does not mean that they have achieved any additional immunity from outside. To put it in metaphor, you are affected more by a little alcohol than is almost any solitary cell (chemists may judge my metaphor). So the fact remains that the process of attack on the living system at the level of its persistence, still comes from outside forces. What the biologist regards as the living unit's "proximal milieu" is too parochial. It is not simply the cell and organism and local environment. While it largely consists of the biochemistry of the genetic coding material[16], which is all that remains of the original organizing process, the "proximal milieu" contains also the total new environment, and that environment remains geophysical-geochemical.

So if we wish to see what continues evolution at higher levels, e.g., species and above, we have to return to that geophysical environment which, to me, means going back first to the 600 My, 50 My, and 8 My processes. If we cannot locate the mechanisms there, then we might have to expand our search further.

Clearly the 600 My process is used up. By loose coupling, it drives the plates, and perhaps it might even affect life in some shadowy fashion. But it is more intimately the 50 My process that confronts life.

That process appears as continent formation and change. The process appears suddenly with drastic plate movements in what is likely one My or less (witness Man's attention to volcanoes and earthquakes). We are not discussing those abrupt changes. It is the longer 50 My or so of gross sedimentization that we should look at.

Now clearly, from a number of specific examples of the last few such continental movements, we know that many living species persist through the period of plate separation, and that the separated species then undergo their relatively slow changes. Why relatively slow? Because we can easily detect the biochemically c1ockable similarities in the separated species.

Let me make the point, however, that the 50 My sedimentization process is a slow process intrinsically. During that long term the only dominant process is the point-mutation process driven largely by cosmic radiation slowly changing contents in the gene pool (as a molecular clock) and the gradualist Darwinian evolution driven by "natural" selection or breeding out of the gene pool (see, for example (2)). The sedimentization process of the continents, other than slowly changing the environment and climate, does not affect any other changes except how it influences the "natural selection" of the organisms. So Darwin, in this segment, was right. But that process does not drive speciation changes.

Those changes come from the two overwhelming physical processes - of the 8 My or so local re-sedimentizations of water-Earth margins (not only at oceans but of all large bodies and fluxes of water, and particularly including ground water changes), and of the fast plate changes (under a million years or so). Those sedimentation changes literally overwhelm the local biochemistry of the genetic code. (We, of course, believe that it is understandable that much rarer astrophysical processes, such as catastrophic asteroids, can also perform such overwhelming functions in both the atmospheric and oceanic phases, but the evidence indicates that it is likely rare). That of course sounds very strange, but it has to be understood.

Recall that within 100 My, starting from scratch, an initial sedimentation was able to go from elementary compounds and complexes to the hierarchically much richer and faster processes of prokaryotic chemical coding. But "now" (after 3.8 Gya; and also after 2.5 Gya with an additional atmospheric transformation from reducing to oxidizing), one is dealing with a richer ensemble of molecular and supramolecular players. The same general issue of a sedimentary bed at a triple interface of atmosphere, hydrosphere, and a stretched out sedimentized solid still serves as a reactor bed for those higher ordered molecular moieties - small ions, medium sized molecules, peptides, proteins and their catalysts - and higher ordered factory subunits, viroid, and virus machines. The tryout reassembly process no longer takes 100 My. The catalysts are a million-fold faster (but the reactor bed is also more diverse). So it comes as no surprise that the new tryout period is now about 8 My in these newly rearranged reactor beds (the catalytic gain is still represented by the liquid rolling boundary condition, but now it can work more selectively on fast catalysts in its 10^{-3} second residence time). Namely, what regional, marginal, sedimentation does in upsetting a local environment is that it "decimates" many species. It creates new chemical combinations and it runs through a whole host of chemical selections, to find higher ordered associations that can work. What kind of viable organismic "monsters", i.e. diversification of species, may arise operationally is another physical question we are not trying to answer. My model estimate (see (35)) is that the precipitant selection process takes place at the phylogenetic level that the geneticist or biologist calls "classes."

What is produced every 8 My or so are Ur-species which can then diversify slowly at the mutation and selection level to produce the phylogenetic complexity of that new "class." <u>That I propose, is the missing ingredient in modern evolution, spelled large</u>.

Comment on mechanisms

One sees that this higher ordered process is more like a "Lamarkian" chemical evolution driven from the same kind of but now more dispersed reactor bed in which life originated - now distributed at the triple interface of gas, liquid, and solid, still depending on an atmospheric stirrer, a hydrological mixer in oceans, ground waters, rivers, reacting on the solid surface of sedimentation.

To those who might view these ideas as speculative philosophy, marvelous or otherwise, but still lacking in mechanistic realizations, I will offer them clues which I believe have already emerged. In order of recentness:

a. In two articles[36] entitled "Economies of Scale" and "Hungry to Evolve?", the former suggests that new separation techniques have demonstrated that tremendously more viruses (0.2 micrometer scale or smaller) are to be found in oceans and lakes than have been identified heretofore only by fine filter separations. The viruses found have been both crystalline-shaped and also bacteriophage-like tailed, the latter presumably quite mobile. The research discussed, reported on originally in *Nature*, had suggested that the viruses might be an avenue for the transfer of genetic information among bacteria. Note that bacteria are also known to leak some genetic material. I take that study to imply three things. First, it suggests that not only the oceans and lakes, but all other condensed and pooled waters are rich sources of rich viral "catalyzing" machinery that can transform genetic material (with their "to hell with the organism" point of view), and also including all porous media, such as ground waters and ocean beds which should also be excellent storage bins for that material which becomes easily available with upwelling and the hydrological drive in its more extended processes. Second, those scaled porous media act as a suitable catalyst for continued viral transformation which would undergo considerable mixing and broadcast with relatively rapid overturn of those water bearing beds and the water contents. Third, at the same time, they furnish both fast and slow scaling processes that can match both the catalytic transformation and the redevelopment of new biochemical symbioses. These porous beds thus carry a graded series of chemical and biochemical ingredients, from small ions, larger molecules, macromolecules, viral informational molecules, bacterial cells, some minimal leakage and sharing of genetic material, electric charges and potentials, considerable concentrations, scalings of both space and time making some kinds of catalysis quite probable, nonlinear convection at fast geological time, e.g., 1 and 8 My scalings, but a wide range of slow chemical processes. Whatever emerges represents the effect of one kind of geo-biochemical stress on the biological environment, but note that it is a stress that changes drastically at these geological turnover scales.

b. The second article, discussing another article in *Nature* suggests that cells can "choose" to mutate beneficially and adaptively. Their evidence is a strain of *E. coli*, which, no longer possessing a gene which permitted them to digest lactose, rather rapidly showed mutants capable of digesting lactose. Another experimenter showed the acquisition of a capability for digesting a particular exotic molecule - salicin - by a strain of bacteria which required the extremely rare occurrence of two specific mutation events. While obviously controversial, the directing of mutations has been reopened for consideration, certainly at viral and simple cellular levels. One interesting and serious suggestion is that cells starved for nutrients may make mistakes in transcription of their genetic material, and/or may cannibalize their own protein for energy. If DNA-repair enzymes are the ones destroyed, that may make errors more frequent. Also, when DNA is in the single strand form, they are much more vulnerable to attack and mutation. This is another possible illustration of the effect of geo-biological stress in calling up "selection" pressures. While the existence of only a few such illustrations are not yet compelling, one can surmise that growth of examples may likely become explosive.

c. The older known illustration, compatible with (b), is that in time of stress, cells will shorten up their transcription biochemical sequences. That also contributes to the notion of mutability of the chemical genetic material as it may be involved in long process chains.

d. As far as the evidence for the geophysical process of driving mantle rolls and roiling the surface plates, very recent evidence beyond even the Glatzmaier studies is to be found in *Nature*, for example the relative sharpness of the end of the gravitational bombardment era as of about 3.9 Gya, and what that means in shaping the existence of atmospheres on the inner planets, and the temperatures and plasticity of their surfaces; also the considerable elastic depth of Earth's continental plates and their age as almost direct evidence for the existence of underlying mantle rolls similar to the configurations suggested by plates.

Coda

Having begun a study of the theory of operation of all naturally working, self-organizing,· viable systems in the mid-60's[37], I began to realize that I had uncovered a new subject for physical study, the physics of complex systems, and that idea crept into the title of every paper I wrote from that time on. My colleagues and I put the name and concept of "homeokinetics" on that subject[38, 39]. To us, *homeokinetics* represents *the dynamic regulation, internal and external, including self-organization and demise of complex systems in nature by thermodynamic - hierarchical - machinery and processes.* I was pleased to find two formal physical measures for those field systems. They were *field systems* because their distributed interiors represented fields, separated from but operating within exterior world fields. These measures were a measure of condensation, the mechanical-thermodynamic bulk modulus, β, and the internalizing transport measure of bulk viscosity, λ. The fantastic beauty of these two measures is that they furnish a space and time scale for such complex natural systems. If

β = bulk modulus

ρ = field density
C = propagation velocity in the field medium
λ = bulk viscosity

then

$$\beta/\rho = C^2, \quad \lambda/\rho C = \delta, \quad \lambda/\rho C^2 = \tau$$

τ = the relaxation time constant of the field
δ = the effective mean free path of the field

and if the bulk viscosity, λ, is compared with the shear viscosity, μ, the transport measure of external momentum, their ratio is a measure of the internal complexity.

$$\lambda/\mu = \text{internal action/external - translational - action}$$

$$\approx \text{internal time constant/external time constant}$$

That is, it can be shown that the bulk to shear viscosity is the ratio of internal action within the system to the external, translational, action that appears out of the system[40]. Action is the physical product of energy and time. That action ratio is essentially the internal time delay in action compared to the translational time delay, or external relaxation time. In complex systems, by our definition, that time ratio is very long.

To illustrate, so that it makes sense: A cookie going into your (or any) complex body does not lose its energy, which is conserved thermodynamically. But compared to all other unit actions you undergo externally, it is long time delayed in its chemical transformations in your interior. That long time delay, because the interiors of complex systems are complex thermodynamic factories, is our notion of the hallmark of a complex system. To us, the physical issue is not the mathematical or logical complexity a description of the system, but the complexity of internal action, which is defined by the relative time allotted to it.

Thus the measure of physical complexity of a field system composed of complex atomistic-like entities is the factory day time scale of action of the individual entities relative to the time scale of their interactive, relaxation time movements.

Now biologist colleagues told me that they might accept this attempt at a physical - thermodynamic - modeling of complex fields such as the living system when I could present a physical theory for evolution. I wish to show why I have been able to reply to that challenge with what I believe to be some measure of success.

First, I want to make certain that the character of the bulk viscosity is understood. The shear viscosity is a measure of the transport of momentum, i.e, externalized momentum, carried by atomistic carriers from region to region. (Recall, that how momentum goes or changes is the hallmark of the Newtonian outlook). The bulk viscosity is a measure of all other such transport. That can only be the transport into internal degrees of freedom of the atomistic-like entities. Chemical processes are identified by their reaction rate measures which are transport or diffusivity measures of chemical bond processes, e.g., the making, breaking, or exchanging of bonds <u>between</u> atomistic components.

Thus while chemistry is one kind of process that might be going on in the complex interiors of some atomistic fields, it is not the totality of such processes. Therefore, complexity is not to be identified solely by the nature of chemical processes going on. The bulk viscosity is a much more inclusive measure of all internal processes going on in complex atomistic entities.

I make this point, because: (a) the bulk viscosity - except for relatively simple kinds of rheological field entities, e.g., simple polymers or complexes - is still largely only viewed as a formal total measure of internal processing, yet (b) it can be shown - in simple cases - to have very interesting properties. For example, it can be shown to augment the hydrostatic pressure. Thus, in a simple gas, the hydrostatic pressure consists only of the momentum flux of atomistic units colliding -- transferring or interchanging momentum -- with each other or a wall; in a denser gas or liquid, in addition, there is a component from the longer range interatomistic forces of attraction or repulsion. In a high bulk viscosity field of atomistic components, there is a third component proportional to the bulk viscosity. That pressure component we have called **the social pressure.** It wells out from the interior of complex atomistic entities to equilibrate the pressure exerted by the environment on these entities. It is that component of pressure that makes complex systems look and act different from simple physical systems. It is responsible, for example, for their extensive memory functions, and the kind of external socializing processes that they enter into. That is why we have referred to our study of complex systems, in a catchphrase representation, as the study of nature, including life, humankind, mind, and society. We have written extensively on such applications[41-44]. Now finally it reaches more adequately up to biological evolution.

Here we see how the bulk viscosity transport process becomes involved in what is called Darwinian selection pressure, but now we see how it reaches farther out to the geophysics and geochemistry of Earth in creating a selection pressure on speciation as more of a Lamarkian-Darwinian evolutionary mix. The social pressure, emergent as a selection pressure, emerges hierarchically from the mixed actions of atomic nuclei, atoms, ions, molecules, macro-molecules including genetic material, viruses and impacts on the internal actions of cells and multicellular organisms to drive speciation all within their geochemical-biochemical fields. Hopefully, now with this mechanism, physics and biology are reasonably joined.

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