

BIOCOSMOLOGY 1

Cosmic Symmetry-breaking, Bifurcation, Fractality and Biogenesis

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ABSTRACT: *This paper explores the non-linear quantum foundations of biogenesis in interactive bifurcations between the properties of the elements, sourced in the transitions induced by cosmic symmetry-breaking [King 1978]. The key interactions forming the biogenic pathway are modeled in terms of interactive quantum bifurcations explaining why the bioelements play the interactive role they do and why central biomolecules are cosmologically abundant products of the gas clouds forming young stars. RNA and related nucleotide molecules gain a plausible cosmic status, along with major features of the genetic code, and key features of metabolism, including ion and electron transport, the citric acid cycle and glycolysis.*

Keywords : cosmology, symmetry-breaking, molecular evolution, chaos, bifurcation, complex system, fractal, biogenesis, astrobiology.

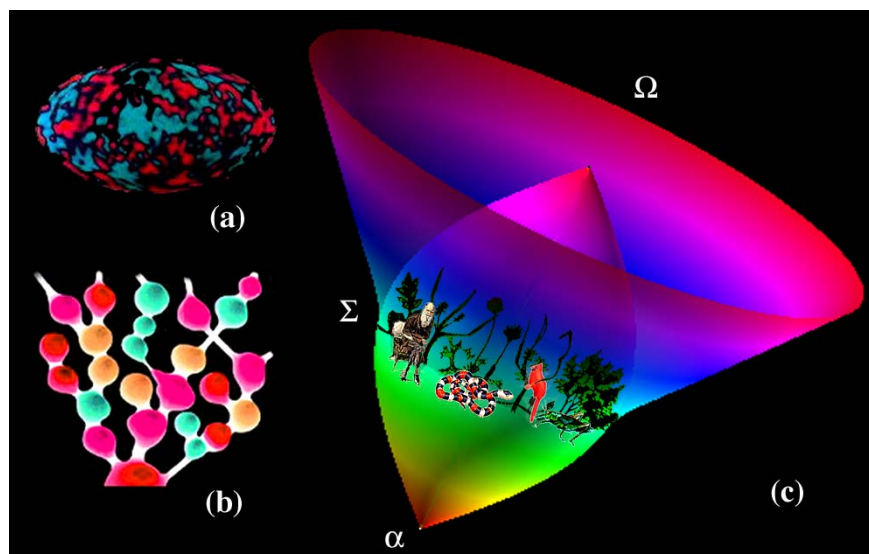


Fig 1: (a) Cosmic background. The inflationary fireball. (b) Paradise on the Cosmic Equator. Biological systems form a central cosmological manifestation of interactive complexity in the universe. The consummative Σ by comparison with the α and Ω of cosmological initial and final 'causes'. Biology's 'equatorial' position in space-time is fundamental in cosmological terms, as interactive culmination, even though biological energetics are too weak to withstand either the big-bang at the origin or the possible final fates, of attrition in an ever-expanding universe, a big crunch, or fractal inflation (b).

1: INTRODUCTION

The thesis of this paper is that biological structures such as tissues, and organisms are cosmological structures, culminating the interactive phase of symmetry-breaking, as fundamental as stars and galaxies to the cosmic design. This process is described in detail in this paper as a fundamental manifestation of non-linear quantum science, elaborating the fractal nature of fundamental force interaction, inevitable from the twisted nature of the forces as they have emerged in our universe. Symmetry-breaking as elucidated firstly in terms of the weak and electromagnetic forces, fig 5(a) results from evolution of the universe from a symmetrical state to one in which the Higgs field has become polarized into a state of lower energy, similar to that of a ferromagnetic substance. It is the transition of this underlying parameter that is responsible for the bifurcations we shall consider.

Although life is of fragile insignificance among the immensity of cosmic energies, its tiny entropy-reducing photosynthetic energy budget and fragile chemical bonds overwhelmed on the cosmic scale, it is nevertheless the interactive consummation of all the forces of nature acting together in sequence. Biological evolution is a stochastic² process combining random mutation and selective advantage, many of whose manifestations are opportunistic, but others the inevitable result of selective forces and environmental bifurcations. Although biological structures are genetically coded in a vast variety of ways by specific nucleic acid sequences, many features of life as we know it on Earth are the product of selective factors which lead inevitably to specific traits. These are founded on the cosmic factors causing the forces of nature to invoke the fractal non-linearities which make life possible. Traditional chemistry, despite its quantum foundations, treats molecules as arbitrary building blocks, which can be arranged in almost any combination using suitable reagents and energetic conditions as driving forces. However this view is incorrect when non-linearity and dynamical feedback are taken into account. The origin of life is dependent on dynamical processes of free interaction, not forced reactions and involves fundamental interactive quantum bifurcations and feedback effects characteristic of non-linear dynamical systems.

There is now clear evidence for the optimality of many prebiotic and biological molecules, giving life as we know it a cosmological basis as a culminating interactive structure. This paper explains how the origins of chemical life, major aspects

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2. Stochastic - a process mediated partly by random factors, such as the drunkard's walk or Brownian motion.

of biological evolution and the elaborate emergent structures of tissues, from biomolecules up to cellular organelles and even to the doors of perception of the conscious brain, are a fractal¹ interactive consequence of the non-linear laws of nature established at the cosmic origin.

In particular, this paper examines major key features of biogenesis, including the selection of the bioelements and the major chemical processes and molecular types contributing to complexifying polymerization and biological metabolism in terms of bifurcations triggered by cosmic symmetry-breaking. The core idea is that the origin of life has occurred as an interactive result of such bifurcations, in the context of the fractal non-linearity of chemical matter, in a transition from far-from-equilibrium dissipative structures to the replicative catalysis we associate with genetic evolution.

Major features of metabolism, including the role of nucleotides and polypeptides, light-absorbing chromophores, phosphate dehydration energy, RNA, the major features of the genetic code, Fe-S groups, ion and electron transport, phosphorylation and the citric acid cycle are all described as being generic features of a cosmically general bifurcation tree.

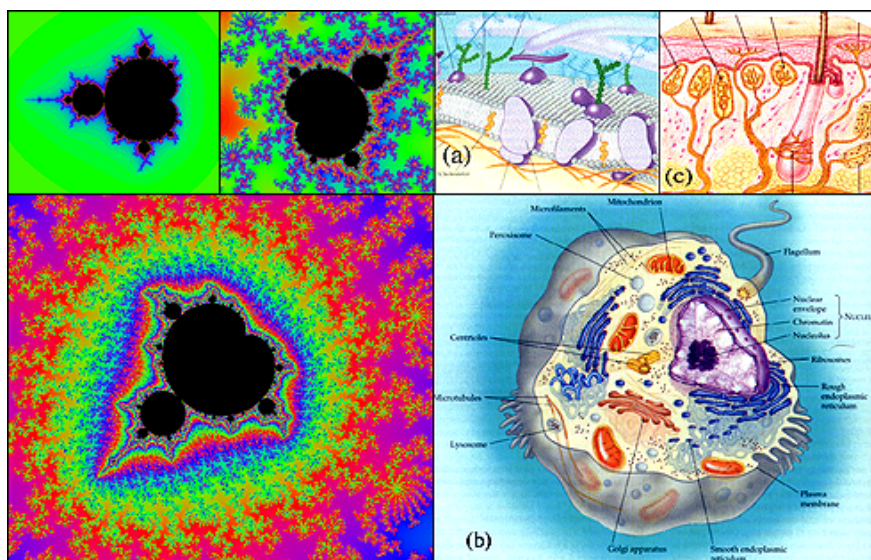


Fig 2: The quadratic iteration of the Mandelbrot set [King] compared with the interactive effects of inverse quadratic charge interaction in tissues [Campbell]. Although their genesis arises from differing non-linear process, iteration on the one hand and interaction on the other, the multi-fractal structures of tissues have features similar to the Mandelbrot set on changes of scale. These fractal effects reach from the molecular (a) in which individual proteins are illustrated embedded in the lipid membrane, through cell organelles (b) to the intercellular structure of whole organs as illustrated by skin (c). Such scale-dependent coherence of structure is possible only because of the highly non-linear nature of the electromagnetic force in quantum charge interactions of fermionic matter.

Biology is a product of the twisted laws of nature derived from cosmic symmetry-breaking. The rich diversity of structure in molecular systems is made possible by the profound asymmetries developing at the cosmic origin, between the nuclear forces, gravity and electromagnetism. The diversity of the elements and their asymmetric charge structure, with clusters of negatively charged electrons orbiting a massive nucleus containing all the positive charges in a concentrated nuclear 'droplet', is made possible only through the divergence of symmetry of the four fundamental forces. Without these asymmetries there would be only one or two simple atoms, consisting of bound particle pairs, without a clear distinction between the nucleus and orbital electrons, and none of the richness of the almost unlimited variety of molecular structures which can be generated by the over one hundred complex atoms occurring in nature as we know it. Chemical bonding is a consequence of the non-linear inverse square law of electromagnetic charge interaction in space-time. This non-linearity also gives rise to a succession of weak bonding interactions, generating the complex non-periodic secondary and tertiary structures of proteins and nucleic acids and ultimately the fractal structure of tissues and organs as indicated in fig 2. To appreciate fully the significance of this effect we need to review some of the elementary foundations of force unification, quantum orbital and bonding theory.

2: GENERATING A COMPLEX, TWISTED UNIVERSE

2.1 Quantum:

The four fundamental forces of nature - the strong and weak forces mediating nuclear binding and neutron-proton conversion, along with electromagnetism and gravity are believed to have emerged from a single superforce, perhaps a form of higher-dimensional string, or membrane theory, in twelve, or so dimensions, in cosmic origin, fig 3(a). In supersymmetry, each half-integer spin fermion (e.g. electron, proton, neutrino, fig 4, which form solid matter because only two particles of opposite spin can exist in the same wave function), is matched by a force/radiation-generating integer spin boson (e.g. Higgs, photon, Z_0 , gluon, graviton, fig 4 which can superimpose freely, as in a laser). This enables the negative ground state energy of the former to cancel the positive energy of the latter. However the lack of manifest supersymmetry may mean this cancellation is collective rather than individual. In string theories point particles become resonant loops, strings or membranes in higher dimensional space as distance shrinks, avoiding the infinite singularity of point particles. Strings and membranes attempt to

1. Fractal: Self-similar as in a tree or fern leaf, or having systematically-related structures on changes of scale, or a non-integer power law, as in molecules and the Mandelbrot set (see fig2).

solve the problem of the infinite self energies of point particles by allowing quantum objects to possess excitations as tiny, but finite loops, strings or branes. M-theory appears to unify several of these theories as dual representations of one another [Hawking]. This higher-dimensional space, containing a single generalized superforce is believed to have subsequently compactified most of its dimensions to sub-particulate scales, leaving the four dimensions of space-time, in a symmetry-breaking between the components of the superforce, to form the different forces we see today, in much the way a ferromagnet is polarized at minimum energy, breaking spatial symmetry, so that at the lowest energy, all domains point in one direction. Thus all but four (space-time) of these many dimensions may have curled up on microscopic scales to form inner dimensions like tiny tubes or tori. One or more of these 'hidden' dimensions may be extensive or even hyperbolic, leading to a fifth dimension hidden from most of the forces and particles, which may explain some of the unique properties of gravity.

The strong nuclear force is a secondary effect of the colour force between the three red, green and blue quarks comprising a proton or neutron in much the same way that molecular bonding is a secondary consequence of the formation of atoms under electromagnetism. The colour force has three colours and three anti-colours instead of two opposite charges. It also comes in pairs of ground flavours so that the proton and neutron are a composite of up and down flavours uud and udd . The quarks' charges of $u = +2/3$ and $d = -1/3$ thus generate in threes the integral charges of the proton and neutron. The weak force behaves as a form of electromagnetism which has become very short range because it is mediated by massive particles, two of which also carry charge, which are believed to gain the required extra degree of freedom of non-zero rest mass and hence varying velocity by assimilating a concealed scalar particle, the Higgs boson [Georgi 1981, 'tHooft 1980, Veltman 1986].

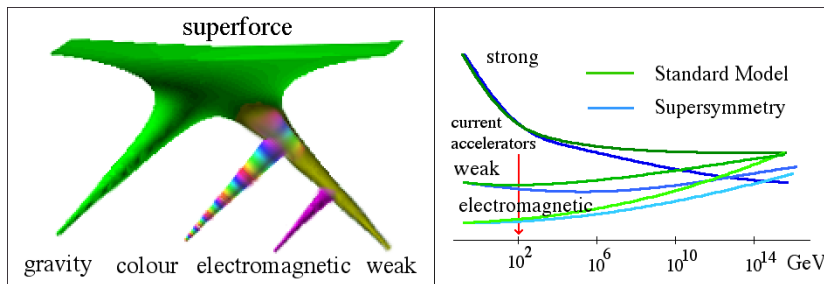


Fig 3 (a) Divergence of the four forces from a single superforce. (b) The three non-gravity forces converge in strength at the unification temperature.

The forces do appear to converge at extremely high energies - the unification temperature. The weak and electromagnetic forces have been successfully unified. Unification of these with the nuclear colour force is well described, but unifying gravity with the other quantum forces presents more fundamental contradictions including fine-

scale topological disruption of the structure of space-time, leading to potential contradictions between quantum theory and general relativity.

The nature of the internal dimensions is at least partially reflected in the internal symmetries of the known particles. If we add to 4-D space time the internal dimensions of colour (3), weak-electromagnetic (2+1), the Higgs field (1) we come close to the 11 or 12 believed to be involved in super-'brane' theories [Green 1985, 1986, Mukerjee 1996, Duff 1998]. However, despite millions of possible compactifications, of this larger space to 4-D space-time, none has so far been defined which completely matches our particles and forces. Whatever the exact features of the ultimate theory resolving the origins of the universe in unification, the form of the forces as we know them is consistently described as a consequence of symmetry-breaking.

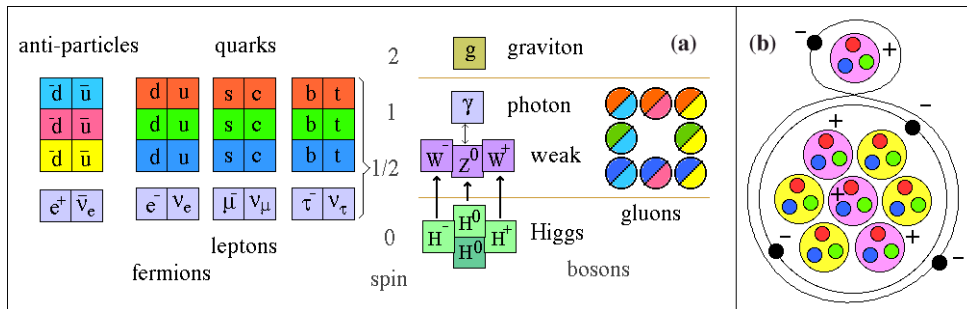


Fig 4: The standard model of particle physics involves half-integer spin fermions which obey the Pauli exclusion principle and form matter; and integer spin bosons which mediate force and radiation. Right: the composite structure of symmetry-broken fermionic matter is molecular, forming a hierarchy involving the forces in sequence colour, weak and electromagnetic.

2.2 Cosmic:

Complementing the quantum description is a cosmic one in which a central theme is inflation. Although recently questioned by difficulties finding enough dark matter to halt the universe's slide towards hyperbolic expansion [Krauss 1999, Bucher and Spergel 1999], inflation concepts remain central to understanding how symmetry-breaking of the forces may have generated the expanding universe we know. In summary, a seed universe in the symmetrical state, below the unification temperature is in an unstable high-energy false vacuum, like a super-cooled liquid which could freeze to form a polarized magnet. The false vacuum causes a gravitational repulsion representing the negative energy difference between the actual temperature and that required to maintain the Higgs field at the unification temperature. Under this 'antigravity', the empty universe, expands exponentially, smoothing quantum irregularities to structures on the scale of galaxies [Guth & Steinhardt 1984]. The breakdown of the false vacuum (in 10^{-39} sec) halts this inflationary phase, releasing a shower of high-energy particles as latent heat, forming the hot expanding universe under attractive gravitation we are familiar with. The gravitational potential energy gained almost exactly equals the kinetic energy of the particles, making the generation of the universe possible from a quantum fluctuation. Indications are that the universe will continue to expand, suggesting a hyperbolic inflation or fractal

cosmic inflation [Linde 1992], in which the active tips of the universe are permanently inflating, to leave behind non-inflating bubble universes such as ours, or a continuing long-range repulsive quintessence 'dark energy' force [Ostriker and Steinhardt 2001]. This problem combines with the evident lack of sufficient matter to keep spinning galaxies stable, to suggest forms of dark matter may also be required. These may explain galaxy clumping around giant structures such as the 'great wall'.

Cosmology is preoccupied with alpha and omega - initial and final causes - the origin and fate of the universe. But there is another perspective, in which life and its complexity is as central to cosmology, forming the central non-linear interactive processes - the consummative sigma that make the universe the complex one we know and exist within, during the vast epochs of its mature evolution (see fig 1). The anthropic cosmological principle [Barrow and Tipler] rests on just such assumptions.

2.3 Interactive:

The consequences of this symmetry-breaking divergence lead to all the complex structures we see around us today. Although life may be created and annihilated during the formation and demise of the universe, just as the creation and annihilation of virtual particles are essential to quantum field theory, the biological forms and processes can have a cosmic origin as generic structures and a cosmic significance as culminating interactive complexity (fig 1). Although fragile, on the cosmic scale of energies, the complexity of life is the supreme culmination in complexity of the interactive quantum process initiated in the quantum symmetry-breaking. The interaction between the wave-particles emerging from the cosmic origin results in distinct effects on microscopic and cosmic scales. On the cosmic scale we find fractal structures - galaxy clusters, star and planetary formation, mediated by gravity, through contraction, heating and the ignition of the strong nuclear force, producing the energy of stars and the secondary photosynthetic energy of visible light. On the quantum scale we find integration of quarks to protons and neutrons then atomic nuclei in stars, then the formation of chemical elements in supernovae, and finally molecules, in the lower energetics of planets of second generation sun-like stars. Quantum interaction of fermions reaches its full interactive complexity only in the molecular assemblies of biochemistry and finally, in tissues, organs and organisms, the brain being the most complex expression of chemical non-linearities so far known, forming "the three-pound universe" [Hooper and Teresi].

The hierarchical process leading to molecular complexity involves all the forces in sequence, fig 4(b). Quarks are bound by colour force gluons into composite particles, such as the proton p^+ and neutron n . These interact by the strong force, via the nucleosynthesis pathway, to form the elementary nuclei. The nucleosynthesis pathway generates over a hundred atomic nuclei from the already composite proton and neutron. Exchange of identity between protons and neutrons is mediated by weak force decay. The parity between these is slightly broken to balance equally filling lowest energy nuclear quantum levels with increasing electromagnetic repulsion of the positive protons, fig 5(c). Nucleosynthesis is a complex process, catalytically moderated by several of the isotopes of lighter elements, such as carbon and oxygen. Subsequently the weaker electromagnetic force interacts, firstly by formation of atoms through aggregation of electrons around nuclei and then by secondary interaction of complete atoms to form molecules. Molecular bonding is a non-linear quantum interaction, which is never fully resolved and thus perpetuates in a sequence of stages through successive strong and weak bonding interactions, making possible the complex tertiary structures of biomolecules.

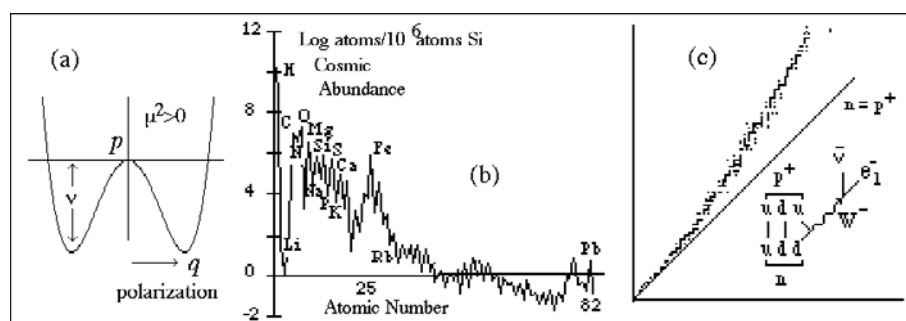


Fig 5: (a) Symmetry-breaking between the weak and electromagnetic forces is modeled as a shift of the Higgs field from zero polarization p to a lower energy polarized state q . It is this shift of the Higgs field as underlying parameter that is at the source of our symmetry-broken non-linear interactions in chemistry, the elementary bifurcation tree. (b) Cosmic abundances of the bioelements. (c) The neutron excess of the stable nuclei reflects the interaction between the strong and electromagnetic forces via the weak force

Generation of the chemical elements requires a cosmic cycle through the supernova explosion of a short-lived hot star, generation of heavier elements like gold possibly involving the collapse of twin neutron stars after supernova formation [Rosswog 2001]. In the second phase, these elements are drawn into a lower energy long-lived sun-like star, the lighter elements associated with terrestrial biology occur in relatively high abundance as a result of nucleosynthesis dynamics, fig 5(b), and can become concentrated on mid-range planets.

The culminating interaction of the differentiated forces representing the final re-interaction of the residual lower energy electromagnetic bosons with their fermionic counterparts in the electromagnetic orbitals of molecules occurs as a result of irradiation of molecular systems by photons emitted as stellar thermal radiation. The typical coupling of the 5000°C surface temperature of sun-like stars provides photonic energy suitable for energizing weak-bonded molecular structures, without destroying them. A pivotal environment in which this final negentropic low-energy reentry occurs in abundance are the surfaces of rocky planets in the temperature belt where water is liquid. The variety of planetary systems so-far discovered demonstrates the capacity of the universe to explore, through the chaotic non-linearities of gravitational orbits, a diverse array of planetary surfaces, ensuring the phase space of potential molecular environments is well explored on a cosmic scale.

3: THE ABUNDANTLY FECUND UNIVERSE AND BIFURCATIONAL ORIGINS

As time passes, more and more evidence is accumulating that, the universe and its galactic gas clouds are abundant in organic chemicals, from the simplest molecules to sugars, amino acids and nucleic acid bases. Since Fred Hoyle coined the term “wooden universe” based on infra-red spectral data indicative of carbohydrate emission, there has been an awareness of the potential of galactic gas clouds to be cosmically abundant sources of prebiotic molecules.

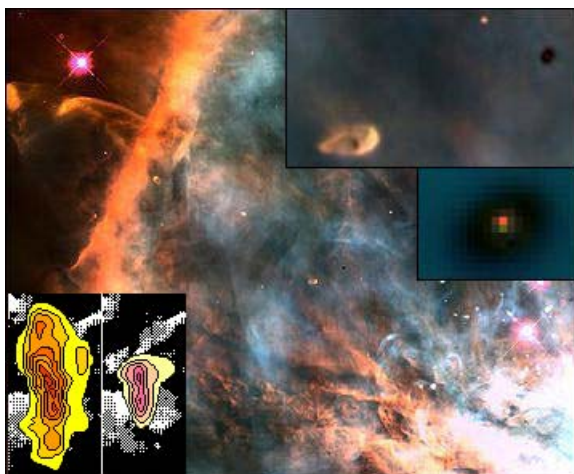


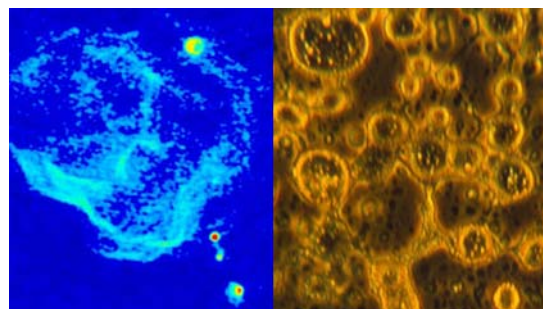
Fig 6: The Orion nebula contains newly forming stellar systems possibly including the propylid (tiny black dot centre) with a dark 'planetary' disc (top and centre right) [Buhl]. Some of these newly forming stars are also surrounded by clouds of HCN and HCHO (inset bottom-left) [Hubble telescope image].

Radio-telescope data as early as 1974, [Buhl] demonstrated clouds of multiple-bonded $\text{HC}\equiv\text{N}$ and $\text{H}_2\text{C}=\text{O}$ spanning the region in the Orion nebula where several new stars are forming, fig 6. These are key precursors of complex polymerization pathways discussed below. Glycine has also been found in interstellar gas and adenine is an abundant product in simulations of collapsing interstellar gas clouds containing a dozen elements including hydrogen, carbon, oxygen and nitrogen [Chakrabarti 2000]. Along with amino-acids, all of A, U, G, and C have been detected in carbonaceous chondrites [Hua et. al. 1986], such as the Murchison meteorite. These also contain amphophilic membrane forming products [Deamer and Pashley 1989]. Cometary impacts are believed to have coated the Earth in a rich endowment of organics from the earliest stages of solar system evolution when impact rates were high.

Glycoaldehyde has recently been detected by Jan Hollis [2000] in a cloud of gas and dust 2 light years across of a type from which new stars are formed. He notes “Interstellar clouds are spread throughout the galaxy and you often find the same molecule in many different clouds. Since these organic molecules are so widespread, it may mean that pre-biotic chemical evolution is an ongoing process.” Glycoaldehyde can combine with other carbohydrate molecules to produce ribose.

A team led by Jason Dworkin [Dworkin et. al. 2001] has also formed complex organic molecules under the harsh conditions of outer space. The main ingredients of interstellar ices are simple chemicals frozen together. Mostly water, some ammonia, carbon monoxide, carbon dioxide and methanol. The team froze a mixture of these chemicals into a thin solid ice at temperatures close to absolute zero ($-441^\circ\text{F}/ -263^\circ\text{C}$) under extreme vacuum and exposed this to harsh ultraviolet radiation that mimics the radiation in space produced by neighbouring stars. Instead of finding a handful of molecules only slightly more complicated than the starting compounds, hundreds of new compounds were produced in every mixed ice studied. The types of compounds produced are strikingly similar to many infalling meteorites and interplanetary dust particles. “Thus much of the organic material found on the Earth in its earliest years probably had an interstellar heritage”.

Fig 7: Left: The cloud from which glycoaldehyde has been detected [Hollis]. Right Droplets made by harsh radiation under interstellar conditions [Dworkin et. al.]



The Kuiper belt contains most of the solar system's water and organic molecules. Infra-red studies have confirmed water-ice and hydrocarbons on some objects [Couper and Henbest]. The capacity of complex organic molecules generated in space to enter Earth's atmosphere intact has been confirmed. Jeffrey Bada has found evidence from a site in Ontario that “mother lodes” of buckyballs, (football-shaped complexes of carbon atoms), have fallen intact to Earth from outside the Solar System when a meteoroid the size of Mount Everest crashed 2 billion years ago. The impact site contained about 1 million tons of extraterrestrial buckyballs loaded with helium, an element rare on Earth, but abundant in interstellar space. If buckyballs could fall on earth without burning up, so could complex organic molecules [Cohen 1996]. Amorphous ice from comets can also protect organic molecules [Blake and Jenniskens 2001].

Although these fecund origins give rise to suggestions of panspermia by researchers such as Francis Crick [1981] and Fred Hoyle [1979], following on Svante Arrhenius' [1907] idea of migratory spores, there are a host of proposed mechanisms for a planetary origin. Many planets have already been discovered orbiting nearby stars, although these tend to be gas giants. Habitable planets are also believed to be relatively commonplace in our galaxy [Frank et. al. 2001], although some problems remain [e.g. Muir 2003]. Origins of life from cometary material, through energetic discharge from lightning, solar radiation, volcanism, hydrothermal vents have all been proposed as well as shock energy from asteroid impacts [Osinski 2003]. Seeding of life from Mars [Davies 2003] as well as the reverse process [Ball 2004] have all been proposed.

Given galactic clouds of organic molecules and rich depositions of cometary material containing the bioelements, the Gordian knot of the origin of life becomes how to explain the known fractal structures of tissues, cells, organelles and molecules and how key molecular processes, from replication, through translation, to the excitable membrane come about. Given the position an Earth-like planet occupies, with a solar input of free energy from stellar nuclear reaction, the planetary surface becomes a classic far-from equilibrium thermodynamic system. Solving the problem of the origin of life is equivalent to asking a fundamental question in non-linear science - “Are there genera of fractal structures in the dynamical space of interactions which can ‘evolve’ as ‘dissipative structures’ to support the onset of replicative, or excitable life.” The ‘evolution’ of such structures has moved from predominantly bifurcation-based chemical processes to the manipulation of these through

the advent of catalytic replication.

This may have also involved a sequence of specialized boundary conditions, which varied over time to include many of the proposed biogenesis scenarios, from energization of molecules through electrical discharge, and irradiation, through phosphate-rich drying shorelines, high temperature iron-sulphur interactions around hydrothermal vents, and mineral processes involving clays. The non-linear bifurcation model places these all in relation to one another as contributory processes rather than stressing one aspect of the bifurcation scheme's features as key over others. The key to understanding this riddle is how the dynamics of catalytic replicators like RNA first get bootstrapped into complexity.

In the bifurcational model, the planetary interface is one which, given its free input and fractal bonding is not unlike cellular automata, such as Conway's game of life, which operating under conditions close to the edge of chaos and which become computationally unpredictable as to whether the process will ever complete. Under these conditions the automaton becomes a universal computer which gains this uncertainty through being able to initiate any computational process.

RNA along with its putated homologues has been proposed as the molecular gateway for the replicative-catalytic process which occupies our central theatre of biological computational unpredictability as a pregenitor and continuing facilitator of DNA- and protein-based life. RNA also presents some of the most serious thermodynamic complexity problems, given its relative difficulty of polymerization, but high capacity to catalyze its own oligomerization and self assembly in ribozyme-mediated interactions. Again RNA possesses generic characteristics which give it a natural place in the bifurcation scheme.

4: QUANTUM CHEMISTRY AS NON-LINEAR SCIENCE OF EMERGENT COMPLEXITY

The basis of orbital energetics, and hence chemical bonds, derives from the solutions of the Schrödinger wave equation. Put in

its simplest form, in one spatial dimension, we have a standard wave equation: $\frac{\partial^2 \Psi}{\partial x^2} = \frac{1}{w^2} \frac{\partial^2 \Psi}{\partial t^2}$ (1) which we separate into a

harmonic time frequency component and a spatial 'orbital' wave: $\Psi(x, t) = \cos(2\pi\nu t)\phi(x)$ (2)

The solutions of this time-independent system, $\frac{d^2 \phi}{dx^2} = \frac{-4\pi^2 \nu^2}{w^2} \phi(x)$ (3), when the particle's Newtonian kinetic energy

$p^2 = 2m(E - V)$ (4) is interpolated, $\frac{-4\pi^2 \nu^2}{w^2} = \frac{-4\pi^2 p^2}{h^2} = \frac{8\pi^2 m(E - V)}{h^2}$ (5), gives the standard representation of the

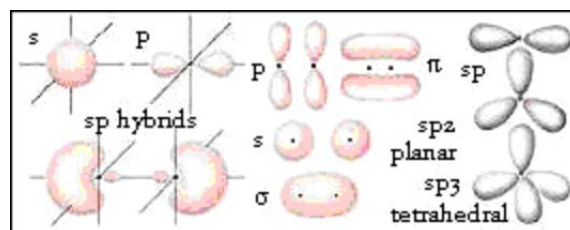
Schrödinger equation in one spatial variable: $\frac{h^2}{8\pi^2 m} \cdot \frac{d^2 \phi}{dx^2} + (E - V)\phi = 0$ (6).

The power of this derivation and the fact that it was generated from wave equations, which are deterministic, and subject to linear wave superposition, has led chemists to conceive of quantum chemistry as linear in basis, however the charge interactions, are manifestly non-linear (inverse quadratic) and both those between the many electrons and the nucleus, and the many body problems of electron-electron interaction, within the quantum wave functions of the orbitals make exact calculations for all but the simplest atoms, let alone molecules, or such notoriously complex issues as the 'protein folding problem', fig 9, computationally intractable. In fact what we are seeing here is the manifestation of a non-linear fractal complexity, which is first manifest in the resonance integral of the covalent bond, but ramifies all the way to the structure of molecular complexes, organelles, and tissues.

The complex expressions of chemistry, particularly in biology, are manifest as a final non-linear interactive consequence of cosmological quantum symmetry-breaking. The stability of the nucleus with increasing nuclear mass number and charge, fig 5(b), permits an unparalleled richness and complexity of quantum bonding structures in the nucleus and consequently in the electron orbitals around the diverse chemical elements. Electron-electron repulsions, hydrogen bonds utilizing lone-pair orbitals, polar and hydrophobic interactions, van-der-Waal's forces involving unoccupied orbitals, spin-orbit coupling, delocalized orbitals, and other effects, perturb the periodicity of orbital properties and lead to the development of higher-order molecular structures.

Fig 8: Although all wave functions obey quantum superposition, the non-linear nature of electronic charge distribution and its resulting occupancy energetics, the Pauli exclusion principle and additional electromagnetic effects results in the non-linear energetics of chemical bonding. This non-linear interaction is never fully resolved by any single bonding step and gives rise through subsidiary weak-bonding interactions to the global interactivity of complex biomolecules and cellular organelles.

Although quanta obey linear wave amplitude superposition, chemistry inherits an inverse quadratic non-linearity in the form of the attractive and repulsive charge interactions caused by redistributing electrons between orbital systems. Such non-linear interaction, combined with Pauli exclusion, is responsible for the diversity of chemical interaction, from the covalent bond to the secondary and tertiary effects manifest in the complex structures of proteins and nucleic acids. The quadratic nature of charge interaction, leads to a situation in polymeric chemistry akin to the Mandelbrot set, fig 2(a), and which is central in making complex molecules, fig 10, and the scale-dependent structures of tissues possible, fig 2(b).



The source of this non-linear¹ interaction is the foundation of all chemical bonding, the inverse square law of electric charge interaction. Although the state vector of a quantum-mechanical system is a linear combination of base states, exemplified by the formation of linear combinations of s and p wave functions to form the four sp³ hybrid orbitals, fig 8, the electrostatic charge of the electron causes orbital interaction to have fundamentally non-linear energetics. The total energy is represented by the resonance integral of the Hamiltonian composed with the wave function, divided by the normalizing overlap integral S.

$$E = \frac{\int \varphi^* H \varphi d\tau}{\int \varphi^* \varphi d\tau} \quad (7)$$

In the case of the one-electron Hydrogen molecule ion, with $S_{aa} = S_{bb}$ normalized to 1, we have 2 non-linear solutions

$$\begin{aligned} E_u &= \frac{H_{aa^-} H_{ab}}{1 - S} \\ E_g &= \frac{H_{aa^+} H_{ab}}{1 + S} \end{aligned} \quad \begin{array}{c} Eu \\ \diagup \quad \diagdown \\ EIs \quad \quad Eg \\ \diagdown \quad \diagup \end{array} \quad (8)$$

The capacity of orbitals, including unoccupied orbitals, to cause successive perturbations of bonding energetics results in an interaction bonding sequence, from strong covalent and ionic bond types, through to their residual effects in the variety of weaker H-bonding, polar, hydrophobic, and van der Waal interactions, merging into the average kinetic energies at biological temperatures [Watson et. al. 1988]. These are responsible for secondary structures such as the α -helix of proteins and base-pairing and stacking of nucleic acids, and result in the tertiary and quaternary structures determining the global form of large biomolecules and the globally-induced active-site effects central to enzyme action.

By contrast with the periodic crystalline or random amorphous structures of most minerals, the non-periodic scale-dependent primary, secondary and tertiary structures in proteins and RNA are critical to establishing the richness of their forms and their bio-activity, fig 9. The almost unlimited variety of monomeric primary sequences induce higher-order secondary and tertiary structures through subsequent folding of the polymer. These are possible only because the non-linearity of charge interaction which causes chemical bonding also gives rise to further residual interactions at lower energies which are resolved by cooperative weak bonding.

Proteins are powerful catalysts partly because, as well having active foci, which can invoke effects such as quantum tunnelling, enzymes bring to bear a global coherence of action, arising from cooperative weak bonding, which makes for both very powerful and responsive active sites. The 'protein folding problem' [Richards 1991] has remained a notorious issue of complexity [Frauenfelder and Wolynes 1994] and computational intractability with initial estimates of the time for molecular random search to be of the order of 10^{27} years [Winkler and Gray 1998]. Modeling in terms of a 'funnel-like' potential energy landscape, given parallel and potentially quantum computation by the molecular orbitals themselves is a plausible explanation for the rapidity of such processes.

Despite being genetically coded, such molecules form fractal structures both in the geometry of their primary, secondary, tertiary and quaternary structures and their active dynamics, as illustrated by the fractal dynamics of myoglobin [Ansari et. al. 1985] and ion channels [Liebovitch et. al. 1987a,b, 1991].

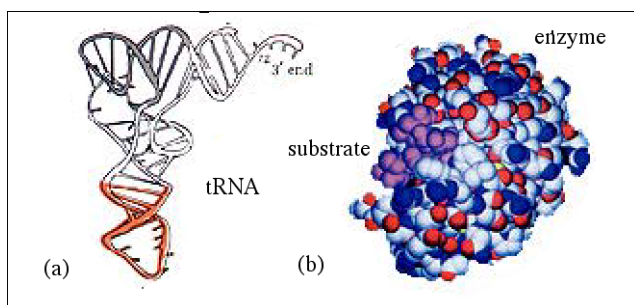


Fig 9: Global t-RNA and protein (enzyme) tertiary structures are the result of hierarchy of strong and weaker chemical bonding interactions operating on a non-periodic secondary structure. These structures are reflected in a fractal hierarchy of primary sequence, secondary structures such as the double and alpha helices, and global tertiary structures capped off by quaternary super-molecular associations. Both nucleotides and proteins derive their structures through polar and non-polar interactions in association with water. The 'protein folding' problem remains a non-trivial issue in computational intractability.

The prebiotic polymerizations leading to the chemical origins of life share an informational paradox, in which a small number of simple reactants lead to a large array of complex interacting products with many potential catalytic interactions, fig 13. The

initial conditions are thus insufficient to causally determine any but a few of the products, except for a few predominant, thermodynamically favoured products, such as adenine, leading to a huge variety of possible end states with increasing complexity. This is illustrated in fig 13 in the formation of polypeptides. This process allows for a high degree of polymeric variability which can be influenced both by autocatalytic feedback and stochastic effects capped by quantum interference [Ball 2003, Arndt 1999, Hackermüller et. al. 2003]. This extreme tendency to non-linear complexity and unpredictability is offset only by the compensating effect of quantum bifurcations between the elements resulting from cosmic symmetry-breaking itself.

5: THE QUASI-PERIODIC TABLE AND THE ELEMENTARY BIFURCATION² TREE

Although the discrete quantum aspects of orbital occupancy are periodic, fig 10 b, c, the properties of successive atoms in the

1. Traditionally quantum mechanics is described as a linear theory (e.g. in Hilbert space) because amplitudes are linear with respect to superposition of states. Here we are however discussing the non-linear interaction of the electromagnetic force due to altered charge attraction and repulsion in covalent and other forms of bonding orbital.

same periods in the table are not exactly, or even approximately, periodic. Successive members of the same group differ significantly in nuclear charge, atomic radius and electron repulsion, resulting in trends which permit interactive bifurcations between their properties. For example the properties of sulphur are significantly different from oxygen, although they are a period apart. The same goes for sodium and potassium through to fluorine and chlorine. When this non-linear non-periodicity complicating the underlying periodicity of the *s*, *p*, *d* and *f* orbitals is further extended to molecular systems, the parameter space of possible interactions resembles a quantum Mandelbrot set, fig 2, forming an atlas of configurations in which the atomic interactions fig 10(a) and resulting molecular species supporting biogenesis, figs 13, 14, play a pivotal generic role.

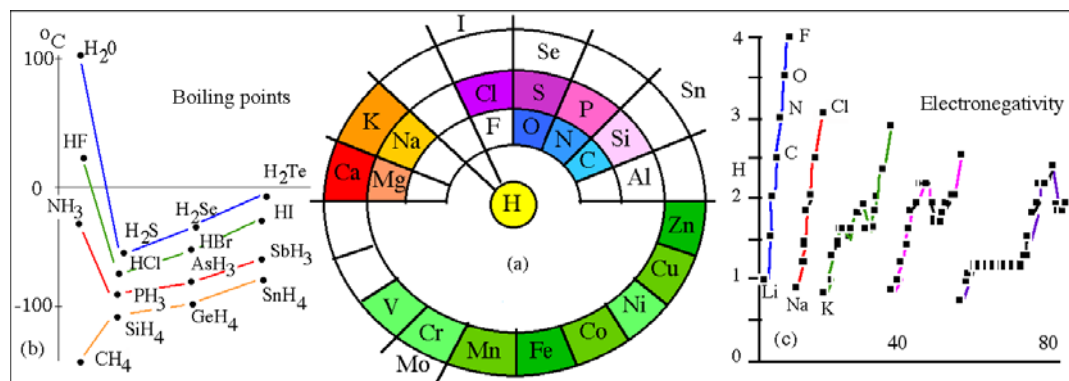


Fig 10: (a) Symmetry-breaking model of selection of bioelements, as an interference interaction between H and CNO, followed by secondary ionic, covalent and catalytic interactions. (b) Boiling points of hydrides illustrate the optimality of H₂O as a polar H-bonding medium. (c) Electronegativities illustrate optimality of O and water as a hydride and emphasize the unique role of first row covalent elements C, N, O. Atomic and ionic radii also result in a two-way bifurcation of the properties of K, Na, Ca and Mg. Transition elements introduce unique catalytic activities partly through bringing the *d*-orbital into play.

Such trends are illustrated in polar and H-bonding properties of hydrides for which H₂O is optimal, fig 10(b), atomic and ionic radii in which the properties of elements like Na and K differ sufficiently to induce distinct H₂O bonding structures, and electronegativity, fig 10(c) in which O is even more electronegative than Cl. Such partial, or quasi-periodicity is also illustrated by the intrusion of the transition element *d*-orbital series between the subsequent *s* and *p* series [Moeller et al.]. The stable aspects of quantum orbital interaction in biochemical evolution can be classified into a tree of fundamental bifurcations, which distinguish the elements structurally and cause divisions between their properties in interaction. This forms a generative sequence in which the bioelements have key roles, fig 10(a). Each bifurcation gives rise to a reaction phase with added degrees of freedom and consequently greater interactive complexity. Describing the evolution of interactive chemical quantum structures in terms of fundamental force bifurcations sheds constructive light on the broad categories into which molecular free interaction differentiates, and determines both the degrees of freedom and the constraints for development of interactive complexity in bio-molecules. Successive bifurcations are as follows :

5.1 Principal Bifurcation : The Covalent Interaction of H with C, N, O.

The central covalent quantum interaction in the table of the elements is between the two-electron *1s* orbital and the eight-electron *2sp³* hybrid. This is the fundamental covalent 1-2 shell quantum interaction and the bifurcation through which biocosmology comes into existence. All the members of the CNO group have tetrahedral *sp³* bonding geometry and form a graded sequence in electronegativity, from carbon in rough parity with hydrogen to electronegative oxygen, with one and two lone pair orbitals appearing successively in N and O. The resulting 3-D covalent bonds give C, N and O optimal capacity to form complex, diverse polymeric structures. Symmetry is split, because the *1s* has only one binding electron state, while the *2sp³* has a series from 4 to 7 with differing energies and varied occupancy, as the nuclear charge increases. The *1s* orbital is unique in the generation of the hydrogen bond through the capacity of the bare proton to interact with a lone pair orbital.

Some of the strongest covalent bonds known to chemistry are the multiple-bonds such as $\text{C}\equiv\text{C}$ -, $\text{C}\equiv\text{N}$ -, and >C=O . These can be generated by applying any one of several high-energy sources such as u.v. light, high temperatures (900°C), or spark discharge to the respective atoms. Because of the higher energy of the resulting π -orbitals, these bonds possess a specific type of structural instability, in which one or two π -bonds can open to form lower energy partially σ -bonded heterocyclic and other oligomeric structures. Most of the prebiotic molecular complexity generated by such energy sources can be derived from mutual polymerizations of $\text{HC}\equiv\text{CH}$, $\text{HC}\equiv\text{N}$, and $\text{H}_2\text{C=O}$, and related hybrids in association with 'sister' molecules such as urea $\text{H}_2\text{N-CO-NH}_2$. These include purines such as nucleic acid bases adenine and guanine, their pyrimidine complements uracil and cytosine, key sugar types such as glucose and ribose, amino acids, polypeptides, porphyrins etc. They form a core pathway from high energy stability to structurally unstable polymerization, and to complexity, which we will elucidate.

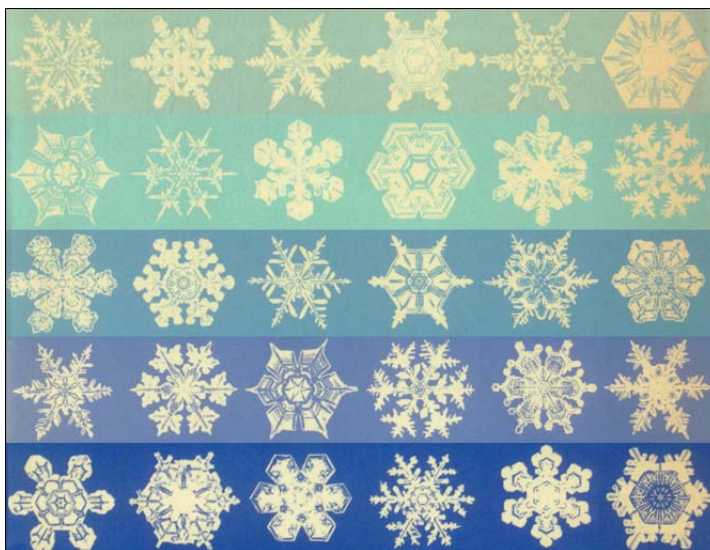
The formation of conjugated double and single bonds in these reactions results in delocalized π -orbitals [Pullman and Pullman 1962]. Such orbitals in heterocyclic (N-C) rings with conjugated resonance configurations also enable lone pair $n \rightarrow \pi^*$ and $\pi \rightarrow \pi^*$ transitions [Rich and Rajbandry 1976], resulting in photon absorption and electron transfer. These two effects in combination play a key role in many biological processes including photosynthesis, electron transport and bioluminescence.

2. Bifurcation is a discrete forking, or change. Dynamical bifurcations are discrete changes occurring at a critical value of a continuous parameter. In this context we are describing parametric effects arising from cosmic symmetry-breaking, which subsequently result in interactive forkings between the properties of the quantum objects involved, in chemical reactions.

5.2 Secondary Splitting between C, N, and O : Electronegativity Bifurcation.

In addition to varying covalent valencies, lone pairs etc., the 8-electron $2sp^3$ hybrid generates a sequence of elements with increasing electronegativity, fig 10(c), arising from the increasing nuclear charge. This results in a variety of secondary effects in addition to the oxidation parameter, from the polarity bifurcation discussed below, to more subtle effects such as the complementation of $-CO_2H$ and $-NH_2$ as generalized organic acidic and basic moieties.

Fig 11: The diversity of ice crystals [Bentley and Humphries] illustrates the complexity of water bonding structures and their diversity under very slight perturbation of initial conditions of vapour condensation..



Differential electronegativity results in several coincident bifurcations associated with water structure. A symmetry-breaking occurs between the relatively non-polar C–H bond and the increasingly polar N–H and O–H. This results in phase bifurcation dividing the medium into polar (aqueous) and non-polar phases in association with low-entropy water bonding structures induced around non-polar molecules. This is directly responsible for the development a variety of structures from the membrane in the context of lipid molecules fig 19, to the globular enzyme form and base-stacking of nucleic acids fig 9.

Critical in this process are the optimal properties of water H_2O among all molecules, making possible in turn polarity interactions, aqueous acid-base bifurcation, ionic solubility and hydrogen bonding. The optimal nature of water as a hydride is illustrated in

boiling points Fig 10(b). Water provides several other secondary bifurcations besides polarity. The dissociation $H_2O \leftrightarrow H^+ + OH^-$ lays the foundation for the acid-base bifurcation, while ionic solubility generates anion-cation.

Many key properties of proteins and nucleic acids, are derived from water bonding structures in which a counterpoint of H-bonding and phase bifurcation effects, determine the form of the alpha helix and nucleotide base pairing and the energetics of global tertiary folding. Hydrophilic-non-polar bifurcation is central to the tertiary structures of globular proteins as 'micelles' and hairpins of RNAs, fig 9. The solubility or otherwise of a variety of molecules and ions is derived from the energies and entropies of their induced water-bonding structures. The large diversity of quantum modes in water is demonstrated by its very high specific heat, contrasting with that of proteins [Cochran 1971]. Polymerization of nucleotides, amino-acids and sugars all involve dehydration elimination of H_2O , giving water a central role in polymer formation. Gerry Pollack in "Cells, Gels and the Engines of Life" has noted that the reactions of ions and biomolecules such as proteins establish an ordered water phase transition throughout the cellular cytoplasm, confirming the pivotal importance of water structures in the molecular systems supporting life.

5.3 Ionic Bifurcation.

The cations bifurcate in two phases : monovalent-divalent, and series (Na-K, Mg-Ca). Although ions such as K^+ and Na^+ are chemically very similar, their radii of hydration differ significantly enough to result in a bifurcation between their properties in relation to water structures and the membrane (compare Pollack [2001] with any biochemistry text). Smaller Na^+ and H_3O^+ require water structures to resolve their more intense electric fields. Larger K^+ is soluble with less hydration, making it smaller in solution and more permeable to the membrane [King 1978]. Ca^{2+} and Mg^{2+} have a similar divergence, Ca^{2+} also having stronger chelating properties. This causes a crossed bifurcation between the two series in which K^+ and Mg^{2+} tend to be intracellular, with Mg^{2+} having a pivotal role in RNA transesterifications. Cl^- remains the central anion along with organic groups. These bifurcations are the basis of membrane excitability and the maintenance of concentration gradients in the intracellular medium which distinguish the living medium from the environment at large.

5.4 P and S as Lower-energy Covalent Modifiers.

The second-row covalent elements are suboptimal in their mutual covalent interactions and their interaction with H. Their size is more compatible with interaction with O, forming e.g. SiO_3^{2-} , PO_4^{3-} & SO_4^{2-} ions including crystalline minerals and silicones. In the context of the primary H-CNO interaction, two new generic properties are introduced.

PO_4^{3-} is unique in its capacity to form a series of moderate energy dehydration polymers, both in the form of pyro- and poly-phosphates, and in interaction with other molecules such as sugars. The energy of phosphorylation falls neatly into the weak bond range (30-60 kJ/mole) making it suitable for conformational changes. The universality of dehydration as a polymerization mechanism in polynucleotides, polypeptides, polysaccharides and lipids, the involvement of phosphate in adenosine triphosphate (ATP) energetics, ribonucleic acid (RNA) and membrane structure, and the fact that the dehydration mechanism easily recycles, unlike the organic condensing agents, give phosphate optimality as a dehydrating salt.

The lowered energy of oxidation transitions in S particularly $S-S \leftrightarrow S-H$, by comparison with those of first row element O,

gives S a unique role in mediating mild covalent linkage, both in protein tertiary bonding and the redox respiration and photosynthesis pathways, enabling such processes to become established more easily in a sulphur environment before the establishment of oxygen-based two-photon photosynthesis. The role of such reactions in relation to FeS centres has become legendary in prebiotic models, particularly involving reactions at higher temperatures and pressures. Following the ideas of Wächtershäuser [1988], George Cody [2000] established the generation of pyruvate in significant quantities from CO at FeS surfaces under high pressure, confirming a possible role for this as a prebiotic energy-dissipating process in hydrothermal vents. Russel [1999] and Martin suggest a similar hadean scenario.

5.5 Transition Element Catalysis

Transition elements add key *d*-orbital effects, forming a catalytic group. Almost all of the transition elements e.g. Mn, Fe, Co, Cu, Zn are essential biological trace elements [Frieden 1972], promote prebiotic syntheses [Kobayashi and Ponnamperna 1985] and are optimal in their catalytic ligand-forming capacity and valency transitions. Zn^{2+} for example, by coupling to the PO_4^{3-} backbone, catalyses RNA polymerization in prebiotic syntheses and occurs both in polymerases and DNA binding proteins. Both the Fe^{2+} - Fe^{3+} transition, and spin-orbit coupling conversion of electrons into the triplet-state in Fe-S complexes occur in electron and oxygen transport [McGlynn et. al. 1964]. Other metal atoms such as Mo, Mn have similar optimal functions, e.g. in N_2 fixation.

5.6 Chirality bifurcation.

There are a variety of explanations for the chirality (handedness) of life into split-symmetry right-handed D-nucleotides and left handed L-amino acids. The most recent and intriguing is that d and l amino acids compete with one another in aqueous solution driving one of the stereoisomers out of solution [Klussmann et. al. 2006]. The most basic manifestation of handedness in nature comes from the weak force. Although the electromagnetic force has chiral symmetry, the electron also interacts via the neutral weak force when close to the nucleus. This causes a perturbation to the electronic orbit causing it to become selectively chiral, fig 12(a) [Bouchiat & Pottier 1984, Hegstrom & Kondputi 1990]. In a polymeric system with competing D and L enantiomer, in which there is negative feedback between the two chiral forms of polymerization, making the system unstable, the chiral weak force may provide a symmetry-breaking perturbation. In a simulation, fig 12(bi) high concentrations of S and T causes autocatalytic bifurcation of system (ii), resulting in random symmetry-breaking into products D or L. Chiral weak perturbation (iii) results in one form only. The selection of D-nucleotides could have resulted in L-amino acids by a stereochemical association [Lacey et. al. 1988, 1990].

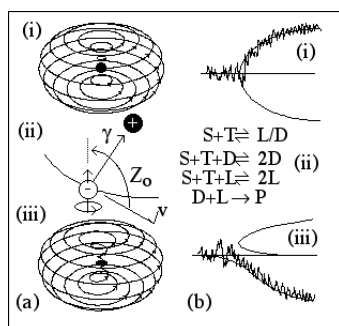


Fig 12: (a) Perturbing effect of the neutral weak force results in violation of chiral symmetry in electron orbits. Without perturbation (i) the orbits are non-chiral, but the action of Z_0 results in a perturbing chiral rotation. (b) Autocatalytic symmetry-breaking causes random chiral bifurcation (i). Weak perturbation breaks stability to one chiral form (iii)

Circularly polarized light has been reported [Bailey 1998] from a region of star formation in the constellation Orion with as much as 17% circular polarization. Such dusty regions probably contain organic molecules, including amino acids, a supposition based in part on the discovery of extraterrestrial amino acids within the Murchison meteorite that fell on Australia in 1969. The handedness of life could be explained if circularly polarized ultraviolet light bathed the dusty cloud that condensed into our own solar system and preferentially destroyed the right-handed amino acids. The astronomers observed only circularly polarized infrared light (a wavelength that can pierce dusty regions), whereas ultraviolet light is needed to weed out chiral molecules, but computations showed that the

scattering could also affect u.v. frequencies. Last year's discovery that even the non-biological amino acids in the Murchison meteorite tend to be left-handed argues that some extraterrestrial mechanism must have operated to create this imbalance.

Kenso Soai [1998] and his team have demonstrated the autocatalytic bifurcation framework as well. They took a mixture of compounds containing a small excess of one enantiomer of the amino acid leucine. In the presence of this imbalance, the components of the solution reacted to form a compound called a pyrimidyl alcohol, also with a small excess of one enantiomer. But this molecule then acted as a catalyst in its own formation, becoming the dominant molecular species.

5.7 Phase Transitions, Interfaces and Tertiary Interaction at the Mineral Interface.

Both silicates such as kaolinite clays [Strigunkova et. al. 1986] and volcanic magmas [Lavrentiev et. al. 1984] have been the subject of intensive interest as catalytic or information organizing adjuncts to prebiotic evolution. Clays have been proposed as a primitive genetic system and both include adsorbent and catalytic sites [Cairns-Smith 1982, Weiss 1981]. Clays also appear to play a key role in stabilizing ribonucleotide polymerization [Ferris et. al. 1996, Ferris 2001]. The mineral interface involves crucial processes of selective adsorption, chromatographic migration, and fractional concentration. In addition a compact metabolic phase may be reinforced by a phase transition to K^+ ion - polypeptide water gel formation. Such process may be essential to explain how rich concentrations of molecules such as polypeptides and oligonucleotides could have occurred over geologic time scales. Interface interactions are characteristic of the diversity micro-environments brought about by non-linear interaction on the planetary surface. They include redox and electron transport processes such as the FeS catalyzed reactions suggested by Wächtershäuser and others. A key interface is likely to have been a four-way interaction over time between phosphate-nucleotide dehydration processes (see RNA section), negatively charged polynucleotides and positively charged silicate mineral surfaces, the redox potential of FeS systems, and polypeptide-induced water structures interacting with positive ions to undergo phase transition to compact gels [Pollack 2001].

The above processes between them constitute the major quantum bifurcations in the free interaction of the elements. They are

also the central processes operating in biogenesis. Put together this says the following: The central biogenesis pathways are themselves results of the central interactive quantum bifurcations of symmetry-breaking and its resulting non-linear interactions. While life may be possible from other combinations of elements and other temperatures and pressures, life as we know it has taken the optimal '*sang raal*' or blood-royal route of quantum cosmology.

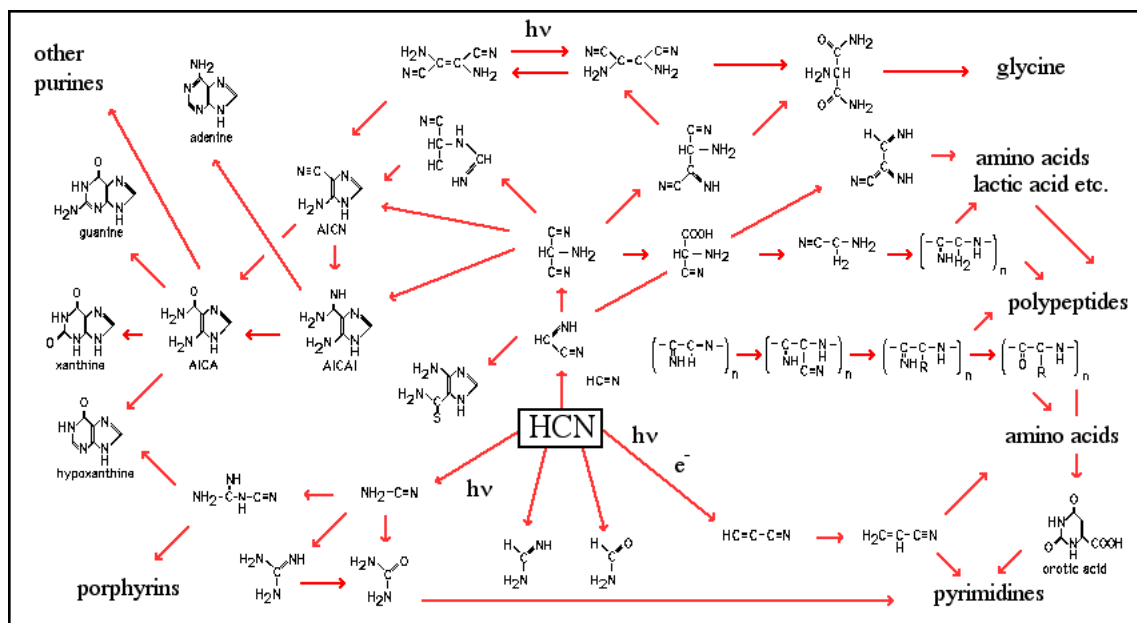


Fig 13: Known product structures and pathways in HCN polymerization [ex. Mizutani et. al.].

6: STRUCTURAL DYNAMICS OF THE CORE POLYMERIZATION PATHWAYS

The initial polymerizations of energetic multiple-bonded monomers in the reactions in figs 13 and 14 form a paradoxical information puzzle from a quantum-chemical point of view, because they provide some of the richest examples of growth in quantum-mechanical complexity, in which a relatively small number of simpler precursors give rise to increasingly complex product structures whose properties cannot be fully predicted from the simpler initial conditions.

$\text{H}_2\text{C}=\text{O}$ in aqueous solution gives rise to 4 to 7 carbon sugars, including ribose, as well as branched polysaccharides. $\text{HC}\equiv\text{N}$ gives rise to heterocyclic purine and pyrimidine nucleic acid bases, and in addition several amino acids, polypeptides, porphyrins, and many other types of biomolecule [Lowe et. al. 1963, Calvin 1969, Mizutani et. al. 1975]. A similar array of products arises from hybrids such as cyanogen $\text{N}\equiv\text{C}-\text{C}\equiv\text{N}$ [Schwartz et. al. 1975] and cyanoacetaldehyde $\text{N}\equiv\text{C}-\text{CH}_2-\text{H}_2\text{C}=\text{O}$. Although several of these products, such as the ring polymers adenine $(\text{HCN})_5$ and ribose $(\text{H}_2\text{CO})_5$ are stable product structures, many of the more complex products, such as particular oligopeptides are metastable or stochastic products of the reaction. These conditions differ markedly from the current biochemical regime in which structurally-stable metabolic pathways are maintained through genetically-coded enzyme catalysis except where recombinational stochasticity is specifically initiated as in generation of antibody immuno-diversity.

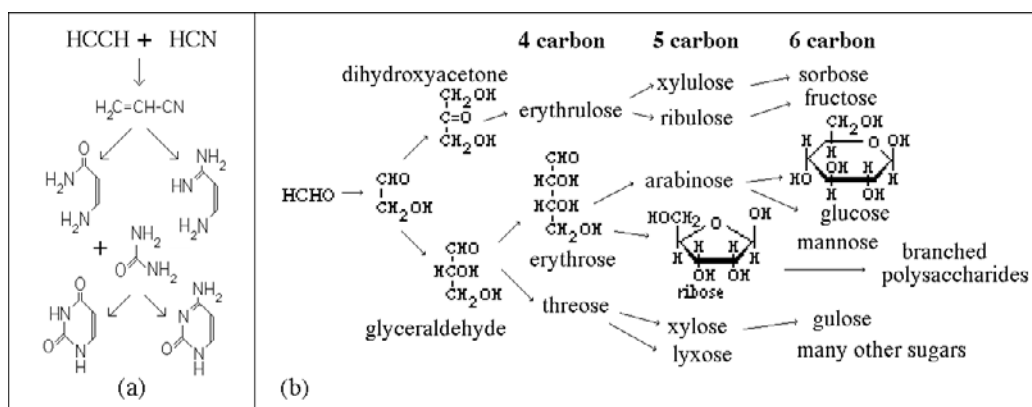


Fig 14: (a) One of several synthesis pathways for pyrimidines. (b) Sample HCHO polymerization routes. Phosphorylation of the oligo-aldehydes causes the reaction to favour ribose. [Eschenmoser 1992].

Since the initial conditions do not contain sufficient information to determine the final products, the system contains many potential outcomes. The lower energy configuration of key products, such as adenine's resonance stabilization, leads to some stable conformations based on free energy. Stochastic indeterminacies in the interaction of simpler molecules can lead to

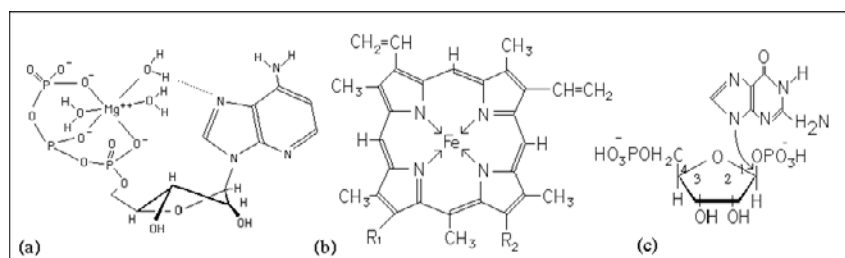
multiple branching pathways. Products of increasing complexity such as polypeptides possess increasingly active catalytic potential, which may alter the structural-stability of polymerization to favour certain types of product. The dynamics may trigger a sequence of autocatalytic bifurcations, forming catalytically attracting molecular products. These reaction pathways are capable of producing a vast variety of complex molecules with generic relationships to key biomolecules, including amino acids, polypeptides, HCN polymers, purines, pyrimidines and porphyrins.

Both HCN and HCHO polymerizations have prominent cyclic products which act as spontaneous end points of polymerization, because cyclization mutually neutralizes reactive moieties. The purines, pyrimidines, ribose and porphyrins all display structure consistent with being cyclic terminators. The capacity of polymers for non-periodic primary sequencing gives rise to complex tertiary structures, which are fractal as a result of structure on several overlapping scales from the atom, through local groups, to structures such as α -helices through to global conformation changes. This fractal nature is reflected both in the geometry and the quantum energetics of molecular transformations [Ansari et. al. 1985, Liebovitch & Toth 1991]. Substrate form is dependent firstly on local active sites, and in turn on the global tertiary structure of catalytic molecules.

Although the first syntheses produced the purines adenine and guanine readily, cytosine and uracil, the complementary pyrimidine bases making up the other half of the pair A-U and G-C, however Stanley Miller, forty three years after his original pioneering experiment in spark synthesis, with Michael Robertson, discovered a way for the primordial pond to make them in high yield. Although urea is produced in Miller's original experimental setup, it never reaches a high enough concentration. When he added more urea, it reacted with cyanoacetaldehyde, another by-product of the spark synthesis, churning out vast amounts of the two bases. Urea would have been able to reach high enough concentrations as shallow pools of water on the Earth's surface evaporated. [Cohen 1996, Horgan 1996].

Eschenmoser [1992] has found that glyceraldehyde phosphate in the presence of HCHO will produce 5-carbon sugars with up to 33% ribose. In the absence of HCHO the reaction tends to produce 6-carbon sugars. The phosphate-induced reaction is key here because RNA, ATP and glycolysis all involve phosphate dehydration energy. This indicates a specific link to phosphate energy primordial to the formation of oligonucleotides and even ribose.

Fig 15: (a) MgATP-complex illustrates linkage between primal stability structures. Cyclic pentamers of HCN (adenine) and HCHO (ribose) are linked by phosphate dehydration, stabilized by cation and water structures. (b) Heterocyclic form of heme. Porphyrins have also been detected in primal syntheses. (c) Nucleophilic attack of adenine N9 on ribose.



7: RNA AND COSMOLOGY

In 1981 Francis Crick commented that “the origin of life appears to be almost a miracle, so many are the conditions which would have to be satisfied to get it going.” [Horgan 1996] Now, several findings bolster the dominant theory of genesis - that life began in an era in which RNA was both the genetic and catalytic basis - the RNA era [Gilbert 1986, Benner et. al. 1989, 1993] in which simple replication and ‘enzymatic’ processes based on RNA catalysis established evolutionary biochemistry.

The general outlines are clear. Ribose as $(\text{HCHO})_5$, unlike the deoxyribose in DNA, has plausible prebiotic syntheses. RNA's capacity to both form double-helices, like DNA and to also three-dimensional tertiary structures similar to proteins, fig 9(a), through base-backbone bonding to ribose causes RNA to have both genetic and catalytic capacity. Simple biological RNAs have been demonstrated to have autocatalytic self-assembling capacity. The catalytic activity of polynucleotides, hinges on various forms of proton transfer fig 17(a,b,c) [Pace and Marsh 1985], in particular transesterification.

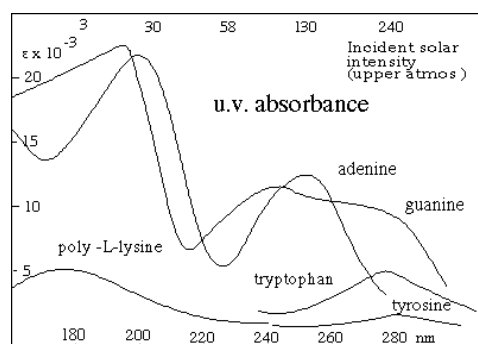


Fig 16: Ultra-violet absorption of the nucleotide bases compared with amino acids and polypeptides.

Recent biophysical simulations [Mulikidjanian et. al. 2003, see also Bhattacharya 2003] also indicate u.v.-radiation could have been a lot less harmful than previously thought, as a result of the strong absorbance of nucleotide bases, supporting their capacity to transfer energization into potentially complexifying oligomer interactions. A regime of cyclic dehydration of a phosphate rich shoreline combined with partial irradiation could thus provide a direct transition to replicative catalysis, consistent with the formation of oligonucleotides by u.v.-irradiating kaolinite clays [Strigunkova et. al. 1986] and that of Ponnampetuma et. al. [1963], who first synthesized ATP under primitive earth conditions using u.v. irradiation.

The essential core of the protein-assembling ribosome remains RNA as does the signal recognition particle which shepherds nascent proteins through the membrane. The ancient fossil nucleotide coenzymes including ATP, NAD, coenzyme-A and Vitamin B12 are all ribonucleotides. Eucaryote organisms continue to have a massive commitment to RNA processing within the nucleus, including the use of many small nuclear ribonucleotides or snRps involved in RNA splicing. This suggests eucaryotes have never fully transferred from an RNA-based metabolism. Reverse transcriptases also remain ubiquitous and essential for such basic functions as telomere extension, and have a common evolutionary tree, giving retrotransposons and retroviruses a potentially ancient origin in the commonality of the RNA era.

There is still debate about whether RNA was actually the primordial genetic molecule and other hybrid molecules such as peptide-nucleic acids which use peptide rather than sugar linkages also have genetic potential and plausible prebiotic status

[Nelson et. al. 2000] , and more recently TNA, based on the 4-carbon sugar threose has also been suggested as a viable replicative nucleotide polymer [Coglan 2003], however it is clear RNA itself has plausible generic status as a cosmological molecular structure on several grounds. Adenine is a principal thermodynamic product of HCN polymerization in industrial yields. All of A, G, U and C now have prebiotic status as favoured products of such reactions. Ribose is an optimal sugar conformationally in terms of permitting complementary double helix formation, and has a synthesis route from glyceraldehyde phosphate. The H-bonding complementations A-U and G-C possess structural optimality by comparison with other bases found in primitive syntheses, such as xanthine. The heterocyclic polymers are restricted in their variety by the positions of N atoms required by the polymerization process. The tautomeric states of A, U, G and C indicate AU and GC may be optimal for base-pairing among close prebiotic variants.

The nucleotide unit, as exemplified in ATP consists of a direct concatenation of key products of HCN and HCHO polymerizations. Adenine and ribose are the cyclic pentamers of HCN and HCHO linked via dehydration to a dehydrating oligo-phosphate giving it the status of a generic structure, fig 15(a) stabilized by water and Mg^{2+} . Positive ions also play an important role in stabilizing mono- and oligo-nucleotides. Mg^{2+} ions are also bound to transfer RNA and play a critical role in transesterification, balancing the negative phosphates. The fact that the polymerizing phosphodiester bond results from the removal of H_2O from phosphate suggests that phosphate was the active moiety linking of the base-sugar-phosphate complex, fig 15(c) and thus drove the entire formation of nucleic acids.

RNA proved difficult for a time to induce into complementary replication in enzyme-free systems, but its relative difficulty of synthesis may be essential to its function. It is necessary that RNA be thermodynamically unstable, or life could not exist dynamically but would 'crystallize' all the way to non-genetic polymers. A variety of partial model systems of complementary replication have been realized by Orgel and his coworkers, however instabilities in polymerization have hindered experimental enzyme-free complementary polymerization of RNAs [Orgel 1992]. It is clear that a regime of polynucleotide chemistry would have to have occurred stably over evolutionary time scales for an RNA-based form of life to evolve to the point where it had established translation and captured metabolic synthetic pathways.

Ferris has reported [Ferris et. al. 1996, Ferris 2001] that he has found a means by which the first large chains could have been forged. When his team added montmorillonite, a positively charged clay believed to be plentiful on the young Earth, to a solution of negatively charged adenine nucleotides, it spawned RNA 10-15 nucleotides long. If these chains, which cling to the surface of the clay, were then repeatedly 'fed' more nucleotides by washing them with the solution, they grew up to 55 nucleotides long. Ferris notes the clay gets RNA off the hook of having to take on the tasks of information storage and catalysis in one fell swoop. It would catalyze RNA synthesis, stocking pools with a large range of RNA strands that, as Szostak and others have shown, would evolve a catalytic capacity of their own. [Horgan 1996]. Thus complementary replication can come into existence after a phase of single-stranded polymerization has given rise to a fractal RNA environment with a diverse array of oligomeric and polymeric structures, which in turn feedback autocatalytically on replication and monomer synthesis.

A central scenario out of many, including volcanic hot pools, and hydrothermal vents, is the three-phase boundary of a phosphate-rich, clay shore line under tidal or weather-related variations in a pool in which the margin is reversibly dehydrated e.g. by sun-drying. Both clays and volcanic basalts have been cited as possible mineral interfaces. Precipitated phosphate at 37° , leads to pyrophosphate formation and hence phosphate bond energy [Hermes-Lima 1990]. Since the energy for nucleotide polymerization is driven by H_2O removal, reversible dehydration of a medium containing phosphate, bases and sugars provides one of the most direct and simple routes to polynucleotide formation.

8: DIVERSE HORIZONS OF THE RNA EPOCH

A whole new field of RNA research has developed from the discovery of spontaneous splicing of RNAs in living systems by Tom Cech [1986a] and the demonstrated capacity of such RNAs to function as catalysts in transesterifications and the work of Jack Szostak's teams in selective RNA catalysis [Horgan 1996]. This immediately made the idea of the RNA world before proteins a natural hypothesis. This work has grown with artificial selective evolutionary studies, culminating with the development of a ribozyme which is capable of high fidelity complementary replication of short RNA oligomers of arbitrary sequence [Johnston et. al. 2001]. This has become a turning point in the credibility and maturity of the RNA world as a precursor to DNA-based life which can develop as an autonomous molecular system. The model has been extended to others for RNA-based error-correction, synthetases and the ribosome [Bass and Cech 1984, Cech 1986b, Zany and Cech 1986, Garriga et. al. 1986, Weiner and Maizels 1987]. Modified ribozymes are capable of acting as polymerases which can replicate complements to subsections of themselves [Green et. al. 1990, Doudna et. al. 1991].

The discovery that RNA appears to be the agent of peptide-bond synthesis in the modern ribosome [Guthrie 1992, Pace 1992, Noller et. al. 1992] and the capacity of modified ribozymes to act as amino-acyl esterases [Picarilli et. al. 1992], the first step of ribosomal action in protein synthesis, establish RNA has the potential to act as synthetase as well as transfer, messenger and ribosomal functions. This gives RNA the capacity to act on its own to catalyze both its own replication and the ordered polymerization of proteins. Simpler model systems have also been advanced of the stereospecific capacity of D-nucleotides to act as a catalyst of L-amino acid polymerization [Lacey et. al. 1990]. These results enable RNA to be the key prebiotic molecule generating ordered polynucleotide and polypeptide structures.

Szostak and Wilson [1996, Wilson and Szostak 1995] have evolved ribozymes capable of a broad class of catalytic reactions. The catalysis of previous ribozymes tended to involve only the molecules' sugar-phosphate "backbone," but these could also promote the formation of peptide bonds (which link amino acids together to form proteins) and between carbon and nitrogen. [Horgan 1996]. David Bartel a former member of Szostak's team, has evolved RNAs that are as efficient as some modern protein enzymes. The problem with most ribozymes is that they are as likely to snip an RNA molecule apart as stitch one together which makes copying a molecule fifty nucleotides long (the minimum size necessary to catalyze a chemical reaction) difficult or impossible. Bartel's new ribozymes, on the other hand, can stitch small pieces of RNA together without breaking

larger molecules apart. These ribozymes use high-energy tri-phosphate bonds similar to ATP as their fuel, speeding the reaction up several million-fold [Cohen 1996].

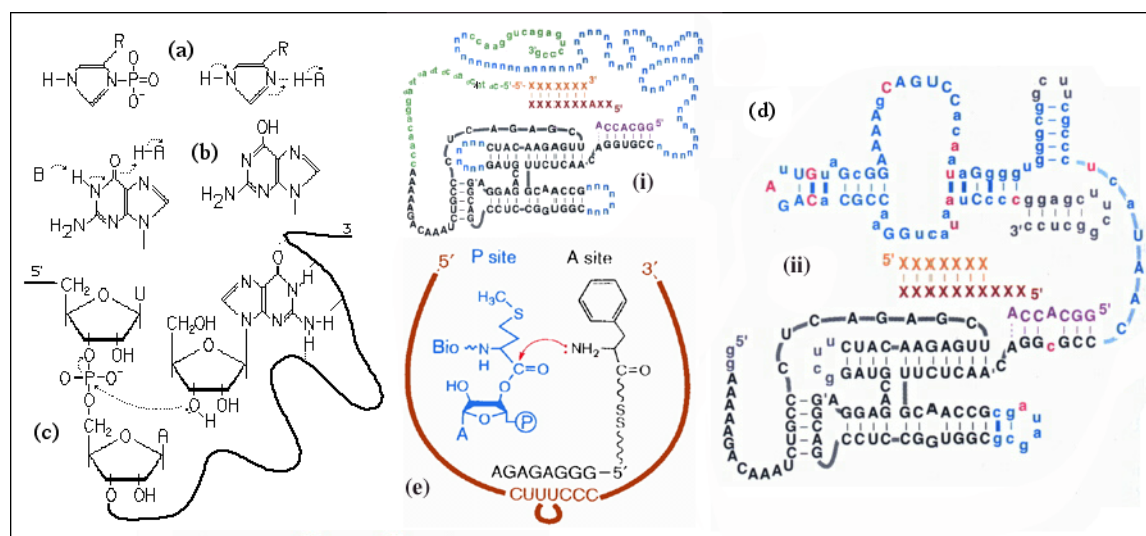


Fig 17: The ribozyme world: (a) Phospho-imidazole. Proton transfers in (a) imidazole, (b) in base tautomerization, (c) in Tetrahymena intron. (d) The first effective ribozyme RNA polymerase (ii) - a 172 unit molecule bred by molecular selection from a ligase ribozyme (i black section) through selective evolution of a pool of other intermediates (i coloured). This ribo-RNA polymerase will faithfully perform complementary replication of oligo-ribonucleotides of arbitrary sequence up to 14 units long with accuracies of up to 98% per base pair [Johnston et al. 2001]. (e) Trans-acting ribozyme replicates key sequence and structure of the ribosome [Zhang and Cech 1997, 1998].

Zhang and Cech have reported a step towards linking amino-acids. They isolated RNAs that could efficiently link specific amino acids together [Zhang and Cech 1997]. These pseudo-ribosomes were selected from a random pool of 1015 synthetic RNAs. They then elicited a trans-acting by coupling one of the amino acids to a short RNA with complementary sequence to the ribozyme achieving a ribozyme which would join a ribosynthetase-amino acid to form a peptide bond with another thus replicating even more closely ribosomal function. They also found that a small region of many of the RNAs they selected was 70 per cent identical to some regions of the ribosomal RNA. "We not only copied ribosome function, we seemed to have recapitulated its evolution," says Cech. The two researchers then removed or mutated these sequences in the synthetic RNAs [Zhang and Cech 1998] any change to this region cut the activity of the RNA by a factor of between 20 and 600. This suggests this region in both the modern ribosome and the synthetic RNA may have the same role in the fusion reaction, such as holding the amino acids in the correct position and that they may have converged on the same molecular solution.

The alternative hypothesis is that replication began with a molecular hybrid - PNA, or peptide nucleic acid. PNA has a similar structure to RNA except for having a peptide backbone based on prebiotically abundant glycine and can co-instruct complementary RNA sequences and vice versa [Böhler, Nielsen and Orgel 1995]. The units of PNA are joined together with peptide links like those in proteins which may not present the instabilities which sugars may have faced on the early earth. Matthew Levy and his colleagues [Nelson et al. 2000] persuaded up to 78 per cent of plausible prebiotic chemicals to transform into PNA backbone subunits amino-ethyl glycine or AEG. The acetic acid derivatives of the bases A, G U and C can likewise be generated from prebiotic reagents including NH_4CN with glycine and cyanoglyceraldehyde. AEG units link up readily at 100 deg C, which may have been common temperature four billion years ago when our planet was rich in volcanic activity. PNA is an alternative route to establishing the RNA era which also has a good cosmological foundation.

9: UNIVERSAL STABILITY STRUCTURES IN MOLECULAR BIOLOGY

The previous discussion of the RNA era can unravel a double-bind that is central to biogenesis - how did the core biochemical pathways become generated? The traditional viewpoint is that they were successively created starting from a simple chemical-feeding heterotroph, through mutational evolution, building one-by-one the protein components necessary to make a working whole. This however does not explain how integrated systems such as electron transport and the citric acid cycle could have functioned at all with only a vestigial complement of enzymes.

This suggests that many of the major features of molecular biology are generic structures which can come into existence under suitable conditions, through bifurcation, independently of the emergence of genetic RNA, and that these were subsequently captured by genetic takeover as genetic complexity permitted. Such generic structures include the polymeric structure of proteins and nucleic acids, nucleotide coenzymes, bilayer membrane structure and the topological closure of the cell, ion transport and membrane excitability, membrane-bound electron transport, glycolysis and the citric acid cycle.

Such a perspective has far-reaching consequences for molecular biology in cosmological terms, for while the details of mutational evolution will be unique to each environment, the major features underlying biology could be universal.

9.1 Nucleotides and the Nucleotide Coenzymes.

The nucleotide co-enzymes are widely regarded as ancient molecular fossils retained from the RNA-era. In addition to the key role of ADP and ATP as energy currency in the bio-metabolism, GTP is used in protein synthesis, and the nucleotides UDP and CDP are carriers of glucose and choline and other membrane components. Model prebiotic reactions have successfully

coupled UDP and CDP to glucose and choline [Mar et. al. 1986]. Both NAD, and FAD function as carriers of redox energy. Coenzyme A consists of adenosine coupled to pantothenic acid and functions as a carrier of acyl and other groups via the terminal SH bond [Reaney 1977]. Vitamin B12 also illustrates how a di-nucleotide can bind a metallic porphyrin ring. Eschenmoser [1988] has also discovered a plausible prebiotic pathway generating the more complex B12 molecule which involves two nucleotides and a Co-porphyrin. Prebiotically such a molecule could have also utilized a lowered $\text{Fe}^{2+} - \text{Fe}^{3+}$ activation energy as a carrier of electrons.

9.2 Translation.

According to the genetic takeover hypothesis, evolution of RNA captured existing stability structures in the prebiotic medium that are a result of bifurcation. The most central of these and the most complex is the use of proteins as coded enzyme catalysts. Such a process could only have occurred in an environment in which RNAs coexisted with amino-acids and in which a very small additional genetic advantage could capitalize on simple coding of existing structures to good effect.

Fig 18: The genetic code contains evidence for several primal bifurcations [King 1982]. Centre position AU selects polar /non-polar as broad groups. VLIP are Val-Leu-Ileu-Phe. First position G determines primarily abundant amino acids. Expansion: first codon C and A fix synthesis routes from Glu and Asp Subsequent bifurcations include H-bonding block and acid-base.

A variety of amino acids and oligopeptides are common products of prebiotic syntheses. The polymerization of amino acids and the development of peptide backbones with cyanide side chains from the linear HCN oligomer fig 13, provide alternative routes to oligopeptide structure. A natural propensity for $-\text{NH}_2$ and $-\text{CO}_2\text{H}$ moieties as basic and acidic groups arises directly from the electronegativity bifurcation.

CCY Pro	CGY N-base	CUY VLIP	n o n	CAY N-base	p o l a r
GCY Ala	GGY Gly	GUY VLIP	abundant	GAY Acid	
UCY Ser	UGY Cys	UUY VLIP	p o l a r	UAY Stop	
ACY Thr	AGY Ser	AUY VLIP	a m i n o a c i d e s	AAY N-base	

The discovery that ribosomal, synthetase, messenger and transfer functions of protein synthesis can all in principle be carried out by RNAs alone leads to a natural interpretation of the development of the genetic code from a protein-free translation system. The major partitions of the genetic code have structural features consistent with an origin in underlying chemical bifurcations. The fundamental bifurcation sequence, fig 18 is as follows:

(a) Polarity bifurcation: There is a major bifurcation in polarity between amino acids with anticodons having centre bases U and A. Uracil is correspondingly more hydrophilic than adenine, as reflected in their dominant split in hydrophobicity $A(3.86) > G(2.3) > C(1.5) > U(1.45)$ and water solubilities $A=1/1086$, $U=1/280$. This leads to the idea that the polarity bifurcation was a principal symmetry-breaking factor in the origin of the nucleic acid code [King 1982].

(b) Abundance and GC: The initial base G also codes the most abundant amino acids, consistent with a GXY code starting with $\text{GAY}=\text{polar}$ (anticodon U), $\text{GUY}=\text{non-polar}$ (anticodon A) providing binding strength of GC and frame shift suppression (Y=pyrimidine).

(c) Four-fold code: Extending to include GGY, GCY, provides a fourfold specificity for polar (Asp/Glu), non-polar (Val and larger), along with Gly, and Ala as most abundant.

(d) Eight- and Twelve- fold codes: This could have then doubled to an 8-word code by including CAY, CUY, CGY, and CCY coding for non-polar and basic groups, and then a similar series based on AAY, AUY, AGY, and ACY Wong [1975] originally noted a correspondence between the first codon base and biosynthetic pathways in primitive organisms such as sulphur bacteria with Pro, Arg, Gln Leu, His derived from Glu and having first codon base C and Ser, Thr, Ile, Asn, Met, Lys being derived from Asp having first codon base A [Knight, Freeland and Landweber 1999]. OH- and SH-containing amino acids also form a single additional block (UA)(GC)Y, suggesting a third bifurcation for H-bonding, with UAY reading stop. Notably there is significant stereospecific affinity between certain amino acids such as Ile and Arg and their codons [ibid].

(e) Evolutionary takeover: From this point evolutionary selection begins to optimize the bifurcations caused by stereospecificity and the growth of these interactions into synthesis pathways, based on error minimization and the incorporation of the last of the amino acids. Later assignments such as Trp are consistent with evolutionary adaptations, consistent with the evolutionary emergence of differences in these codons [Cohen 2003].

Freeland and Hurst [1998], have shown that strong selective pressures must have acted on the code during its evolution. Hurst found that single-letter changes to a codon, inserting the wrong amino acid into a protein, tended to specify amino acids that were very similar chemically to the correct ones, minimizing the impact on the protein. Freeland then reasoned that the code should minimize chemical differences most between the correct and incorrect amino acid at the third base in the codon since translation misreads this base 10 times as often as the second. In an analysis that gave extra mathematical weight to the vulnerable sites most likely to be mistranslated, Freeland showed that no more than one in a million random codes was better at reducing the impact of errors than the natural code. The possibility of evolutionary change in the code is affirmed by both mitochondrial and nuclear variants [Knight, Freeland and Landweber 1999].

Ikehara [2002] suggests a 16 member code exemplifying an intermediate stage of this diversification. Freeland et. al. [2000] have analyzed other work showing that more optimal global solutions do exist to propose that stereochemical and synthesis path constraints fixated the code early on into one which was later evolutionarily optimized on error minimization constraints, the modern code being optimal under these constraining conditions. This analysis gives strong weight to the idea that the form of the code is derived from chemical, historical and selective factors rather than being a frozen accident which happened to the predecessors of the last common ancestor of living cell lines.

9.3 The Membrane, Excitability and Ion Transport.

Life as we know it is dependent on maintaining a distinct internal micro-environment as an open far-from-equilibrium thermodynamic system [Glansdorff and Prigogine, Agladze et. al. 1984, Epstein et. al. 1983], through the topological closure of the cell. Viruses, for example, depend on cellular life. The structure of the bilayer membrane is a direct consequence of the polarity bifurcation. The formation of amphophilic lipid-like molecules, joining a linear non-polar hydrocarbon section to an ionic or H-bonding polar terminal, leaves 2 degrees of freedom for layer formation. Backing of the non-polar moieties to one another, fig 20(b), completes the bilayer. Cell structure can then arise directly from budding of the bilayer, as illustrated in budding in several types of prebiotic reaction medium. Microcellular structures are abundant in many origin of life syntheses, fig 19. The use of CDP associated with choline, inositol & lipids in membrane construction is consistent with membrane formation in the RNA era. The structure of typical biological lipids such as phosphatidyl choline display a modular structure similar to ATP, consisting of fatty acid, glycerol, and substituted amine again linked by dehydration and involving phosphate, fig 20(e).

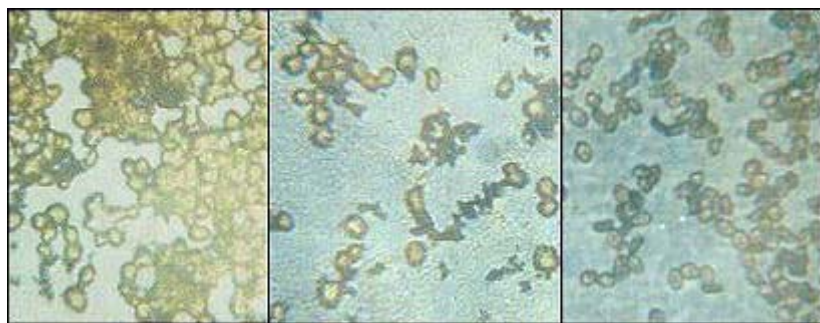


Fig 19: Left and centre: Microcellular formations generated by the author from HCN and HCHO [King]. Right: Spores of a psilocybe species at the same magnification for size comparison.

The existence of the membrane as a non-polar structure leads to segregation into ionic and non-polar reaction phases. Ion transport is essential in maintaining the concentration gradients that distinguish the cytoplasm from the external environment and thus must develop in the earliest cellular systems [MacElroy et. al. 1989]. Ion transport is a source of significant electronic effects, because the membrane under polarization is piezoelectric and is capable of excitation in the presence of suitable ions. Model systems using the simple 19 unit oligopeptide Na-ionopore alamethicin and artificial membranes display action potentials [Mueller and Rudin 1968]. Similar results have been reported for microcells produced by prebiotic techniques containing light irradiated chromophores [Przybylski and Fox 1986], demonstrating that such effects are fundamental to the quantum architecture of lipid membranes [King 1990]. Four groups of non-polypeptide neurotransmitters: acetyl-choline, catecholamines (epinephrine and dopamine), serotonin and histamine are all amines, the latter three being derived from amino acids tyrosine, tryptophan and histidine by decarboxylation. Two others are amino acids and thus also contain amine groups. This may represent a fundamental chemical bifurcation between basic amines and the acidic phosphate groups in the lipid membrane. Alamethicin also has glutamine amides located in the core of the pore [Fox and Richards 1982]. The catecholamines are linked to indoles such as serotonin by a prebiotic pathway, fig 20(c).

Ion transport, the membrane and excitability appear to have a common progenitor in the phase transition to ordered water gels [Pollack 2001] with negatively-charged proteins, under ion gradients which reject Na^+ and attract K^+ , the latter leading to a compact ordered water phase transition leading to a stable gel phase cytoplasm without the need to impose a structurally unstable membrane and ion transport mechanism at the birth of the first cell to maintain a far from equilibrium thermodynamic limit cycle.

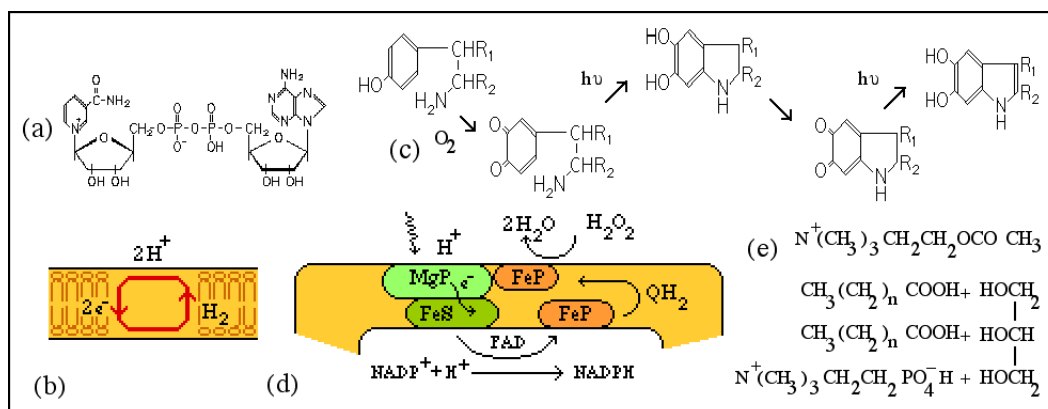


Fig 20: (a) NAD structure permits linkage of other energies to a redox bifurcation. (b) H^+ and e^- transport linked by H_2 in membrane due to insolubility of e^- and solubility of H^+ . (c) Prebiotic link between catecholamines and indole via quinone-type photoreduction. (d) Hypothetical form of primitive electron transport as a non-equilibrium limit cycle. (e) Acetyl-choline and phosphatidyl choline compared. Phosphatidyl choline lipid stacks tail to tail as shown in the clothes pegs (b).

9.4 Electron Transport

The fact that the proton is soluble in water to form the hydrogen ion, but the electron is not, unless attached to another group such as a protein, causes a physical linkage to exist between the polarity bifurcation and the charge bifurcations associated with electron and proton transfer, fig 20(b) mediated by H transport through quinone reduction, (c). Despite the complexity of modern electron transport in photosynthesis and respiration, there is considerable evidence that membrane electrochemistry

could have arisen before translation could produce coded enzymes. Firstly there is a consistent basis for the existence of many of the components of electron transport during the RNA era, since the nucleotide coenzymes NAD, FAD, a nucleotide-bound Mg and Fe-porphyrin ring similar to B12, a cysteine-bound FeS group [Hall et. al. 1974], possibly based on glutathione (γ-glutamyl-cysteinyl-glycine) and quinones provide all the key components of electron transport in an RNA dependent but protein-free form, fig 20(d) [King 1990]. The Fe-S-centre has also been cited a basis for prebiotic metabolism as discussed in section 5.4. Russel and Martin [1999] in line with Wächtershäuser [2000] suggest a hadean scenario as a basis for a transition from an Fe-S dissipative cycle to peptide nucleic acids, however a similar event could happen as a hydrothermal phase in the RNA era.

Both porphyrins and quinones have obvious prebiotic syntheses and the primal role of nucleotide coenzymes has already been discussed. Secondly, membrane structure and the solubility differences between the electron and proton guarantee a link between electron and hydrogen ion transport fundamental to quantum symmetry-breaking. Electron transfer does not in principle require the complex coded active sites required to catalyze specific molecular transformations. Model systems using Fe-porphyrins and imidazole can couple oxidative electron transport to phosphorylation [Brinigar et. al. 1966] and photo activated Mg-porphyrin to phosphate [Goncharova and Goldfelt 1990, Lozovaya et. al. 1990]. These would initially have used H₂S as a substrate rather than the higher splitting energy of H₂O.

9.5 Glycolysis

Glycolysis forms a bridge between six and three carbon sugars, reversing the synthesis pathway from H₂CO, glycoaldehyde and glyceraldehyde to cyclic sugars, fig 14(b). Glycolysis is made energetically possible by phosphorylation, and releases high energy phosphate capable of driving other phosphorylations [Hermes-Lima and Vieyra 1989], fig 21(a). It is notable that glycolytic di-phosphorylation of fructose is homologous with the route for nucleotide formation of fig 15(c). The high phosphate environment leading to RNAs would then naturally lead to similar phosphorylation of other sugars, and release of the high-energy phosphate bond through cleavage of the sugar. Mineral catalysis associated with phosphate gives the glycolytic pathway a natural basis for lysis of sugars as a dissipative structure. Biological UDP-glucose coupling is consistent with nucleotide-dependent glycolysis in the RNA era.

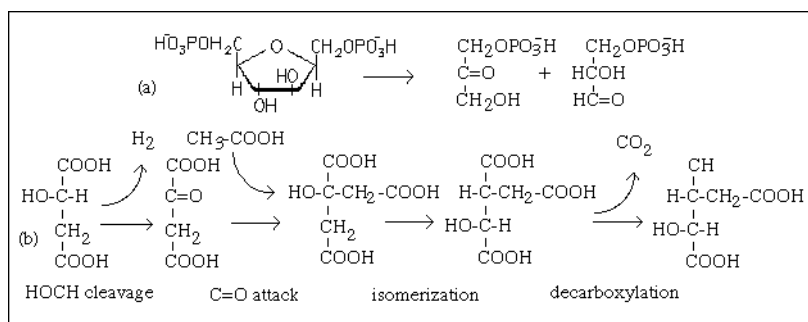


Fig 21: (a) Di-phosphorylation of sugars leads to glycolysis through interaction of charged phosphates. (b) Generic examples of group transfer in the tricarboxylic acid cycle.

9.6 The Tricarboxylic Acid Cycle

The tricarboxylic acid cycle forms a pool of multiply carboxylated molecules which carry CO₂ in various states of energy, and result in reducing energy via nucleotide coenzymes NAD and FAD, which coupled with the use of coenzyme A provide a basis for the tricarboxylic acid cycle in the RNA era. This

could have existed as a limit cycle of di- and tri-carboxylated molecules acting both as an acceptor of acetate (a carbohydrate-equivalent i.e. (H₂CO)²) and as an emitter of molecular CO₂ and reducing H, thus bifurcating carbohydrate level redox potential into reduced and oxidized components.

The linkage to nucleotide coenzymes such as NAD would have served to create a bifurcation of redox potential in the molecular milieu contributing to the diversity of reacting species. The cycle may have been hypercyclic [Eigen et. al. 1981] or chaotic, consisting of a population of molecules undergoing various generic transformations with net inflow of carboxylic acids and net emission of CO₂ and transfer of H, due to generic transformations as illustrated in fig 21(b). Isomerization would have been catalyzed by Fe²⁺. Several steps may have been driven by sunlight photolysis [Waddell et. al. 1989].

The hypothesis that the central structures of molecular biology existed in the RNA era is consistent with their being chemical stability structures utilized by catalytic RNAs. The small genomes during the RNA era and limited catalytic capacity of RNAs by comparison with protein makes it likely that the emerging RNA-based system had to capitalize on existing chemical stability structures because it lacked enzyme-based biosynthetic pathways. Genetic takeover also places these stability structures in a category determined by the cosmological milieu, thus giving evolutionary biology a cosmological foundation.

Together these systems answer in convergence the potentially diverse definitions of life drawn attention to by Clelland and Chyba [2002]. Eventually each of these systems became sequentially fixed into metabolic relationship by the evolution of genetically coded enzymes through the translation process, fixing nucleotide coenzymes, Fe-S groups, porphyrin-based factors and metal atom catalysis as markers of the original catalytic bifurcation landscape.

10.1 : The Precocious Origins of Life on Earth

Far from being an improbable accident taking billions of years to find the right conditions, life may have become established on Earth as soon as the conditions permitted a liquid water ocean. Either Earth was richly bombarded with complex organic molecules which quickly found within the diversity of microclimates on Earth some which were directly conducive to the processes leading to the genetic epoch, or life had already begun in the gas and dust cloud initially forming the solar system. Gustaf Arrhenius, [Mojzsis et. al.] studying tiny apatite grains in the Isua formation of Greenland, has found carbon 12 to 13 ratios consistent with the grains originating from living matter. The Isua rocks date from 3.85 billion years ago. Although oxygen-18 in zircon crystals indicate a solid crust 4.2 billion years ago, suggesting a cool start with liquid water

hospitable to life [Valley et. al. 2002], no intact rocks have been discovered older than 3.96 billion years.

Fig 22: Modern stromatolites (left), generated by cyanobacteria (blue-green algae) Shark Bay, Australia. J. W. Schopf has found remnants of 3.6 billion-year-old stromatolites lying near fossils of 3.5 billion-year-old cells that resemble modern cyanobacteria (right). Life thus arose within the first billion years of earth's formation from the planetary disc [Scientific American Feb 1991].



The moon and probably the Earth likewise was heavily bombarded with meteors up to 3.8 billion years ago, suggesting that life may have evolved on earth as soon as environmental conditions allowed. There is continuing debate about whether these chemical and 'fossil' traces, now further studied with Raman spectroscopy to give carbon isotope evidence, really represent early cyanobacterial life, prebiotic 'soup' or volcanic or meteorite material [Schopf et. al. 2002, Brazier et. al. 2002, Mojzsis 2002]. However some researchers contend on the basis of inorganic simulations that these microfossils are purely mineral [Hogan 2003]. Jacques Touret [2003] has found that methane as well as high salt water trapped in pillow lava from Isua suggesting the involvement of hydrothermal vents beside an undersea volcano. However these findings are questioned by David Vanko [Necht 2003]. John Parnell has also suggested radioactivity trapped in oily grains may have had a role [Lawton 2003]. In any case there is consensus agreement that life was under way by 3.5 billion years the age of the fossil stromatolite in fig 22, although the nature of these is also debated. These fossils could be the earliest evidence of life on Earth, yet these relics, with names like Chromococceae and Osdclotorioceae, are morphologically identical to modern cyanobacteria that cover the globe from Antarctica to the Sahara [Cohen 1996].

The emergence of the eucaryotes that led to the higher organisms is also very ancient. Compounds in traces of oil extracted from Australian shale suggest that eucaryotic cells, which make up all life on Earth except for bacteria, had evolved as early as 2.7 billion years ago. It is not until about 2.1 billion years ago that fossil imprints appear in the geological record that are so large that they can only be eucaryotes. A team of researchers in Australia has found steranes, molecules with 26 to 30 carbon atoms arranged in four rings, in droplets of oil extracted from rock 700 metres below the surface in the Pilbara region of northwestern Australia. These are produced by the decay of cholesterol and other steroids found in the membranes of eucaryotes, but not bacteria [Brocks et. al.].

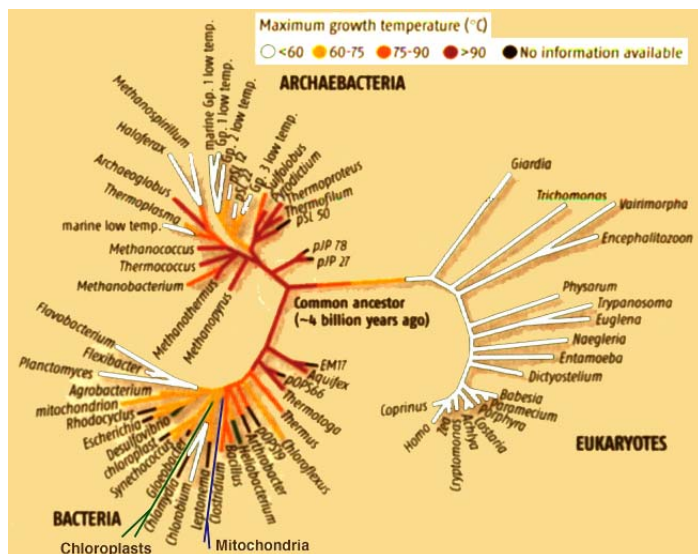


Fig 23: The root of the tree of life [ex Pace Anathswamy]: shows the division into archaea, bacteria and eucaryota, with subsequent divisions of eucaryotes into multicellular plants, animals and fungi (zea, homo and coprinus). Earliest branches of bacteria and archaea are thermophiles (red). Symbiotic mitochondria and chloroplasts are also shown. Recent adjustments of the tree suggest a cold start, with the thermophiles peripheral specialized adaptations [Brochier and Philippe] and planctomycetes, which share budding and an encapsulated nucleus with the eucaryotes, close to the root. Tertiary analysis is also consistent with a eucaryotic origin [Caetano-Anolles].

10.2 Universality Three Realms, Five Kingdoms and the Auto-heterotrophic Bifurcation

The five kingdoms of plants, animals and fungi, protista and prokaryotes, are now known to be completed by the archaea, grouped into three realms with eucarya and bacteria. These divisions reflect major bifurcations of the thermodynamic and metabolic environment. There is a fundamental bifurcation of energy metabolism between

photosynthetic fixation of incident solar energy, the principal incident energy source at the planetary surface, and all other forms of heterotrophic energy-pilaging budget, including animals as frank predators, fungi as saprophytic and symbiotic decomposers, the highly catalytic biochemical pathways of prokaryotes subtended by the diverse partially differentiated protista. The biochemical basis of both photosynthesis and respiration is through a common electron transport pathway which utilizes primal molecules such as porphyrins and nucleotide coenzymes as receptors. The major divisions of life are thus clearly universal in nature. Such universality also extends to the formation of excitable cells using amine-based neurotransmitters and ion channels.

Williams and da Silva [2003] note a series of major evolutionary developments as reactions to bifurcations in the environment precipitated in turn by previous evolutionary innovations, establishing the idea that many stages of evolution may be bifurcatory. These include the transfer from a reducing metabolism to oxidized form as a result of generation of O_2 by the biota, the role of Ca^{++} and Na^+ ions as expelled cytoplasmic poisons becoming cell signalers and mediators of excitation.

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BIOCOSMOLOGY

Part 2: Evolutionary Epoch: Complexity, Chaos and Complementarity

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ABSTRACT: This paper continues the biocosmological description (King 1978,1999, 2003) into the evolutionary epoch, extending the biocosmological thesis - that the form of life's origin and evolution is a cosmological interactive process initially defined in the cosmic symmetry-breaking at the origin of the universe. This second paper surveys aspects of evolution which may arise from universal bifurcations common to fermionic matter, and deeper trends towards universality and complementarity in evolution. The paper then investigates the evolution of conscious neurosystems as a potentially universal process expressing fundamental cosmological complementarity in a selectively advantageous way, supported by a quantum transactional model of conscious anticipation.

Keywords : cosmology symmetry-breaking, molecular evolution, chaos, complex system, neurodynamics, quantum non-locality, transaction, consciousness.

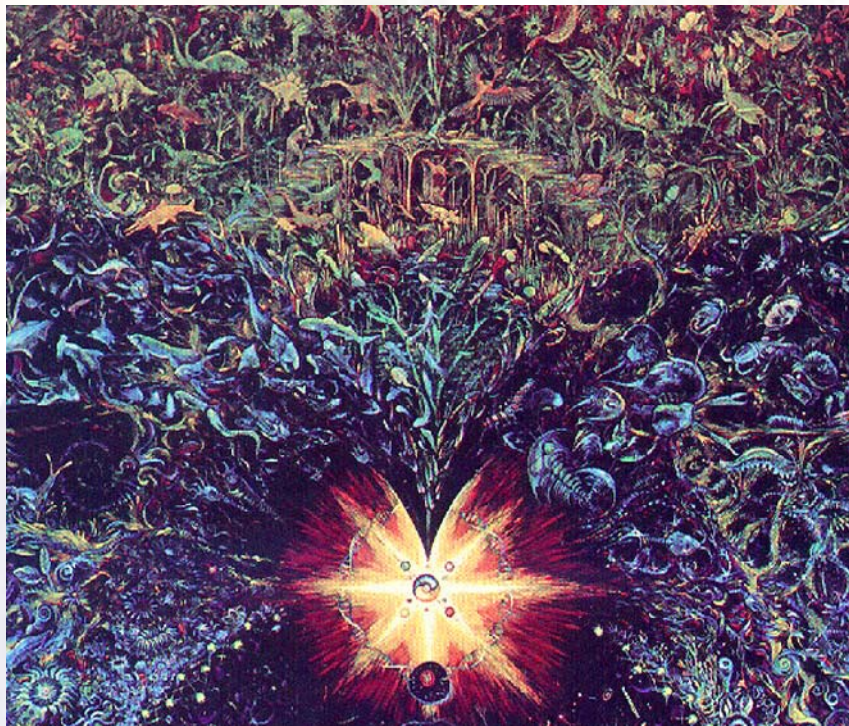


Fig 24: Dion Wright The Mandala of Evolution detail (Arguelles). Evolution is a complementation between unique idiosyncratic quantum mutations fixed in the historical process by genetic replication on the one hand and inevitable effects of bifurcation in which many mutations combine to explore a 'phase space' of potentialities converging towards universal genetic algorithms.

10: EVOLUTION AS QUANTUM COSMOLOGY AT THE EDGE OF CHAOS

Complexity theory finds its dynamical source at the 'edge of chaos', in transitions between chaos and order which enable form to emerge and become fixed as new order, from the diverse fractal structures hidden within the chaotic realm. The teeming diversity arising from evolution is nature's and the universe's most outstanding manifestation of complexity. Darwin himself noted the complementary roles played by natural and sexual selection in shaping evolution. While natural selection is broadly a constraint imposing order, either from the environment, or the effects of other species, sexual selection is intrinsically an unstable positive feedback process, which leads to runaway instability and chaos. In the mutual interaction of these two factors, evolution finds itself endlessly converging towards the edge of chaos in climax diversity.

10.1 : The Precocious Origins of Life on Earth

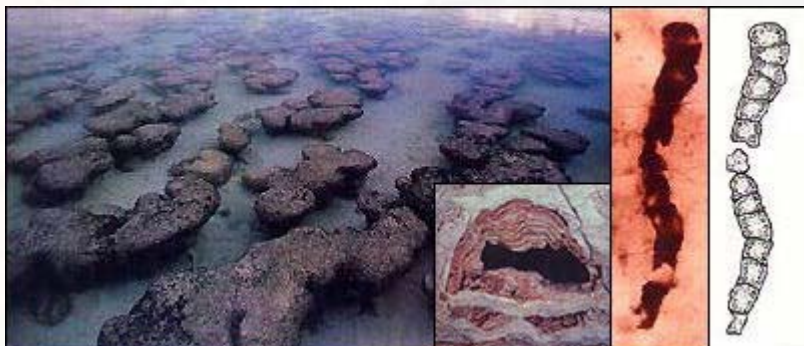
Far from being an improbable accident taking billions of years to find the right conditions, life may have become established on Earth as soon as the conditions permitted a liquid water ocean. Either Earth was richly bombarded with complex organic molecules which quickly found within the diversity of microclimates on Earth some which were directly conducive to the processes leading to the genetic epoch, or life had already begun in the gas and dust cloud initially forming the solar system. Gustaf Arrhenius, (Mojzsis et. al.) studying tiny apatite grains in the Isua formation of Greenland, has found carbon 12 to 13 ratios consistent with the grains originating from living matter. The Isua rocks date from 3.85 billion years ago. Although oxygen-18 in zircon crystals indicate a solid crust 4.2 billion years ago, suggesting a cool start with liquid water hospitable to life (Geology **30** 3511), no intact rocks have been discovered older than 3.96 billion years. The moon and

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probably the Earth likewise was heavily bombarded with meteors up to 3.8 billion years ago, suggesting that life may have evolved on earth as soon as environmental conditions allowed. There is continuing debate about whether these chemical and 'fossil' traces, now further studied with Raman spectroscopy to give carbon isotope evidence, really represent early cyanobacterial life, prebiotic 'soup' or volcanic or meteorite material (Schopf et. al. 2002, Brazier et. al. 2002, Mojzsis 2002). In any case there is consensus agreement that life was under way by 3.5 billion years the age of the fossil stromatolite in fig 23, although the nature of these is also debated. These fossils could be the earliest evidence of life on Earth, yet these relics, with names like *Chromococceae* and *Oscillatorioceae*, are morphologically identical to modern cyano-bacteria that cover the globe from Antarctica to the Sahara (Cohen).

Fig 23: Modern stromatolites (left), generated by cyanobacteria (blue-green algae) Shark Bay, Australia. J. W. Schopf has found remnants of 3.6 billion-year-old stromatolites lying near fossils of 3.5 billion-year-old cells that resemble modern cyanobacteria (right). Life thus arose within the first billion years of earth's formation from the planetary disc (Scientific American Feb 1991).

The emergence of the eucaryotes that lead to the higher organisms is also very ancient. Compounds in traces of oil extracted from Australian shale suggest that eucaryotic cells, which make up all life on Earth except for bacteria, had evolved as early as 2.7 billion years ago. It is not until about 2.1 billion years



ago that fossil imprints appear in the geological record that are so large that they can only be eucaryotes. A team of researchers in Australia has found steranes, molecules with 26 to 30 carbon atoms arranged in four rings, in droplets of oil extracted from rock 700 metres below the surface in the Pilbara region of north-western Australia. These are produced by the decay of cholesterol and other steroids found in the membranes of eucaryotes, but not bacteria (Brocks et. al.).

10.2 Mutation, Bifurcation and the Quantum Limit

Evolution is traditionally regarded as an opportunistic drunkard's walk by random mutation into a variety of advantageous configurations, which then become fixed by selective advantage as stunningly effective incremental historical accidents. However, just as with the prebiotic epoch, key aspects of biological evolution may be a reflection of fundamental bifurcations.

Evolution is partly a stochastic opportunistic process and partly an optimizing selective response to bifurcations in the natural, sexual and ecological landscape, as T.H. Waddington emphasized in "The Strategy of the Gene" (1957) in his concept of the 'chreode'. The balance between the adventitious and the selectively optimized is a reflection of the deeper underlying process of quantum complementarity. In an interference experiment, the trajectories of individual photons are unpredictable through quantum uncertainty of position and momentum. The pattern of wave interference only becomes established statistically through the passage of many photons, which through their statistics of particle absorption by individual atoms demonstrate the wave amplitude variation of the interference pattern. This convergence to the probability interpretation is even more marginal in the complex macroscopic biological world than it is in the quantum world of small numbers of events, and for the same reason. Although their effects are large in macroscopic organisms, mutations themselves are unique kinetic events in the quantum world of molecules and molecular orbitals. Such highly specific mutational transformations are vastly rarer than the photons in a conventional interference experiment and tend to the uncertainty of a single unrepeatable event which by its very fixation permanently changes the context which created it. This makes it possible for adventitious aspects of evolution to become enduring historical manifestations of the underlying nature of quantum uncertainty and entanglement. Effectively adventitious mutations are single quantum events which become captured and replicated by the genetic process.

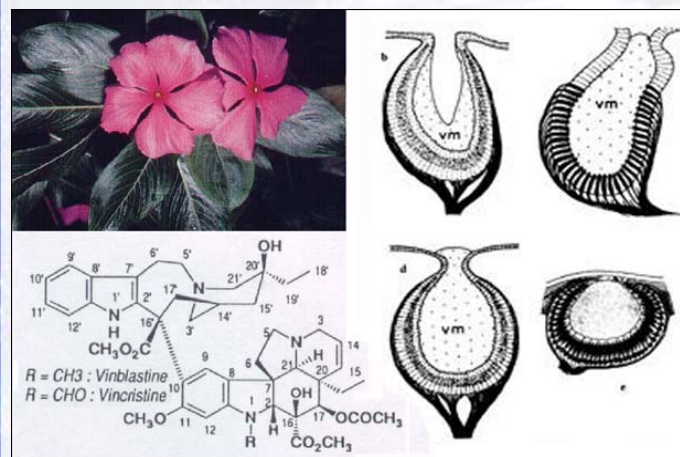


Fig 25: Two aspects of evolution, adventitious mutation and cumulative selection are contrasted. Left: *Cantharanthus rosea* makes the unusual indole vincristine, unusual in structure and almost unique to the biological world. While this has occurred through natural selection, it is an unusual avenue which appears to be the result of an initial fortuitous mutation. Right: By contrast, the development of the camera eye (Dawkins 1996), despite being touted by creationists as impossible for evolution, is virtually inevitable by natural selection, because its formation results from a simple topological bifurcation of a photoreceptive hollow and the fact that directional photon reception is a core quantum interaction as fundamental as photosynthesis itself, evidenced by the same carotenoids in vision and as accessory pigments in photosynthesis. These two examples contrast aspects of evolution which do and do not converge to the statistical limit as quantum phenomena.

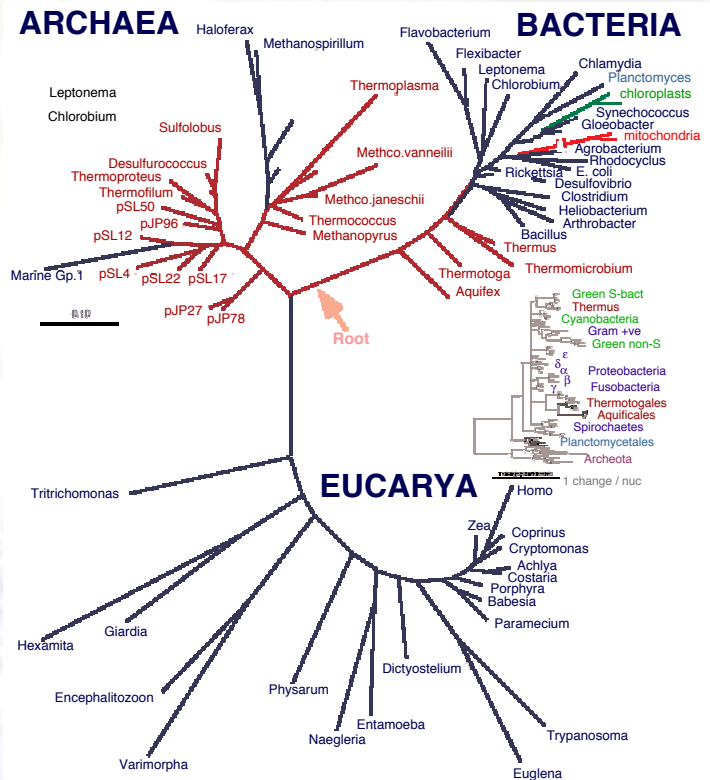
Complementing this, selective advantage has unrestricted gain, which can and will over time, given sufficient mutations, explore any bifurcations or optimalities in the physical environment. Thus many of the marvels of the evolution, such as the camera eye, are inevitable because of the capacity for bifurcational change which incrementally enhances the immense optimality in survival of accessing the fundamental quantum mode of directional photon absorption, the most selective and discriminatory sense we have. This is illustrated in the evolution of the camera eye, fig 25.

10.3 Universality A: Three Realms, Five Kingdoms and the Auto-heterotrophic Bifurcation

The five kingdoms of plants, animals and fungi, protista and prokaryotes, are now known to be completed by the archaea, grouped into three realms with eucarya and bacteria. These divisions reflect major bifurcations of the thermodynamic and metabolic environment. There is a fundamental bifurcation of energy metabolism between photosynthetic fixation of incident solar energy, the principal incident energy source at the planetary surface, and all other forms of heterotrophic energy-pillaging budget, including animals as frank predators, fungi as saprophytic and symbiotic decomposers, the highly catalytic biochemical pathways of prokaryotes subtended by the diverse partially differentiated protista. The biochemical basis of both photosynthesis and respiration is through a common electron transport pathway which utilizes primal molecules such as porphyrins and nucleotide coenzymes as receptors. The major divisions of life are thus clearly universal in nature. Such universality also extends to the formation of excitable cells using amine-based neurotransmitters and ion channels.

Williams and da Silva (2003) note a series of major evolutionary developments as reactions to bifurcations in the environment precipitated in turn by previous evolutionary innovations, establishing the idea that many stages of evolution may be bifurcatory. These include the transfer from a reducing metabolism to oxidized form as a result of generation of O_2 by the biota, the role of Ca^{++} and Na^+ ions as expelled cytoplasmic poisons becoming cell signalers and mediators of excitation.

Fig 26: The root of the tree of life (ex Pace): shows the division into archaea, bacteria and eucaryota, with subsequent divisions of eucaryotes into multicellular plants, animals and fungi (zea, homo and coprinus). Earliest branches of bacteria and archaea are thermophiles (red). Symbiotic mitochondria and chloroplasts are also shown. Recent adjustments of the tree (inset) suggest a cold start, with the thermophiles peripheral specialized adaptations (Brochier and Philippe) and planctomycetes, which share budding and an encapsulated nucleus with the eucaryotes, close to the root. Tertiary analysis is also consistent with a eucaryotic origin (Caetano-Anolles).



10.4 Universality B: Homeotic Body Plans

A major quantum-leap of universality in the evolutionary realm is the ubiquitous use of the homeotic genes for morphogenic organization of the organism, particularly the segmental organization from the head to the tail, which are common not only to all metazoa but to plants and fungi as well, fig 27. The underlying mechanism of homeotic gene morphogenesis may represent a type of universal solution to developing body plans. The development of this system seems to be the key step enabling the emergence of multicelled organisms and their divergence into plants, animals and fungi, particularly in the Cambrian radiation. Although the homeobox sequence and the key proteins are too complex to be accounted for simply by a cosmological argument, the principles by which they evolved and the chemical morphogens may be an evolutionary universal. This is consistent with the long time from the first emergence of eucaryotes to metaphyta in the Ediacaran and Cambrian radiations about 600 million years ago. This long delay, fig 37(a), is indicative of there being only one, or a few effective solutions to this problem, giving it potential universality beyond our own metaphyta.

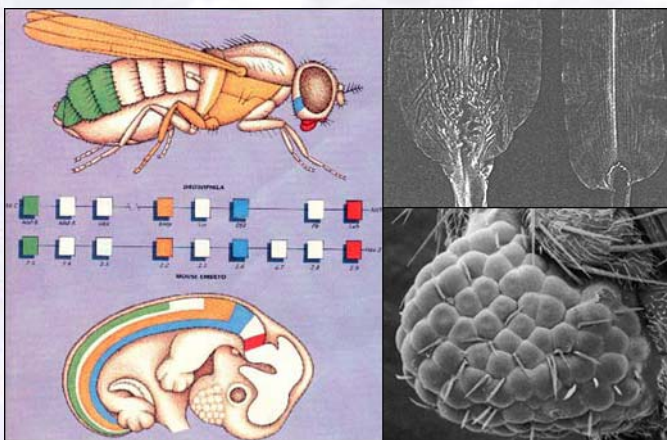
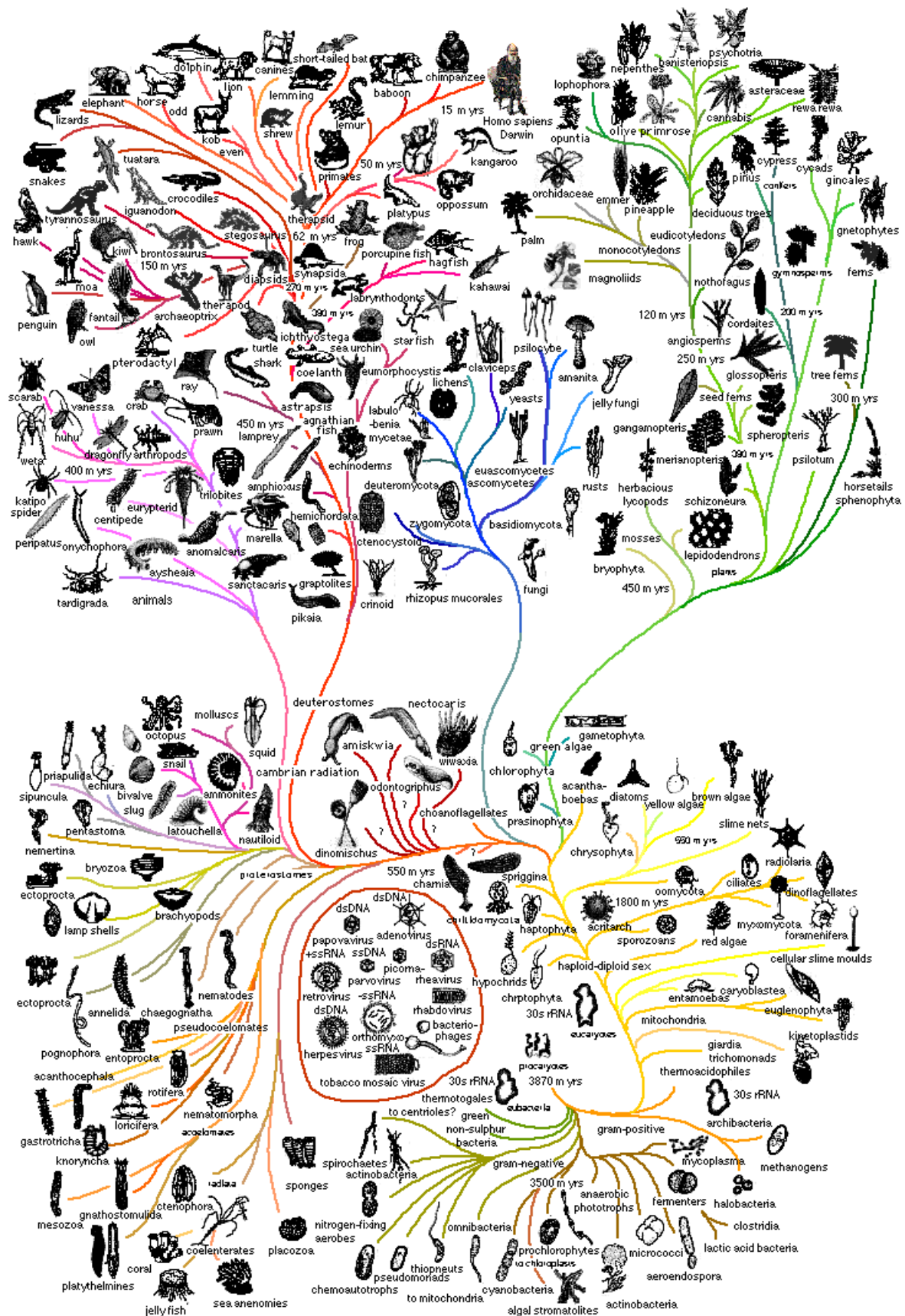


Fig 27: Homeotic genes. Left: Sequence of homeotic genes compared between insect and vertebrate, showing their common role in segmental organization (De Robertis et. al., McGinnis et. al.). Top right: Knotted maize mutants have a mutation in a homeobox gene regulating differentiation. Similar homeobox genes have been found in tomatoes and rice (Homeobox Harvest Sci. Am. June 91). Lower right: Mammalian regulatory gene, pax6 elicits ectopic eyes on the leg of a fruit fly, showing the genes even have comparable action. (Dawkins 1996).

Other signs of universality in this epoch are the predominance of bilaterally symmetrical organisms with an asymmetric ventro-dorsal and head-tail axis. The major division between arthropods and vertebrates also hints at a universality, which in addition to complementations, such as exoskeleton versus endoskeleton and anal versus buccal gastrulation, adopt broadly complementary roles in ecosystemic terms.



Comprehensive Evolutionary Tree of Life

10.5 Universality C: Immunity, Variation and Genetic Symbiosis

Common to plants and animals are a basic set of pathways to deal with microbial infection and tissue stress caused by injury and predation (Johnson and Liu, Gura). The development of immunity and tissue complexity also comes with a major theme of gene and particularly regulatory functional domain rearrangement. The adaptive immune system of vertebrates uses transposase activity inherited from a transposable element (David Schatz Nature 1998).

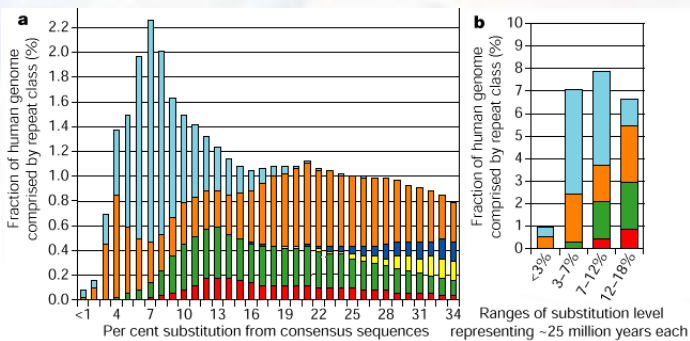


Fig 29: Human transposable element evolutionary history of L1-LINES (brown) and Alu elements (lt. blue) along with retrovirus-like LTR elements (green) and DNA transposons (red). Older LINES and SINEs are in yellow and dk. blue. This history extends back over 200 million years indicating the very ancient basis of this potentially symbiotic relationship (Human Genome Consortium Nature 2001).

In the human, coding sequences comprise less than 5% of the genome (see below), whereas repeat sequences account for at least 50% and probably much more. The need for functional rearrangement of modular genetic domains favours an interpenetration of transposable elements and structural gene sequences. Evidence from the human and other genome projects now shows clear evidence of a complementation between cellular and

transposable element genes, particularly the almost ubiquitous retroviral and retrotransposon elements, which still carry the reverse transcriptases capable of generating DNA from an RNA template. The 100,000 LINE (long intermediate) elements ubiquitous in humans extends far back to the origins of multi-celled organisms, as indicated in their evolutionary history fig 29.

Although the data from the human genome project indicated that human LINES are becoming less active as a group by comparison with the corresponding elements in the more rapidly evolving mouse genome, there remain about 60 active human LINE elements which are known to be responsible for mutations in humans. More recent investigation (Boissinot et. al. 2001) shows that the most recent families are highly active. Around four million years ago shortly after the chimp-human split, a new family Ta-L1 LINE-1 emerged and is still active, with about half the Ta insertions being polymorphic across human populations. Moreover 90% of Ta-1d, the most recent subfamily are polymorphic, indicating highly active lines remain present. LINES are more heavily distributed on the sex chromosomes with X chromosomes containing 3 times as many full length potentially active elements and the Y chromosome 9 times as many! This is consistent with a continuing mutational load on humans which is removed more slowly from the sex chromosomes by crossing over in proportion to the degree to which crossing over is inhibited in each (i.e. totally on the Y and largely in males in the X but not in females).

LINES are believed to have transduced up to 1% of the human genome comparable with that of the exons that form active modular gene regions (Pickeral et. al. 2001, Moran et. al. 1999, Kazazian et. al. 1998). The LINE reverse transcriptase shares evolutionary homologies with telomerase and viral reverse transcriptases, fig 30. LINES are also believed to provide the replication machinery for the more active shorter human SINEs. Along with their more recent fellow-traveller SINEs such as the 300,000 Alu in the human genome, LINES have been proposed to be in a form of genetic symbiosis permitting modular evolution of the genome (King 1992). This is consistent with the 1.4% point mutation divergence between humans and chimps, being overshadowed by an additional 3.9% divergence to 5.4% overall, when insertions and deletions are accounted (Britten 2002).

Moreover it has been suggested that LINES play a key role in X chromosome inactivation, with the defective LINE elements resulting from the inactivation of the LINES resulting from natural nuclear resistance to the onslaught of active disruptive mobile elements, functioning to inactivate the receptors of X genes. X-inactivation is a very unusual process in several respects. It is controlled by a gene called Xist, but this gene does not produce a translated protein. It merely produces a messenger RNA which appears to 'paint' the inactivated X chromosome from end to end. An anti-sense complementary version of this mRNA is also produced, appropriately called Tsix. In mice, the active X secretes Tsix to oppose Xist however in humans Tsix does not repress Xist and is expressed on the inactive X. The original central dogma of Crick and Watson that DNA makes RNA makes protein which carries out the essential catalytic tasks. X inactivation smacks of the ancient forms of RNA processing that may have preceded the DNA genome of eucaryote cells, which still appear to be major players in processing mRNAs from the majority of genes containing introns, non-coding inserts between functional sub-domains of genes. The key violation of the central dogma that opened up a major reconceptualization of the field was the discovery of reverse transcription from RNA to DNA, a process shared by retroviruses, LINE elements and the telomerase which adds now telomeres is essential to maintaining the immortality of the germ line. There are sequencing homologies between the reverse transcriptases of all of these indicating a viral origin for telomerases. Significantly LINE elements, which are concentrated in specific regions of other chromosomes are also spread over the X-chromosome and concentrated around the inactivation centre where Xist lies. This mechanism suggests a very ancient symbiotic relationship between cellular RNA processing and retro-elements.

SINEs are derived from generic cellular RNAs such as tRNA and the RNA of the signal recognition particle that admits nascent proteins into the membrane from the ribosome. They have recently been found to be concentrated in in genomic sites associated with transcribed functional genes, and to act as binding sites for regulatory proteins (Reynolds 1995), illustrating a form of convergent evolution based on genetic symbiosis. Alu act as regulators of cell stress increasing protein production under insult and potentially connecting to other vital cell functions through the kinase regulated by double stranded RNA. (Schmid 1998, Int. Human genome Consort 2001). The cell stress role is complemented by evidence that heat shock proteins such as hspgo can store up latent phenotypic mutations by stabilizing proteins and regulating developmental pathways in a way which can be disrupted by subsequent stress to display latent adaptive variety (Lindquist 2002).

Fig 30: Complementary tree of life: Evolution of Reverse transcriptases from a common ancestor bearing a LINE archetype (Xiong and Eickbush 1990 Nakamura et. al. 1997). Telomeres retroviruses and Line 1 elements ubiquitous in the human and other mammalian chromosomes share a common phylogeny in this tree consistent with a common origin in the RNA-era, since they instruct DNA from RNA.

Endogenous retroviruses may be essential for placental function. They 'blossom' on the placentas of every mammal so far investigated and appear to play a key role in enabling the massive cell fusion to form the syncytium the ultra-thin super-cellular membrane through which diffusion occurs, and inhibiting immune reactions to the placenta both features characteristic of retroviruses like HIV, again suggesting a genetic symbiosis with these elements. Viral transfer may explain up to a hundred vertebrate genes which appear to be inherited from bacteria (Villareal 2001, Int. Genome Consortium 2001).

10.6 Universality D: Sexuality as Complementarity-based Symmetry-breaking

Sexuality is absolutely essential to the evolution of all higher organisms. No branch of the tree of life lacks any form of sexual exchange. Bacteria possess a non-complementary form of pan-sexuality mediated by viruses and plasmids, enabling genetic recombination even between distinct species. However eucaryotes have developed a specifically complementary form of recombination which permits an almost endless variety of genetic recombinations.

Sexuality's immediate cause appears to lie in an arms race between parasites and their hosts in which sexual organisms survive epidemic disease and inherit recombinational diversity as a spin off. This is the key explanation which can provide the 2:1 advantage in the first generation which can compensate for the 50% loss of our genes in sexuality by comparison with full parthenogenesis (Ridley 1993, 1996). A symmetry-breaking can then occur in which sex becomes gender. In genetic terms this appears to have resulted from the effects of cytoplasmic 'selfish gene-wars' (Dawkins 1976), causing cytoplasmic incompatibility between isogametes. Such cytoplasmic genes are associated with parthenogenesis or male inhibition because they travel only down the female line with the cytoplasm. To avoid incompatibility, which can cause the loss of a majority of the cytoplasmic resource, one sex, now the female, precipitates gender through digesting the cytoplasm and organelles of the other (male) sex's isogamete. Consequently the sperm contributes only its DNA and perhaps an occasional mitochondrion. The lower reproductive investment of the sperm and the male reproductive strategy of venture risk follows inevitably (Ridley 1993, Watson 1995).

The symmetry-breaking is a manifestation of wave-particle complementarity between a huge enveloping ovum containing the wave-manifesting membrane and all the cytoplasm including cytoplasmic DNA and cell organelles complementing millions of essentially particulate sperm - simply motile molecular DNA - competing to fertilize it. Its basis is complementary aspects of molecular structure, in forming the membrane, on the one hand, and particulate DNA on the other. Sperm DNA is tightly packaged in inactive bound form, having no capacity to display wave-like conformational dynamics. Fertilization is a hair-trigger reaction between competing sperm dissolving the outer coat of the ovum and the critically-poised threshold electrochemical state of the ovum, ready to enter a hair-trigger explosive chain reaction to prevent more than one sperm entering, culminating in active amoebic engulfing. Resolving the exact sequence of these processes in fertilization remains difficult (Vacquier 1998). The one membranous engulfing ovum and the many discrete particulate sperm imply that sexuality and its symmetry-breaking into male and female genders may be a biological manifestation of wave-particle complementarity.

In suggesting sex has a basis in quantum complementarity, which runs deeper than analogy or metaphor, we need to note complementarity can manifest in a variety of ways which may have an underlying relationship which may be hard to establish experimentally, but is nevertheless an important hypothesis in cosmological terms. If biological gender has a basis in quantum complementarity, we would expect it to be a common feature of all biological organisms in the universe, despite possibly having separate origins of life. It also has major implications for the status of complementarity in terms of subjective consciousness. Complementarity manifests in three distinct contexts which appear to be categorically distinct. Firstly we have complementarity between the subjective and objective description of waking existence, viewed either as a description of the physical universe or an internal model of reality possibly evoked by the brain. The subjective and objective descriptions are interdependent but also mutually exclusive in the sense that mind states and brain states cannot be identified. Wave-particle complementarity likewise has an interdependent yet mutually exclusive expression in which a quantum can manifest as a wave or a particle but not both at the same time, although each can be expressed in terms of superpositions and processes involving the other. Sexuality would seem to be a very late comer in cosmic and even biological evolution for a potentially cosmological process, but is nevertheless a phenomenon based on wave and particle properties of matter which is mutually exclusive in its symmetry-broken form. It is also a direct manifestation of a fundamental quantum complementarity between the essentially particulate nature of the encoded DNA molecules in the nucleus and the manifestly wave-based processes of electrochemical excitation in the membrane. It is this complementarity which becomes the dividing embryo.

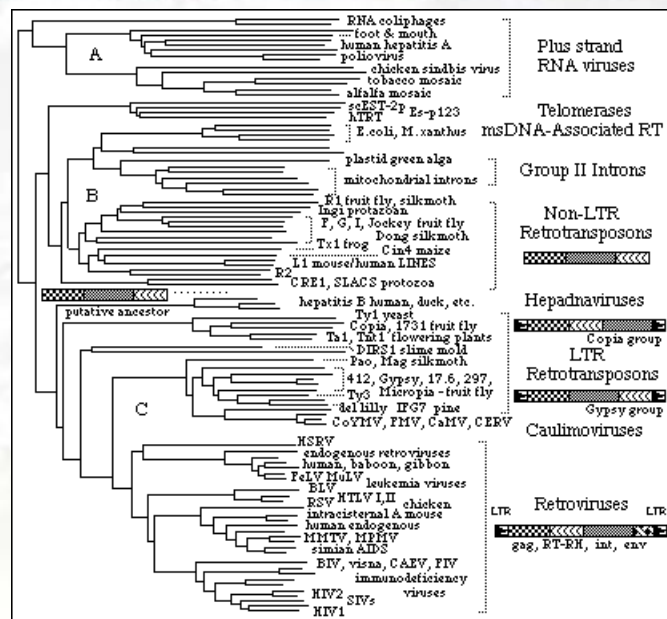




Fig 28b: Engendered sexuality is a symmetry-breaking general to almost all higher organisms.

Sexual symmetry-breaking may also have functional significance in regulatory evolution (King 1991). It is notable that less than 5% of human DNA codes for proteins, leaving the vast majority to have regulatory, structural or evolutionary function, including the repeated sequences corresponding to active and defective transposable elements noted above. The critical problem facing human evolution is how a species with a long and increasing generation time can adapt in evolutionary terms, give limits on viable mutation rates per

generation. One possible solution to this is that higher organisms still possess similar forms of viral and plasmid-mediated 'sexual' exchange apparent in procaryotes. The association of SINEs with stress and the ubiquitous nature of LINEs which still retain active elements, combined with endogenous retroviruses, leaves open that these agents can promote types of structured 'mutagenesis' which, while mostly deleterious could enable coordinated regulatory responses to forms of organismic stress. Since the deletion-insertion mutation rate has now been recognized to be higher by a factor of three than the point mutation rate, this raises the possibility of a symbiotic ecology of transposable agents which although they may also cause deleterious effects make possible some aspects of modular regulatory evolution through transposition.

In this context, LINEs are preferentially expressed in both steriodogenic and germ-line tissues in mice (Branciforte and Martin 1994, Trelogan and Martin 1995), suggesting stress could interact with meiosis. The L1 expression occurs in embryogenesis, at several stages of spermatogenesis including leptotene, and in the primary oocytes of females poised at prophase I. Conversely the SRY-group male determining gene SOX has been found to regulate LINE retrotransposition (Tchenio et. al. 2000). Similarly LINE elements have been proposed to have a function as 'boosters' in the inactivation of one X chromosome that happens in female embryogenesis (Lyon 2000). If LINEs are capable of intra-organismic movement to any degree, this could enable somatic stress to have a potential effect on translocation in the germ-line. This is not in any way a Lamarkian view because it is fully consistent with Darwinian mutation and selective advantage, and the ecology of viral and cellular genomes manifest in bacterial and eucaryote lineages. However it does allow for an intermittent response to regulatory stress which could have a degree of relation to the stress involved.

The 'lampbrush' phase of extended chromosomes during meiosis has also been suggested to enable forms of genetic re-processing. In non-mammals this extended phase involves open transcription of coding and non-coding regions and has been proposed to be a form of genetic processing (Wolfe), which probably occurs in a less obvious way in mammals as well. The much longer time primary oocytes remain suspended in meiotic stasis before eventual maturation might to give the female a tendency to express stress-induced translocational effects during adult life, 'compensating' for the up to four-fold higher base rate of male point mutation, because the continual mitotic production of sperm cells leads to more cell divisions, by contrast with quiescent immature oocytes (Ellegren 2000, Nachmann and Crowell 2000, McVean and Hurst 1997). Some of the early radioactive tracer studies of diplotene 'lampbrush' chromosomes in amphibians showed apparent spooling of the DNA during maturation of the ovum, consistent with a gene comparison mechanism (Callan, Wolfe). The purpose of such openly transcribing stretches of the whole chromosomes including vast regions which are not coding for any protein remains obscure (Angeleir et. al. 1996). All transcription units functioning in lampbrush loops synthesize RNA at a maximum rate. In situ hybridization has provided evidence for transcription of both unique coding sequences and highly repetitive sequences. For repetitive sequences, their intense transcription appears to be non-productive, in that RNAs are not translatable and might be useless products of readthrough transcription, unless they have a role in genetic modulation as RNAs.

The effects of this symmetry-breaking are extreme in the human species - difference of reproductive investment in which men make a small multiple investment in many partners while women have to make an honest overt investment in massive pregnancy, lactation and early child-rearing. Female orgasm, concealed estrus and sperm competition attest to female reproductive choice in human evolution which necessarily involves covert sexual liaisons as well as 'monogamous' pair bonding. (Fisher 1992, Angier 1999).

The complementarity between these competing genetic strategies has ensured the evolution of most species, including humans, is based on female reproductive choice in a situation of strategic gender paradox. Although gendered sexuality appears to arise late in the evolutionary tree, it may thus nevertheless be a response to complementarities of a fundamental physical nature which emerge as part of the interactive phase of cosmological re-entry.

Sexual selection, which is itself an unstable positive feedback process, has been proposed to be the basis of human cultural emergence, art and the dimensions of good nature which extend beyond kin and reciprocal altruism - agreeableness, compassion and the capacity to experience selfless love (Miller 2000). It is salient that sexual selection is a complementary force to natural selection which, rather than being conservative and ordering, is a potentially chaotic process which leads to runaway through positive feedback and to the growth of forms of generosity and compassion as genuinely costly indicators of genetic fitness in the process of encouraging the opposite sex to consent to reproduce, without which survival would be fruitless. This applies particularly to female reproductive choice which is pivotal to male reproductive survival. Humanity in particular has no specific defining niche and is effectively a meta-species in which sexual selection under gender paradox appears to have been pivotal in all the displays of complexity in forming language, culture, art and science during our 100,000 year gatherer-hunter emergence.

10.7 Universality E: The Mammalian Cortex and the Emergence of Human Consciousness

An ultimate universality which is of great significance to homo sapiens as a species arises from the universality of quantum modes of perception and the nature of the edge of chaos, neurotransmitter-based electrochemical nervous system to form in the mammalian brain a universal sensory manifold in the cortex combined with an emotional spectrum which transcends all direct notions of genetic selfishness. Within the domain of nervous systems there is in mammals an evolution towards universality as significant as that of the homeotic genes.

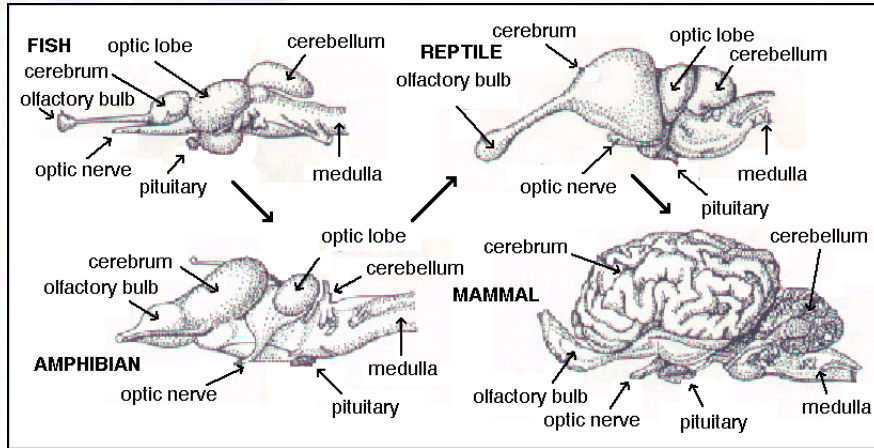


Fig 31a: Evolution of the vertebrate brain shows reduction of the specialized sensory areas such as the optic lobe, which is replaced by outgrowth of primitive generalized cerebral tissue from the olfactory processing area to form a universal sense and conceptual organ embracing all sense (and thus quantum) modes.

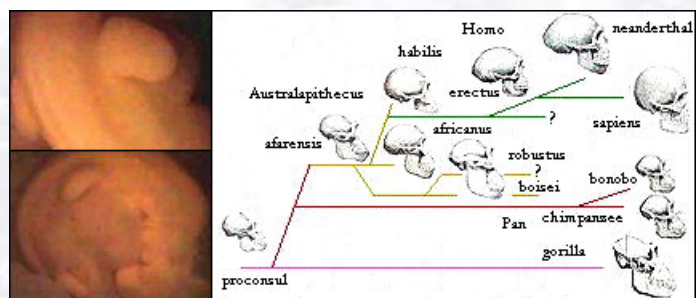
There is a great deal of commonality between wide varieties of organism with seemingly very different nervous system organization, in terms of common neurotransmitter types and the modes of neuronal communication. Although the nervous systems of arthropods and vertebrates are very different in net organization, they use a similar array of amine and other neurotransmitters which themselves may originate from primal

interaction with the lipid membrane and its excitability in prebiotic times as noted earlier. Also shared are the principles of parallel processing, edge of chaos dynamics and the use of 'silent' cells with continuous potentials as organizers.

Within the vertebrate phylum, there is a clear evolution from specific hard-wired dedicated structures for the senses, such as the primitive optic lobe towards generalized sense organs. In mammalian evolution is a remarkable trend towards universality in the evolution of the cerebral cortex, arising from the region for smell, the least differentiated and most 'chaotic' of the senses, to form, not only a generalized sense organ, spanning all the quantum modes of the senses, but also a universal cognition and experiential organ. This generalized organ has almost completely taken over the original sensory areas to the point where a new paradigm of sensory modeling has emerged, in which all the senses, from smell through hearing to vision using variations on the same general set of principles, as evidenced by neural plasticity and the capacity of one sense to take over function from another such as the use of optical regions for other spatial senses in blind people.

This development of cortical organization is also accompanied by a transformation to form the emotional system of the limbic brain which universalizes the genetic paradigm, from the confines of the selfish gene and its direct generalizations in kin and reciprocal altruism, to a much more general emotional connection, which can transcend familial, racial and even species boundaries to make possible a new paradigm of ecological evolution and to manifest the mysteries of love which now so galvanize our sexual and reproductive life. Central to the evolution of the mammalian cortex is its foundation in the limbic system and with it fundamental questions of the relationship between flight and fight and personal transformation lurking in the regions linking the amygdala and the temporal cortex. This region, sometimes called the "god spot" illustrates how subtly evolution at the edge of chaos can reach towards an ecological manifestation which may permit a win-win solution through exploiting the frontiers of physical cosmology to generate coherent human social cultures based on a collective sense of integrated design and purpose through mutual affection.

Fig 31b: Left: Early human embryo with fish-like fins. Right: Periods in which there have been more than one species of specialized hominid have given way to a single meta-species. Homo is more closely related to the chimpanzee than the chimp is to the gorilla. (BBC, King). The line of evolution from the mammalian adaptive radiation to primates, apes and humans has seen a marked trend towards universality, which humans have exemplified most extremely, becoming a meta-species, in which the cultural epoch has seen humans developing as many diverse cultural niches as biological species have in a living ecosystem. The basis of this meta-species capacity is extreme universality and plasticity in neurodynamic function in which our senses are converging towards perceptual quantum universality in a way which enables diverse cortical areas to adapt and adopt new kinds of function as the environmental conditions demand, from compensating for a loss of function in one sense, to establishing new language areas for multilingual live translation. This trend to universality extends all the way back to the first small eutherians which coexisted with the dinosaurs provoked by a state of optimum adaptability with short life spans and rapid genetic turn over.



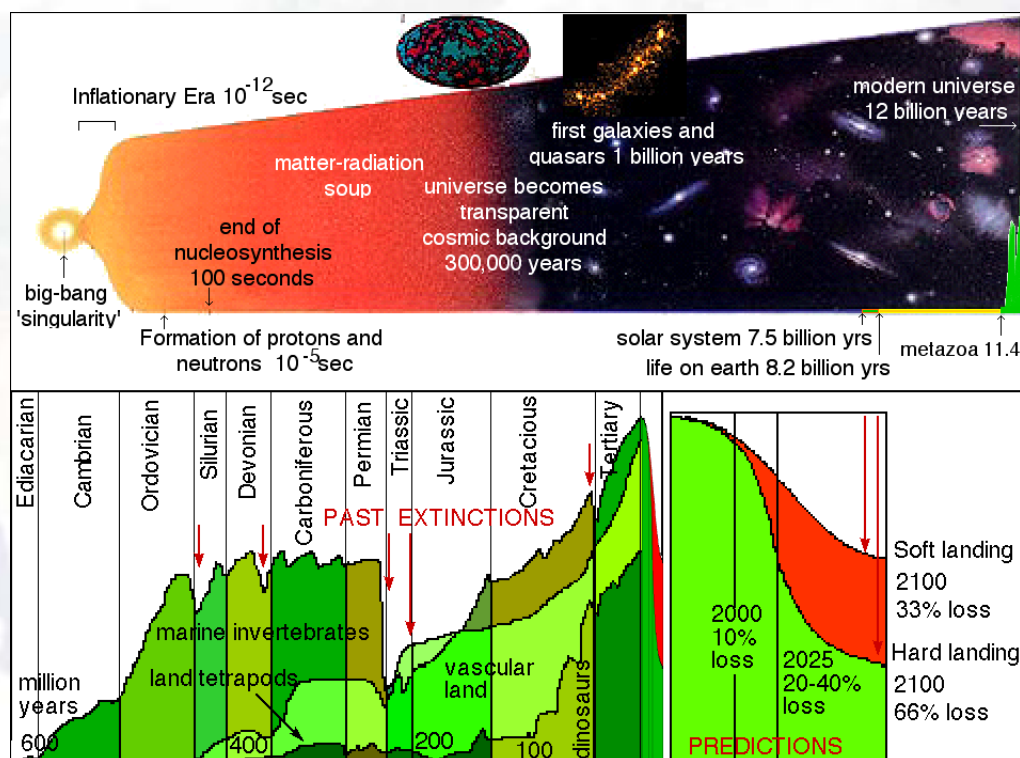


Fig 32: Comparison of the evolution of the universe from the big bang and the evolution of life on Earth shows that life has existed for a full third of the universe's lifetime and is a long-term, stable feature of cosmic evolution. Astronomical events, such as asteroid and cometary impacts and nearby supernovae have always played a major role in causing mass extinctions accompanied by volcanism possibly as a secondary consequence of the impacts themselves. However the advent of so-called human civilization is threatening in the next century to cause a mass extinction more serious than the Cretaceous-Tertiary event that wiped out the dinosaurs. The process is caused both by direct impacts such as deforestation and habitat destruction and by genetically modifying the very species upon which we depend without conserving their naturally viable forms, so that our future becomes brittle and fragile, dependent on maintaining artificial growing environments and high-tech food distribution processes which would be disabled globally by the slightest of astronomical disturbances, leading directly towards human extinction. For a single species to cause a mass extinction of life's diversity, possibly lasting 10 million years in one century is thus terminal folly. It is compounded by the ever increasing value biological resources have in the genetic epoch. There is thus a paramount need for us to rediscover our relationship with the cosmos and to take the responsibility to regenerate genetic and biological diversity to sustain our own future generations.

11: THE COSMOLOGY OF LIFE'S DIVERSITY

This places upon us an awesome responsibility to care for the living Earth in space-time so that its future can flower regardless of the heat death or cosmic crunch which will await us far further down the track. It is urgent to consider the mass extinction of life the failure to understand this cosmic principle is leading us to in the acute and devastating holocaust of Earth's genetic and biological diversity. Survival of any species depends on endurance over evolutionary and thus cosmic time scales. All the indications are at present that humanity remains unaware of its increasingly perilous disruption of all natural long-term processes of evolutionary diversity and robustness on the planet in the naive belief in a technological quick fix after the damage has become inescapable.

This deranged social phenomenon appears to source from a break in the human evolutionary stream which led us from a hundred thousand year epoch of sustainability as gatherer-hunters into a transient period of gender, natural and social exploitation and domination by war, genocide, famine and nascent overpopulation. The result is short term exploitative investment based on winner-take-all venture capital investment, reflecting the spermatogenic strategy of boom and bust and reproductive risk over the longer-term investment of female fecundity over generations. If we are going to survive, we need urgently to reinvest in our coherent relationship with the cosmos and interdependence with the diversity of nature.

Life has existed on Earth for a third of the universe's lifetime of some 10 billion years. It is the most eloquent and complete expression known of the universe's cosmological capacity for complexity. The quantum universe is not the Newtonian machine we once envisaged and neither is it a substrate for human and religious dominion over woman and nature alike. Discovering that consciousness and free-will does have an impact on the evolving history of the universe may be a first step to regaining our survival prospects in the universe over cosmic time and thus regaining our natural and possibly pivotal place in the cosmic process which we lost in Jericho ten thousand years ago when men assumed reproductive imperative over women and the right to dominion over all the natural processes on the planet, overthrowing the evolutionary sexual paradox between the genders which saw *Homo sapiens* emerge sustainably in evolutionary time and as gatherer-hunters over the last 100,000 years (King 1999, Fielder and King 2004). Human civilization, and with it the biosphere, is becoming increasingly brittle and fragile to the mildest of astronomical disruptions, which could take out our food distribution systems, sever our communications and render much of the arable area of the planet unproductive. It is essential for the evolutionary robustness of our future survival to preserve the full diversity of life, particularly the species upon which we depend in their natural viable state in well-conserved habitats, yet we are systematically on a global basis undermining the very source of our own genetic

future. Not only is there wholesale destruction of species and genetic diversity by habitat destruction but we are failing to adequately maintain the natural habitats and diversity of even those food, medicinal and commercial species upon which our livelihood depends.

The advent of unbridled genetic modification is likely to exacerbate this problem further through the loss of the viable natural varieties through the devotion of the vast proportion of the arable areas of the planet to non-viable engineered varieties, the loss of natural diversity through aggressive marketing of patented varieties, the disruption of the immortality of the germ line through terminator and leaky exorcist technologies and the horizontal transfer of engineered traits into natural ecosystems through cross-fertilization. On the same count the human gene pool is on the brink of a new kind of genetic war fought thorough germ-line engineering and cloning ambitions, for utopian and selfish ends, without a clear idea of where humanity is heading genetically, or the interaction between the components of our genome. The extensive use of reproductive technologies such as IVF, routine Caesarian intervention and surrogacy to both undermine our natural viability genetically and technologize and dislocate our natural reproductive protocols, which have sustained the emergence of humanity in evolutionary time. Only by developing a consensual social ethic which preserves the personal autonomy of our reproductive process and safeguards the living diversity of the biosphere is it likely humanity will survive minor astronomical, climatic and social onslaughts over cosmic time.



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BIOCOSMOLOGY 3

Quantum Cosmology and the Hard Problem of the Conscious Brain

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Abstract:

The conscious brain poses the most serious unsolved problem for science at the beginning of the third millennium. Not only is the whole basis of subjective conscious experience lacking adequate physical explanation, but the relationship between causality and intentionally willed action remains equally obscure. We explore a model resolving major features of the so-called ‘hard problem in consciousness research’ through cosmic subject-object complementarity. The model combines transactional quantum theory, with chaotic and fractal dynamics as a basis for a direct relationship between phase coherence in global brain states and anticipatory boundary conditions in quantum systems, complementing these with key features of conscious perception, and intentional will. The aim is to discover unusual physical properties of excitable cells which may form a basis for the evolutionary selection of subjective consciousness, because the physics involved in its emergence permits anticipatory choices which strongly favour survival.

1: Subject-Object Complementarity and the Hard Problem

In “The Puzzle of Conscious Experience” David Chalmers (1995) summarizes some of the main points of his definition of the now renowned ‘hard problem in consciousness research’. He contrasts with the hard problem what he calls the ‘easy’ problems such as: ‘How can a human subject discriminate sensory stimuli and react to them appropriately?’ ‘How does the brain integrate information from many different sources and use this information to control behaviour?’ ‘How is it that subjects can verbalize their internal states?’ Each of these deal broadly with problems of consciousness, but in ways which could in principle be resolved by straightforward functional explanations.

The ‘hard problem’, by contrast, is the question of how physical processes in the brain give rise to subjective experience. This puzzle involves the inner aspects of thought and perception and the way things feel for the subject - all of them subjective experiences known only to the participant. This is much harder to resolve because trying to compare brain states, which are in principle objective and replicable, with subjective experiences, which, however rich for the experienter, are unavailable to an external observer, pose a severe problem of qualitative difference, which seems almost unbridgeable.

Chalmers rejects any simple resort to neuroscience explanations about brain states in solving the hard problem. He notes for example that the 40 Hz oscillations made famous by Crick and Koch (1992) and others, which might provide an explanation for the coherent binding together of different brain regions, for example visual and auditory into one attended perception, may explain how the brain integrates different processing tasks (an easy problem) but don’t explain how any of these modes evoke the subjective conscious experiences of vision and sound. Likewise he rejects philosophical explanations such as Daniel Dennett’s (1991) ‘multiple drafts’ theory of consciousness as an explanation of ‘how we produce verbal reports on our internal states’ (an easy problem) which tells us very little about why there should be a subjective experience behind these reports.

Even when we proceed to theories which attempt to use new types of physics to bridge this chasm, Chalmers remains sceptical:

“Some have suggested that to solve the hard problem, we need to bring in new tools of physical explanation: nonlinear dynamics, say, or new discoveries in neuroscience, or quantum mechanics. But these ideas suffer from exactly the same difficulty. Consider a proposal from Stuart R. Hameroff of the University of Arizona and Roger Penrose of the University of Oxford. They hold that consciousness arises from quantum-physical processes taking place in microtubules, which are protein structures inside neurons. It is possible (if not likely) that such a hypothesis will lead to an explanation of how the brain makes decisions or even how it proves mathematical theorems, as Hameroff and Penrose suggest. But even if it does, the theory is silent about how these processes might give rise to conscious experience. Indeed, the same problem arises with any theory of consciousness based only on physical processing.”

Following on to examine the trend in cosmology and unified field theories, Chalmers speculates that conscious experience may be a fundamental feature cosmologically:

“If the existence of consciousness cannot be derived from physical laws, a theory of physics is not a true theory of everything. So a final theory must contain an additional fundamental component. Toward this end, I propose that conscious experience be considered a fundamental feature, irreducible to anything more basic.”

This perception of the central nature of consciousness to the cosmological description is more acute than an academic or philosophical matter. Although the scientific description is based exclusively on the objective physical universe, our contact with reality is entirely *sine que non* through our subjective conscious experience. From birth to death, we experience only a stream of consciousness through which all our experience of the physical world is gained. All scientific experiments performed on the physical world ultimately become validated by the subjective conscious experience of the experimenters, and the subsequent witnesses to the phenomena and conclusions.

Because its subjective nature makes it unavailable to objective investigation, reductionist descriptions identify subjective consciousness with functional attributes of the brain, inferring computational machines might also possess consciousness. At best in such views, the subjectively conscious mind remains an enigma considered to be merely a passive ‘epiphenomenon’. However it is the physical world which is secondary to our personal experience, a consensus of stable subjective representations we assemble into our real world view. It thus remains unclear whether a physical universe without conscious observers could exist in any more than a purely conceptual or theoretical sense. Subjective consciousness may be necessary for the actualization of physical reality, and thus fundamental to physical existence in a cosmological sense, as expressed in the ‘anthropic cosmological principle’ that ‘observers’ are significant and possibly necessary boundary conditions for the existence of the universe (Barrow and Tipler 1988).

Of course this somewhat ‘idealistic’ view of subjectivity as a cosmic complement to the physical universe has a variety of critiques. Our conscious experience, while it remains mysterious, appears to be an inner manifestation of a functioning brain. Knock us out and consciousness is interrupted. The brain is a notoriously sensitive and easily damaged organ. Moreover it is a recent development in a universe where brains are by no means a forgone conclusion, the product of an idiosyncratic process of biological evolution, which at the surface appears to have little to do with the vast energies and forces shaping the cosmology of the universe as a whole. Nevertheless an argument based on non-linear interactions arising from cosmic symmetry-breaking and evolutionary universality can make the claim that the brain is accessing universal properties of a quantum nature, which may be the basis of its capacity for

conscious subjectivity.

The conscious mind can also be described functionally as an internal model of reality. While such an explanation does not address the basis of subjectivity, it does help explain some of the more bizarre states of consciousness and is supported by many actively constructive aspects of sensory processing and the modular architecture of the cerebral cortex. Such an internal model can be described functionally in terms of dynamical brain processes which undergo unstable transitions to and from chaos (Skarda and Freeman 1987). Dynamical resonance and phase coherence also provide direct means to solve the 'binding problem', how the unitary nature of mind emerges from distributed parallel processing of many brain states.

A second critical property of subjective consciousness comes into play as we move from perception into volition. To quote Sir John Eccles : "It is a psychological fact that we believe we have the ability to control and modify our actions by the exercise of 'will', and in practical life all sane men will assume they have this ability" (Hooper and Teresi 1986). However this premise, which is basic to all human action, contradicts physical determinism, because any action of mind on brain contradicts the brain functioning as a deterministic computational machine, in its own right, in the physical world.

A confluence between quantum physics and the science of mind may resolve this apparent paradox. Firstly physics has difficulty determining when collapse of the wave function from a set of probabilities into an actual choice takes place, leading to some interpretations in which the conscious observer collapses the wave function. Secondly quantum uncertainty and non-locality provide exactly the types of explanation which could enable the subjective experience of free-will to be consistent with a non-deterministic model of brain function. The unpredictability of chaos (Stewart, Schuster) due to its amplification of arbitrarily small fluctuations in what is known as 'sensitive dependence on initial conditions, could provide a means to link quantum indeterminacy to global brain states.

2: Wave-Particle Complementarity, Uncertainty and Quantum Prediction

Associated with the nature of quanta themselves are unreconciled problems, which share an intriguing logical homology with problem of conscious intent. To explore these we will first summarize some of the core ideas of quantum reality.

If we have to find the frequency of a wave using the beats we can produce by comparing it with another similar wave, without being able to measure the exact amplitude of the wave at a given time (the actual situation in root quantum interactions), we then have let a considerable time elapse, to gain enough beats for an accurate measurement so we don't know exactly when the frequency was at this value. The relationship between the frequencies and the beats is: $\Delta\nu\Delta t \geq 1$, a smeared-out 2-D 'interval' of time and frequency combined.

Fig 1: Measuring a wave frequency with beats has intrinsic uncertainty as to the time

Einstein's law is a fundamental equation of quantum mechanics which connects to every energetic particle a frequency $E = h\nu$ Measuring one is necessarily measuring the other. If we apply the above together, we immediately get the Heisenberg uncertainty relation:

$$\Delta E\Delta t = h\Delta\nu\Delta t \geq h$$

Each quantum can be conceived as a particle or as a wave, but not both at the same time. Depending on how we are interacting with it or describing it, it may appear as either. We can visualize the interchange between particle and wave natures by generating photons and allowing them to flow through a pair of closely spaced slits. When many photons pass through, their waves interfere as shown and the photographic plate gets dark and light interference bands where the waves from the two slits cancel or reinforce, because the photons are more likely to end up where their superimposed wave amplitude is large. The experiment confirms the wave nature of light, since the size of the bands is determined by the distance between the slits in relation to the wavelength where c is the velocity of light: $\lambda = \frac{v}{c}$

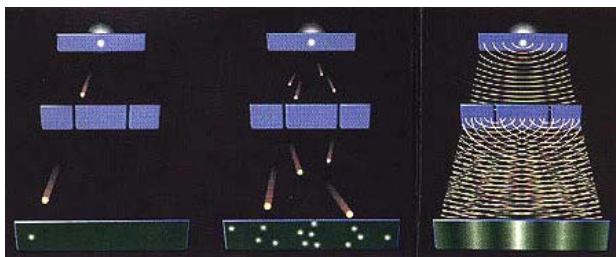
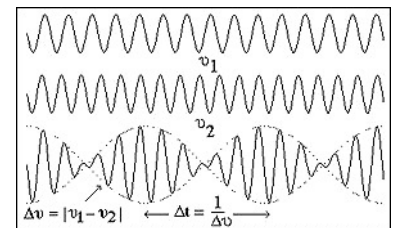


Fig 2: Two-slit interference experiment (Sci. Am. Jul 92)

We know each photon passes through both slits, because we can slow the experiment down so much that only one photon is released at a time and we still eventually get the interference pattern. Each photon released from the light bulb is emitted as a particle from a single hot atom, whose excited electron is jumping down from a higher energy orbit to a lower one. It is thus released locally and as a single 'particle' created by a single transition between two stable electron orbitals, but it spreads and passes through both slits as a wave. After this the two sets of waves interfere as shown in fig 2 to make bands on the photographic

plate.

The evolution of the wave is described by an equation involving rates of change of a wave function ϕ with respect to space and time. For example for a massive particle in one dimension we have a differential equation:

$$\left(\frac{\partial^2}{\partial t^2} - \frac{\partial^2}{\partial x^2} + m^2 \right) \phi = 0$$

For the bands to appear, each single photon has to travel through both slits as a wave. If you try to put any form of transparent detector in the slits to tell if it went through one or both, you will always find only one particle, but now the interference pattern will be destroyed. This happens even if you use the gentlest forms of detection possible, such as an empty resonant maser chamber (a maser is a microwave laser). Any measurement sensitive enough to detect a particle alters its momentum enough to smear the interference pattern into the same picture you would get if the particle just went through one slit. Knowing one aspect destroys the other.

At the other end of the process, the photon has to be absorbed again as a particle by an atom on the photographic plate, or somewhere else if it doesn't career forever through empty space, something we shall deal with shortly. Where exactly does it go? The rules of quantum mechanics are only statistical. They tell us only that the particle is more likely to end up where the amplitude of the wave is large, not where it will actually go on any one occasion. The probability is precisely the complex square of the wave's amplitude at any point:

$$P = \phi^* \phi$$

always has the same velocity, c regardless of the movement of the observer, or the source. Einstein realized that Maxwell's equations and the properties of physics could be preserved under all inertial systems - the principle of special relativity - only if the properties of space and time changed according to the Lorentz transformations as a particle approaches the velocity of light c :

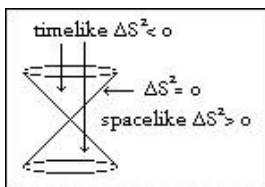
$$x' = \frac{x - vt}{\sqrt{1 - v^2/c^2}}, y' = y, z' = z, t' = \frac{t - (v/c^2)x}{\sqrt{1 - v^2/c^2}}$$

Space becomes shortened along the line of movement and time becomes dilated. Effectively space and time are each being rotated towards one-another like a pair of closing scissors. Consequently the mass and energy of any particle with non-zero rest mass tend to infinity at the velocity of light: $m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$

By integrating this equation, Einstein was able to deduce that the rest mass must also correspond to a huge energy $E_0 = m_0 c^2$ which could be released for example in a nuclear explosion, as the mass of the radioactive products is less than the mass of the uranium that produces them, thus becoming the doom equation of the atom bomb. General relativity goes beyond this to associate gravity with the curvature of space-time caused by mass-energy.

In special relativity, space and time become related entities, which form a composite four dimensional space-time, in which points are related by light-cones - signals travelling at the speed of light from a given origin. In space-time, time behaves differently to space. When time is squared it has a negative sign just like the imaginary complex number $i = \sqrt{-1}$ does.

Hence the negative sign in the formula for space-time distance $\Delta S^2 = x^2 + y^2 + z^2 - c^2 t^2$ and the scissor-like reversed rotations of time and space into one another expressed in the Lorentz transformations. Stephen Hawking has noted that if we treat time as an imaginary variable, the space-time universe could become a closed 'manifold' rather like a 4-D sphere, in which the cosmic origin is rather like the north pole of Earth, because imaginary time will reverse the above negative sign and give us the usual Pythagorean distance formula in four dimensions.



Space-time light cone permits linkage of 'time-like' points connected by slower-than-light communication. In the 'space-like' region, temporal order of events and causality depends on the observer.

A significant feature of special relativity is the fact that the relativistic energy-momentum equation

$$E^2 = p^2 + m^2 \text{ has dual energy solutions: } E = \pm(\sqrt{p^2 + m^2})$$

The negative energy solution has reversed temporal direction. Effectively a negative energy anti-particle travelling backwards in time is exactly the same as a positive energy particle travelling forwards in time in the usual manner. The solution which travels in the normal direction (subsequent points are reached

later) is called the *retarded* solution. The one which travels backwards in time is called the *advanced* solution. A photon is its own anti-particle so in this case we just have an advanced or retarded photon.

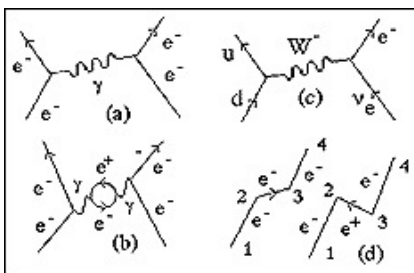


Fig 4: Quantum electrodynamics: (a,b) Two Feynman diagrams in the repulsion of two electrons. In the first a single virtual photon is exchanged between two electrons, in the second the photon becomes a virtual electron-positron pair during its transit. All such diagrams are integrated together to calculate the strength of the electromagnetic force. (c) A similar diagram shows how neutron decay occurs via the W^- particle of the weak nuclear force, which itself is a heavy charged photon. (d) A time reversed electron scattering is the same as positron creation and annihilation.

4: Reality and Virtuality: Quantum fields and Seething Uncertainty

The theories describing force fields such as electromagnetism through the interaction of wave-particles are the most succinct theories ever invented by the human mind. Richard Feynman and others discovered the field is generated by uncertainty itself through particles propagated by a rule based on wave spreading. These particles are called *virtual* because they have no net positive energy and appear and disappear entirely within the win-

dow of quantum uncertainty, so we never see them except as expressed in the force itself. This seething tumult of virtual particles exactly produces the familiar effects of the electromagnetic field and other fields as well. We can find the force between two electrons by integrating the effects of every virtual photon which could be exchanged within the limits of uncertainty and of every other possible virtual particle system, including pairs of electrons and positrons coming into a fleeting existence. However, we can't eliminate the wave description because the amplitudes with which the particles are propagated from point to point are wave amplitudes. Uncertainty not only can create indefiniteness but it can actively create every conceivable particle out of the vacuum, and does so.

Each more complex interaction involving one more particle vertex is smaller by a factor $\frac{e^2}{hc} \sim \frac{1}{137}$ where e is the electron charge and h and c are as above, called the 'fine structure constant'. This allows the contribution of all the diagrams to sum to a finite interaction unlike many unified theories, which are plagued by infinities. The electromagnetic force is generated by virtual photons exchanged between charged particles existing only for a time and energy permitted by the uncertainty relation. The closer the two electrons, the larger the energy fluctuation possible over the shorter time taken to travel between them and hence the greater the force upon them. Even in the vacuum, where we think there is nothing at all, there is actually a sea of all possible particles being created and destroyed by the rules of uncertainty.

The virtual particles of a force field and the *real* particles we experience as radiation such as light are one and the same. If we pump energy into the field, for example by oscillating it in a radio transmitter, the virtual photons composing the electromagnetic field become the real positive energy photons in radio waves entering the receiver as a coherent stream of real photons, encoding the music we hear.

Relativistic quantum field theories always have both advanced and retarded solutions, one with positive and the other with negative energy, because of the two square roots of special relativity. They are often described by Feynman space-time diagrams. When the Feynman diagram for electron scattering becomes time-reversed, it then becomes precisely the diagram for creation and annihilation of the electron's anti-particle, the positron, as shown above. This hints at a fundamental role for the exotic time-reversed advanced solutions.

The weak and strong nuclear forces can be explained by similar field theories related to electromagnetism through symmetry-break-

ing, but gravity holds out further serious catch-22s. Gravity is associated with the curvature of space-time, but this introduces fundamental contradictions with quantum field theory. To date there remains no fully consistent way to reconcile quantum field theory and gravitation although higher-dimensional string and membrane theories show promise (Hawking 2001).

Fig 5: Wheeler delayed choice experiment: A very distant quasar is gravitationally lensed by an intervening galaxy. We can sample photons either by an interference pattern, verifying they went around both sides of the galaxy, or place separate directional detectors which will detect they went one way around only as particles (which will destroy the interference pattern). Moreover, we can decide which to perform after the photon has passed the galaxy, at the end of its path. Thus the configuration of the latter parts of the wave appear to be able to alter the earlier history.

5: The Spooky Nature of Quantum Entanglement

We have already seen how the photon wave passing through two slits ends up being absorbed by a single atom. But how does the wave avoid two particles accidentally being absorbed in far flung parts of its wave function out of direct communication? Just how large such waves can become can be appreciated if we glance out at a distant galaxy, whose light has had to traverse the universe to reach us. The ultimate size of the wave of such a photon is almost as big as the universe. Only one photon is ever absorbed for each such wave, so once we detect it, the probability of finding the photon anywhere else, and hence the amplitude of the wave, must immediately become zero everywhere. How can this happen, if information cannot travel faster than the speed of light? The same thing happens when I shine my torch against the window. The amplitude of each photon is both reflected, so I can see it, and transmitted, so that it could also escape into the night sky. Although the wave may spread far and wide, if the particle is absorbed anywhere, the probability across vast tracks of space has to suddenly become zero.

Moreover collapse may involve the situation at the end of the path influencing the earlier history, as in the Wheeler delayed choice experiment illustrated in fig 5. In this experiment we can determine whether a photon went both ways round a lensing galaxy, focusing the light from a very distant quasar long after the light has passed across the universe, by either measuring the interference between the paths as in the double slit experiment or by detecting light from one direction or another.

Because we can't sample two different points of a single-particle wave, it is impossible to devise an experiment which can test how a wave might collapse. One way to learn more about this situation is to try to find situations in which two or more correlated particles will be released coherently in a single wave. This happens with many particles in a laser and in the holograms made by coherent laser light and in Bose-Einstein condensates. It also happens in other situations where two particles of opposite spin or complementary polarization become created together. Many years ago Einstein, Rosen and Podolsky suggested we might be able to break through the veil of quantum uncertainty this way, indirectly finding out more about a single particle than it is usually prepared to let on.

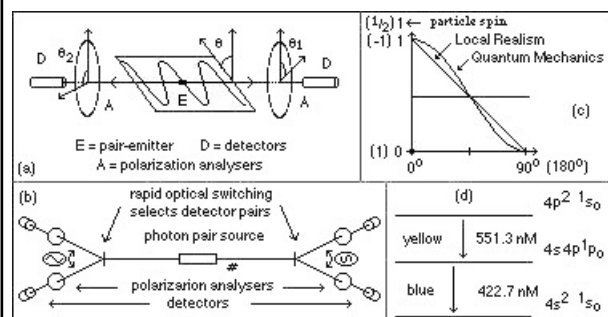


Fig 6: (a) Pair-splitting experiment for photons. (b) Time-varying analyzers are added driven by an optical switch to fast for light to cross the apparatus. (c) The results are consistent with quantum mechanics but inconsistent with Bell's inequalities for a locally causal system. (d) The calcium transition (Aspect 1982).

For example a calcium atom's electron excited into a higher orbital sometimes cannot fall back to its original orbital in one step because a photon always turns out to have spin 1 and the spins don't match. For example you can't go between two orbits of equal spin and radiate a spin-1 photon or the spins don't tally. The atom however can radiate two photons thereby cancelling one another's spins, to transit to its ground state, via an intermediate spin-1 orbit. This releases a blue and a yellow photon, each of which travel off in opposite directions, with complementary polarizations.

When we perform the experiment, it turns out that the polarization of neither photon is defined until we measure one of them. When we measure the polarization of one photon, the other immediately - instantaneously - has complementary polarization. The nature of the angular correlations between the detectors is inconsistent with any locally-causal theory - that is no theory based on information exchanged between the detectors by particles at the speed of light can do the trick, as proved in a famous result by John Bell (1966) and subsequent experiments (Clauser and Shimony 1978). The correlation persists even if the detectors' configurations are changed so fast that there is no time for information to be exchanged between them at the speed of light as demonstrated by Alain Aspect (1982). This phenomenon has been called quantum non-locality and in its various forms quantum 'entanglement', a name itself very suggestive of the throes of a sexual 'affair'.

The situation is subtly different from any kind of classical causality we can imagine. The information at either detector looks random until we compare the two. When we do, we find the two seemingly random lists are precisely correlated in a way which implies instantaneous correlatedness, but there is no way we can use the situation to send classically precise information faster than the speed of light by this means. We can see however in the correlations just how the ordinary one-particle wave function can be instantaneously auto-correlated and hence not slip up in its accounting during collapse.

Since this result in the 1980s there have been a veritable conjurer's collection of experiments, including quantum teleportation, erasure computing and encryption, all of which verify the predictions of quantum mechanics in every case and confirm all the general principles of the pair-splitting experiment. Even if we clone photons to form quartets of correlated particles, any attempt to gain information about one of such a multiple collection collapses the correlations between the related twins.

Some of the more challenging aspects of quantum entanglement arise when we consider quantum computation. Classical computation has a problem which is the potentially unlimited time it takes to check out every one of a collection of possibilities. E.g. to crack a code we need to check all the combinations, whose numbers can increase more than exponentially with the size of the code numbers and possibly taking as long as the history of the universe to compute. For example factorizing a large number composed of two primes is known to be computationally intractable enough to provide the basis for public key encryption by which banks records and passwords are kept safe. Although the brain ingeniously uses massively parallel computation, there is as yet no systematic way to boot strap an arbitrary number of parallel computations together in a coherent manner. Quantum reality is a superposi-

tion of all the possible states in a single wave function, so if we can arrange a wave function to represent all the possibilities in such a computation, superposition might give us the answer by a form of parallel quantum computation. A large number could in principle be factorized in a few superimposed steps, which would otherwise require vast time-consuming classical computer power to check all the possible factors one by one.

6: Quantum Match-making: Transactional Supercausality and Reality

For reasons which immediately become apparent, the collapse in the pair-splitting experiment has to not only be immediate, but also to reconcile information looking backwards in time. The two photons we are trying to detect are linked through the common calcium atom. Their absorptions are thus actually connected via a path travelling back in space-time from one detector to the calcium atom and forward again to the other detector. Trying to connect the detectors directly, for example by hypothetical faster-than-light *tachyons*, leads to contradictions. Tachyons transform by the rules of special relativity, so a tachyon which appears to be travelling at an infinite speed according to one observer, is travelling only at a little more than the speed of light according to another. One travelling in one direction to one observer may be travelling in the opposite direction to another. They also cause weird causality violations. There is thus no consistent way of knitting together all parts of a wave using tachyons. Even in a single-particle wave, regions the wave has already traversed also have to collapse retrospectively so that no inconsistencies can occur in which a particle is created in two locations in space-time from the same wave function, as the Wheeler delayed choice experiment makes clear.

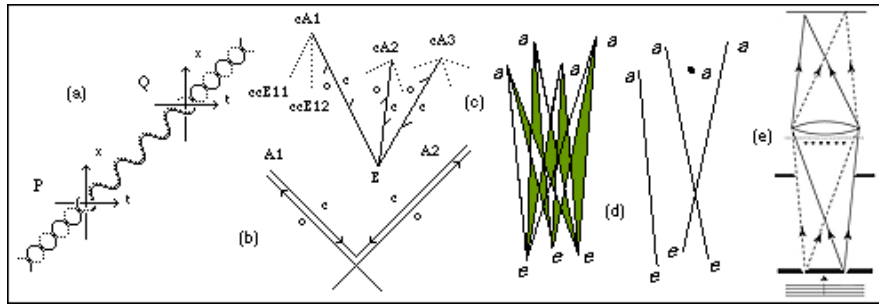


Fig 7: (a) In the transactional interpretation, a single photon exchanged between emitter and absorber is formed by constructive interference between a retarded offer wave (solid) and an advanced confirmation wave (dotted). (b) The transactional interpretation of pair-splitting. Confirmation waves intersect at the emission point. (c) Contingent absorbers of an emitter in a single passage of a photon. (d) Collapse of contingent emitters and absorbers in a transactional match-making (King). (e) Experiment by Shahri Afshar (see Chown 2004).

In the *transactional interpretation* (Cramer 1986), such an advanced ‘backward travelling’ wave in time gives a neat explanation, not only for the above effect, but also for the probability aspect of the quantum in every quantum experiment. Instead of one photon travelling between the emitter and absorber, there are two shadow waves, which superimposed make up the complete photon. The emitter transmits an *offer* wave both forwards and backwards in time, declaring its capacity to emit a photon. The potential absorbers of this photon transmit a corresponding *confirmation* wave. These, travelling backwards in time, send a hand-shaking signal back to the emitter, fig 7(a). The offer and confirmation waves superimpose constructively to form a real photon only on the space-time path connecting the emitter to the absorber. The transactional approach offers the only viable explanation for the apparently faster-than-light connections between detectors in pair-splitting EPR experiments in which a pair of correlated photons are emitted by a single atom as in fig 6. In fig 7(b), rather than a super-luminal connection between detectors A1 and A2, the photons’ own advanced waves meet at the source in a way which enables the retarded waves to be instantaneously correlated at the detectors.

A possible confirmation of the transactional approach comes from an intriguing experiment by Shahri Afshar (see Chown 2004), fig 7e. A grid is placed at the interference minima of the wave fronts coming from two slits, just below a lens designed to focus the light from each slit into a separate detector. Measurements by detectors (top) test whether a photon (particle) passed through the left or right slit (bottom). There is no reduction in intensity when the grid is placed below the lens at the interference minima of the offer waves from the two slits. The grid does however cause a loss of detector intensity when the dashed left-hand slit is covered and the negative wave interference between the offer waves at the grid is removed, so that the non-interfered wave from the right slit now hits the grid, causing scattering. This suggests both that we can measure wave and particle aspects simultaneously, and that the transactional interpretation is valid in a way which neither many worlds (which predicts a splitting into histories where a photon from the source goes through one slit or other) or the Copenhagen interpretation of complementarity (where detecting a particle forbids the photon manifesting as a wave).

In the extension of the transactional approach to supercausality (King 1989, 2003), a non-linearity reduces the set of contingent possibilities to one offer and confirmation wave, fig 7 (c,d). Thus at the beginning, we have two set of contingent emitters and absorbers as in fig 7(c) and at the end each emitter is now exchanging with a specific absorber. Before collapse of the wave function, we have many potential emitters interacting with many potential absorbers. After all the collapses have taken place, each emitter is paired with an absorber in a kind of marriage dance. One emitter cannot connect with two absorbers without violating the quantum rules, so there is a frustration between the possibilities which can only be fully resolved if emitters and absorbers can be linked in pairs. The number of contingent emitters and absorbers are not necessarily equal, but the number of matched pairs is equal to the number of real particles exchanged, fig 7(d).

The transition is not difficult to model as a sequence of non-linear bifurcations, in which one emitter-absorber pair becomes committed, but notice that the time parameter we are dealing with lies outside space-time, as it is transforming one space-time diagram into another, yet it is happening experientially in real time. This is because collapse of the wave function is a space-time process. Causality with its symmetry-broken sequential time and supercausality with its time-symmetric handshaking form complementary domains, which is why the model is also called dual-time supercausality (King 1981). Directed and symmetric time thus coexist in the model. Notice also that the past contains causal records as well as superpositions, but the future is purely extrapolation plus superpositions. It is at this point that the influence of the conscious observer and the hard problem become pivotal. This transactional time symmetry is paralleled in the time reversibility of a quantum computation so long as it remains in the original superposition of states contrasted with the time directed nature of classical computation, and with it the definitive results of any quantum computation arising from collapse.

The transactional process connects an emitter at an earlier time to an absorber at later time because a real positive energy photon is a *retarded* particle which travels in the usual direction in time. If you wish, you can think of a negative energy photon travelling backwards in time as the anti-particle of the positive one and it will have just the same effect. The two are thus identifiable in the

transaction, just as in quantum electrodynamics above, where time-reversed electron scattering is the same as positron creation and annihilation. One can also explain the arrow of time if the cosmic origin is a reflecting boundary that causes all the positive energy real particles in our universe to move in the retarded direction we all experience in the arrow of time. This in turn gives the sign for increasing disorder or entropy as it is called and the direction for the second law of thermodynamics to work in terms of positive energy. In the pair-splitting experiment, fig 7(b), one can also see that the calcium atom emits in response to the advanced confirmation waves reaching it from both the detectors simultaneously right at the time it is emitting the photon pair. Thus the faster than light linkage is neatly explained by the combined retarded and advanced aspects of the photon having a net forwards and backwards connection which is instantaneous at the detectors.

The equivalence of real and virtual particles raises the possibility that all particles have an emitter and absorber and arose, like virtual particles, through mutual interaction when the universe first emerged. However even if dark-energy, 'quintessence' causes an increasing expansion, or fractal inflation leads to an open universe model in which some photons may never find an absorber, the excitations of brain oscillations, because they are both emitted and absorbed by past and future brain states could still be universally subject to transactional supercausal coupling.

The hand-shaking space-time relation implied by the transactional interpretation makes it possible that the apparent randomness of quantum events masks a vast interconnectivity at the sub-quantum level, reflecting Bohm's (1980) *implicate order*. Although one can readily envisage a non-linear interaction where a sequence of bifurcations of the mutual frustration between the emitters and absorbers, because this connects past and future in a time-symmetric way, it cannot be reduced to predictive determinism, because the initial conditions are insufficient to describe the transaction, which also includes quantum 'information' coming from the future. However this future is also unformed in real terms at the early point in time emission takes place. My eye didn't even exist, when the quasar emitted its photon, except as a profoundly unlikely branch of the combined probability 'waves' of all the events throughout the history of the universe between the ancient time the quasar released its photon, my eye developing, and me being in the right place at the right time to see it. Transactional supercausality thus involves a huge catch 22 about space, time and prediction, uncertainty and destiny. It doesn't suggest the future is determined, but that the contingent futures do superimpose to create a space-time paradox in collapsing the wave function.

The transactional interpretation may combine with quantum computation to produce a space-time anticipating quantum entangled system which may be pivotal in how the conscious brain does its computation (see section 12). The brain is not a marvelous computer in any classical sense. We can barely repeat seven digits. But it is a phenomenally sensitive anticipator of environmental and behavioral change. Subjective consciousness has its survival value in enabling us to jump out of the way when the tiger is about to strike, not so much in computing which path the tiger might be on, because this is an intractable problem and the tiger can also take it into account in avoiding the places we would expect it to most likely be, but by intuitive conscious anticipation.

Fig 8: Human brain showing key underlying structures (Sci. Am, Sep 92) indicate a massively parallel organization with feedback loops linking major cortical and limbic areas and interfacing them with midbrain centres in the thalamus, and basal brain. The limbic structures of the hippocampus and amygdala are indicated. There are only about ten serial connections between sensory input and motor output.

7: Exploring the 'Three Pound Universe'

The human brain has been described as the 'three-pound universe' (Hooper and Teresi) because, along with some other mammalian brains, it is the single most complex system so far discovered in the entire cosmological realm. It is also the most mysterious. Although we have developed super-computers, their architecture remains that of a simplistic deterministic automaton by comparison with the brain. Despite the vast increases of speed and memory capacity of modern computers, they remain trivial by comparison. Few have more than a few processing units and the communication protocols for parallel processing, outside simple matrix calculations, remain simple procedural farming out. The notion that a computer may some day also become subjectively conscious is at this point a science fiction fantasy.

Theoretical models of neural nets likewise remain trivial by comparison with brain structures. Neurons are frequently modeled as simple additive modules summing their inputs and making synaptic adjustments to their connections in response to stimulus. Continuous nets such as the Hopfield net have only transient dynamics seeking a simple energy minimum as an equilibrium condition, perhaps with some thermodynamic annealing to avoid getting stuck in the 'rut' of a sub-optimal local minimum. Biological neurons by contrast are dynamically active, adaptive single-celled 'organisms', having up to 10,000 synaptic connections each and possessing a variety of excitatory and inhibitory neurotransmitters, as well as both dynamical and pulse-coded means of activation. They display both chaos and self-organized criticality and threshold tuning.

The brain is *par excellence* a distributed parallel processing system in which there are only perhaps four to ten serial links between sensory input and motor output, modulated by connections involving up to 10^{11} cells and 10^{15} synapses. Its protocols are thus 'lateral' rather than 'serial'. The mammalian brain is dominated by the cerebral cortex. We are now beginning to gain some idea of how it processes sensory information through a combination of electrical probing and various types of scans.

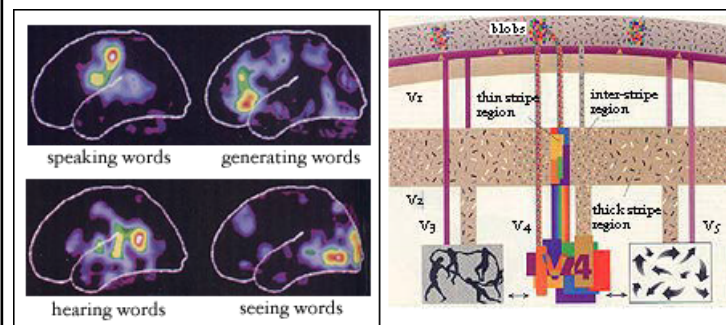
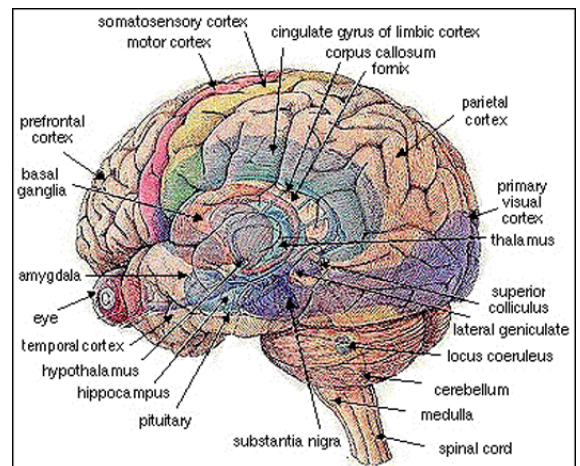


Fig 9: Despite the development of sophisticated techniques for visualizing brain activity such as those for speech (left), and ingenious work tracing connectivity of activity between neurons in the cortex such as that establishing distinct parallel processing regions for colour and movement in vision (right, Zeki 1992), no objective brain state is equivalent to a subjective conscious experience. The difficulty of bridging this abyss is called the hard problem in consciousness research (Chalmers)

The cortex has a dynamic modular organization, in which aspects of sensory 'information' are processed in parallel in distinct areas, including the regions specialized for primary vision and hearing and for somatosensory perception and motor functions. Many of these modular regions can be divided further, for example into specific areas to do with

language, such as Wernicke's and Broca's areas for semantic meaning and linguistic articulation. Using active scanning by multi-channel electroencephalograms, positron emission tomography, or functional magnetic resonance imaging, it is possible to follow conscious activity and compare it with modular activation of the cortex, fig 8. Visual processing can be divided into a significant number of distinct modular areas fig 9, complementing the primary visual area, with distinct processing for colour, movement and moving form. These areas can be investigated, both in scans and through people who display sometimes bizarre perceptual anomalies caused by local damage to these areas, such as colourless visual perception, or fragmented motion.

The cerebral cortex is divided between front and rear into broadly motor and broadly perception by the Sylvian fissure, dividing frontal regions and the motor cortex from the somatosensory (touch) and other sensory areas, including vision and hearing. The broadly sensory 'input' and associated areas of the parietal and temporal cortices are complemented by frontal and pre-frontal areas which deal with 'output' in the form of action rather than perception and with forming anticipatory models of our strategic and living futures. These active roles of decision-making and 'working memory' (Goldman-Rakic 1992), which interact from pre-frontal cortical areas complement the largely sensory-processing of the temporal, parietal and occipital lobes with a space-time representation of our 'sense of future' and of our will or intent.

Fig 10: Left: Ascending serotonin and norepinephrine pathways are evidence for a parallel distributed cortex based on dynamical activation of conscious modes. Serotonin receptors are notably involved in psychedelic effects. Right: Neural plasticity of local cortical function, in changes in regions of optical dominance in the visual cortex after the dominant eye is shade support dynamical rather than hard-wired cortical organization. Such plasticity extends across the senses, enabling the assignment of new functions under the demands of new experiential situations such as learning a new language

However these areas are not rigidly hard-wired genetically. Neurogenesis and neurophysiology are dynamic. The allocation of a given region is a dynamical consequence of a series of interactive processes. These begin in embryogenesis, where neurons migrate up the glial cellular scaffold to make specific types of global connection. Neurogenesis is accompanied by growth and migration and also sacrifice in programmed cell death, and removal as well as establishment of synapses. The overall organization is not static, but derived from the dynamics itself. In visual development, the retina and then the geniculate and finally the cortex become organized, each deriving organizing stimulus from the chaotic excitations established at the previous level. This cortical dynamic plasticity is preserved into later life, where injury, compensation, or a major new learned skill can result in development of new functional areas or significant rearrangement of existing areas. A person studied on live PET before and after becoming a real time translator at the UN, for example, showed the development of a whole new language area.

The cortex itself is relatively inert in electrodynamical terms and may actually form a complex boundary constraint on the activity of more active underlying areas such as the thalamus, which contains a number of centers with ordered projections to and from corresponding areas of the cortex. This suggests in turn that the thalamic centres are the driving force of cortical activity.

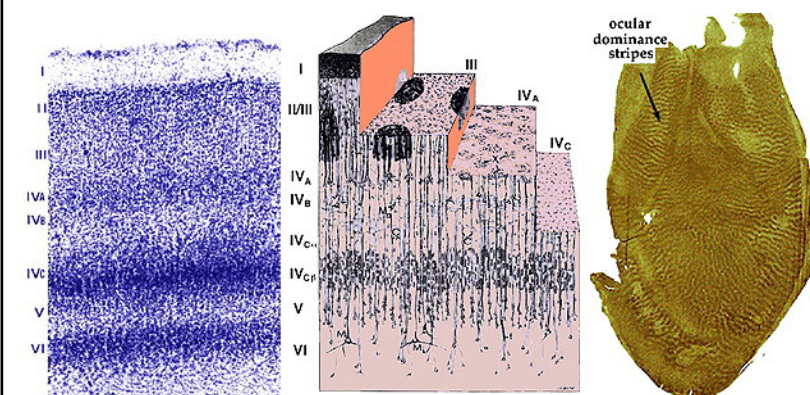
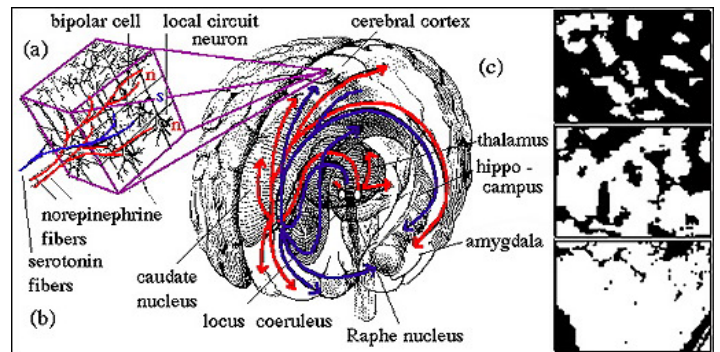


Fig 11: Typical cortical structures (centre) are a combination of five-layers of neurons each composed into columnar modules on a scale of about 1mm on the cortical surface. Such modules are sensitive to particular stimuli such as a line of a given orientation. Blob centres in layer II are also shown (see fig 9). Although specific sensory area have functional and anatomical specializations neural plasticity can enable changes of functional assignment indicating common principles throughout the cortex. Left: anatomical view of the five layers. Right: Ocular dominance columns illustrate functional columnar architecture.

Finally we have the so-called limbic system, fig 8, around the edges of the cortex, involving the hippocampus, amygdala, hypothalamus and areas of the cingulate cortex in a large feedback loop which has become associated with emotional mood, flight and fight, cross-sensory integration and the fixation of long-term sequential memory. These structures fall

very centrally into our concept of the psyche because they mediate the central emotional orientations which govern our survival and our social interaction with others, including the capacity for love, hate, jealousy, compassion and non-genetic altruism.

The varying modes of alert consciousness, dreaming and deep sleep are generated from deeper brain stem centers which have ascending neural pathways which fan out widely across the cortex into specific cortical layers, thus providing long-term modulation of mood and conscious attention fig 10. Two pathways lead from the Raphe Nuclei and the Locus Coeruleus to diverse cortical areas and involve the modulating neurotransmitters, serotonin and nor-epinephrine. The onset of dreaming sleep is heralded by activity of cells in the Pons and silencing of cells in the Raphe Nuclei and Locus Coeruleus. Similar dopamine paths spread out from the Substantia Nigra selectively into the frontal lobes and motor centers. The ascending pathways have been implicated in mental illness, addiction and motor syndromes such as Parkinson's disease. Dopamine is sometimes associated with pleasure and nor-adrenaline with anxiety. The hallucinogens psilocin and mescaline are serotonin and catecholamine analogues, although both appear to interact primarily with serotonin receptors. These pathways clearly have much to do with modulating conscious states of the cortex as a whole and understanding of their exact mechanism of action would give a very productive insight into the brain mechanisms supporting consciousness.

Dreaming or REM (rapid eye movement) sleep in which cortical activation alternates with phases of deep sleep is both one of the most singular phases of conscious activity in which experiential feedback appears to be accentuated at the expense of external input, generating episodic subjective realities or 'worlds within'. The nature and function of dreaming consciousness and its wealth of detail remain obscure although the experiences themselves are intense, sometimes in full sumptuous colour vision as evidenced in lucid dreaming (La Berge 1990). There is some indication that these two phases are complementary and involve reciprocal communication between the hippocampus and the cortex in consolidating long-term sequential memories (Winson 1992, Stickgold 1998, New Scientist 28 Jun 2003 29), but the subjective consequences, and the need for them to occur subjectively as well, as functionally remain enigmatic. Accounts of precognitive dreaming (Dunne c1935) challenge our very notions of causality.

8: Chaos and Fractal Dynamics as a Source of Sensitivity, Unpredictability and Uncertainty

Walter Freeman's model of chaos in sensory perception, fig 12(b,c), (Skarda and Freeman 1987, Freeman 1991) gives a good feeling for how transitions in and out of chaos - a so-called 'edge-of-chaos' complexity phenomenon (Ruthen 1993), could play a key role in sensory recognition. The olfactory cortex undergoes high energy chaotic excitation in time to form a spatially correlated wave across the cortex, as a rabbit sniffs, causing the cortical dynamics to travel through its phase space of possibilities without becoming stuck in any mode. As the sniff ends, the energy parameter reduces, carrying the dynamic down towards basins in the potential energy landscape. If the smell is recognized, the dynamic ends in an existing basin, but if it is new, a bifurcation occurs to form a new basin (a new symbol is created) constituting the learning process, as illustrated below. The same logic can be applied to cognitive problem solving in which the unresolved aspects of the problem undergo chaotic evolution until a bifurcation from chaos to order arrives at the 'eureka' of the solution.

A fundamental reason for any dynamical nervous system to enter chaos is that chaotic systems are arbitrarily sensitive on their initial or external conditions, so a system entering chaos is capable of being acutely responsive to its environment over time, while any stable process heads inexorably towards its equilibrium states or periodicities, entrapped by its very stability. While artificial neural nets invoke thermodynamic 'randomness' in *annealing* to ensure the system doesn't get caught in a sub-optimal local minimum, biological systems appear to exploit chaos to free up their dynamics to explore the 'phase space' of possibilities available, without becoming locked in a local energy valley which keeps it far from a global optimum.

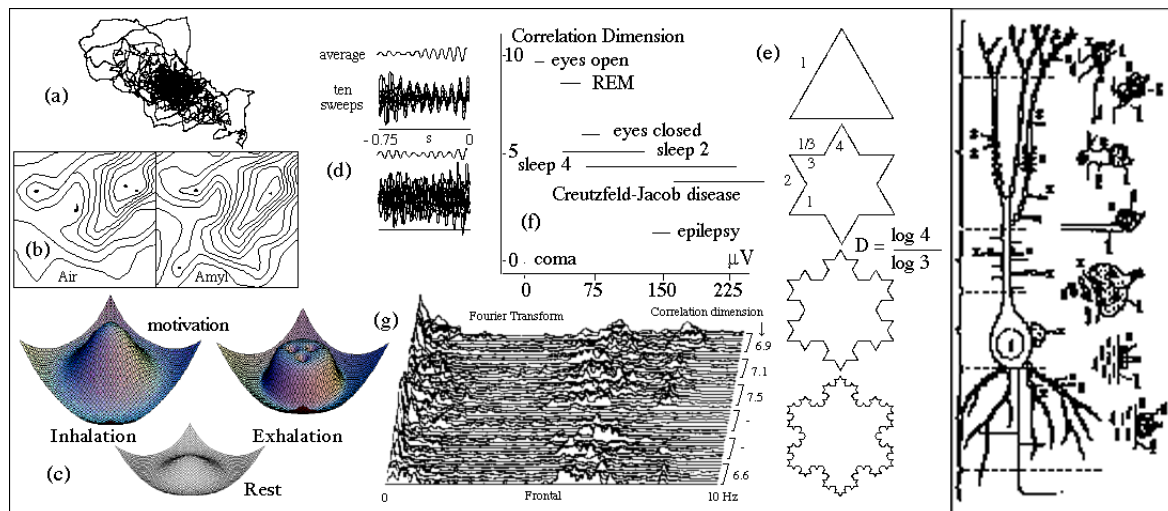


Fig 12: Left: Chaotic and fractal dynamics in the electroencephalogram: (a) 2-D map of a chaotic attractor in stage 4 sleep (b,c) 8x8 matrices of bulb response illustrating topological differences in excitation for air and amyl acetate and phase portrait of the stages of chaotic excitation in the Freeman model. (d) Coherence of EEG recording in anticipated events and desynchronization in the absence of anticipation. (e) Koch flake formed by repeated tessellation of a triangle (f) Typical correlation dimensions of a variety of natural and pathological brain states. (g) Time-evolving 2-D power spectra of electroencephalogram, frontal cortex showing variation with time in the frequency spectrum and the correlation dimension. Right: Neuronal dendrites and their synapses form a fractal architecture and dynamics in the brain in which global and local are interconnected (Schierwagen). Each of the types of synapse engage distinct neurotransmitters. Differing neural types have distinct fractal morphologies related to their firing pattern (Teich 1992).

Several indicators of the use of chaos in neurodynamics come from measurements of the fractal dimension of a variety of brain states, from pathology through sleep to restful wakefulness (Babloyantz et. al. 1985,1986, Rapp 1985, Babloyantz 1989), fig 12(f). Recordings from single neurons, and from other cells such as the insulin-releasing cells of the pancreas indicate their capacity for chaotic excitation. The organizers of neural systems are also frequently non-pulse coded 'silent' cells capable of continuous non-linear dynamics. Despite the classical result of quasi-linearity of the axonal discharge rate with depolarization, virtually all aspects of synaptic transmission and excitation have non-linear characteristics capable of chaos and bifurcation. For example the acetyl-choline ion channel has quadratic concentration dynamics, requiring two molecules to activate. Many cells have sigmoidal responses providing non-linear sensitivity and are tuned to threshold. Nonlinear feedback between excitatory and inhibitory neurotransmitters in cortical layers is believed to be a source of the electroencephalogram (Freeman 1991). The activity of single neurons has been found to include both cells with activity indistinguishable from noise and also neurons displaying low dimensional chaos (Albano et. al. 1986a). The electroencephalogram itself, although nominally described as having brain rhythms such as alpha, beta, gamma and theta actually consists of broad band frequencies, fig 12(g), rather than harmonic resonances, consistent with a ground-swell of chaotic excitation (King 1991,1996,1997). Broadly speaking neurodynamics is "edge of chaos" in the time domain and parallel distributed in a coherent 'holographic' manner (Pribram 1993) spatially. Phase coherence (e.g. in the 40 Hz band) is also associated with perception, providing a mathematical parallel with quantum wave coherence.

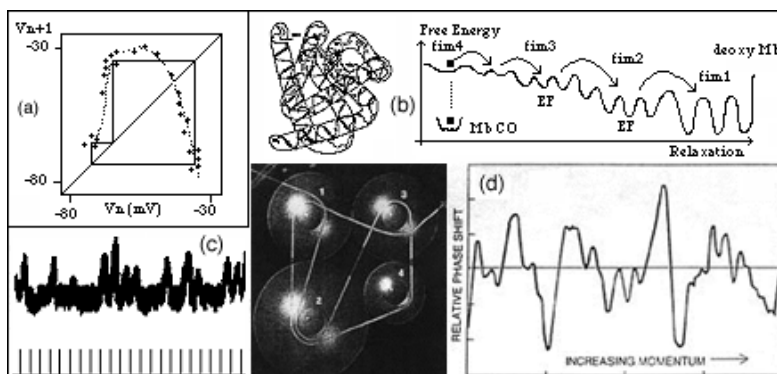
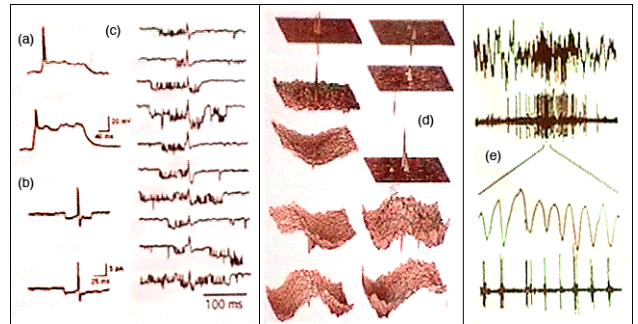


Fig 13: (a) Period 3 indicates chaos. Chaotic excitation in pancreatic cells is demonstrated by perturbing them slightly to period 3 oscillations characteristic of a narrow window of order in the chaotic regime. (b) Fractal molecular structure results in fractal dynamics (Ansari et. al. 1985). Functionally important movements in large protein molecules such as myoglobin occur in an environment of smaller local perturbations due to local fluctuations on fractal scales. (c) Frog retinal cells are sensitive to single quanta (Blakemore). (d) Chaotic variation of phase with increasing momentum in an electron traversing a molecular medium illustrates kinetic chaos in open systems at the quantum level. Enzymes have been shown to use quantum tunneling in their active sites and molecules as large as tetraphenylporphyrin (TPP) and buckyballs (C60) have been demonstrated to display quantum interference (Ball 2003, Arndt 1999, Hackermüller 2003). At biological temperatures a glycine molecule has a self-refraction angle of about 5°.(King 1981).

Into this picture of global and cellular chaos (Chay and Rinzel 1985) comes a second complementary aspect, the fractal nature of neuronal architecture and brain processes and their capacity for self-organized criticality at a microscopic level. The many to many connectivity of synaptic connection, the tuning of responsiveness to a sigmoidal threshold, and the fractal architecture of individual neurons combine with the sensitive dependence of chaotic dynamics and self-organized criticality of global dynamics to provide a rich conduit for instabilities at the level of the synaptic vesicle or ion channel to become amplified into a global change. The above description of chaotic transitions in perception and cognition leads naturally to critical states in a situation of choice between conflicting outcomes and this is exactly where the global dynamic would become critically poised and thus sensitive to microscopic or even quantum instabilities.

Evidence for complex system coupling between the molecular and global levels. Stochastic activation of single ion channels in hippocampal cells (a) leads to activation of the cells (c). Activation of such individual cells can in turn lead to formation of global excitations as a result of stochastic resonance (d). Individuals cells are also capable of issuing action potentials in synchronization with peaks in the eeg (e) (Liljenström and Svedin 2005).

Because of the intrinsic non-linearity of charge interactions, (see section 9), this fractal process runs all the way from the global brain state to molecular quantum chaos (Gutzwiller 1992). From the synaptic vesicle we converge to the ion channel which in the case of the K^+ voltage channel is determined to have a fractal kinetics (Liebovitch et. al. 1987, 1991), fig 19(b), and further to the structure and dynamics of proteins and their conformational dynamics (Ansari et. al. 1995), fig 13(b), both of which operate on non-linear fractal protocols. The brain is thus an organ capable of supersensitivity to the instabilities of the quantum milieu.



9: Classical and Quantum Computation, Anticipation and Survival

A computational process is intractable if the number of computational steps required grows super-exponentially with the complexity. The travelling salesman problem (Bern and Graham 1989), finding the shortest route round n cities illustrates this, growing with $(n-1)!/2$. A proposition may also be formally undecidable in the sense of Gödel's incompleteness theorem which says that any logical system containing finite arithmetic contains undecidable propositions. Many adaption-survival problems in the open environment are intractable problems, because the number of options rapidly exponentiates. This would leave a gazelle stranded at the cross roads unable to decide which path to take eaten in a 'catatonic' state due to Turing's 'halting' problem - the undecidability of whether a computational process will actually complete. An active organism must complete any processing task within 0.1-1 second if it is going to have survival utility, regardless of its complexity. Such arguments make it clear why dynamic parallel processing is an integral feature of vertebrate nervous systems.

Recent models of the quantum mind attempt to solve this problem by suggesting the brain is capable of a form of quantum computing which may be also associated with conscious awareness. For example Hameroff and Penrose (2003) have suggested that microtubules may permit a form of molecular quantum computing through two-state q -bits formed from tubulin monomers which exist in two quantum states. They suggest the tubulin monomers form a type of cellular automaton. While these ideas are exciting, they also introduce new problems. Microtubules are involved in neuronal activity and their pathologies do affect learning and memory, but it remains unclear their changes operate on the rapid time scale of electrodynamical changes and consciousness. The quantum computing model proposes individual cellular quantum computation through quantum isolation of the microtubules within the neuron to prevent decoherence, preventing the quantum computations from being integrable with many-cell resonances and hence the global brain states we naturally associate with conscious awareness.

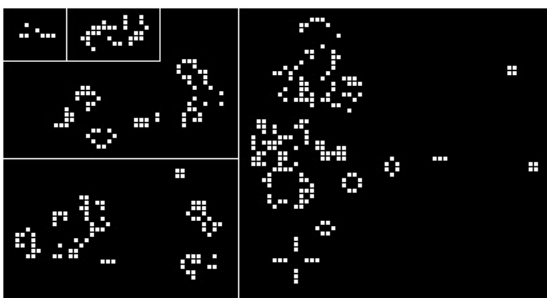


Fig 14: Conway's game of life is a two-dimensional cellular automaton with simple rules. Any cell with 2 or 3 of its 8 possible neighbours alive 'survives' and one with just 3 is 'born'. The rest die. The system, which is a digital version of edge of chaos complexity dynamics is capable of universal computation.

Some of the more challenging aspects of quantum entanglement arise when we consider quantum computation. Classical computation has a problem which is the potentially unlimited time it takes to check out every one of a collection of possibilities. E.g. to crack a code we need to check all the combinations, whose numbers can increase more than exponentially with the size of the code numbers and possibly taking as long as the history of the universe to compute. For example factorizing a large number composed of two primes is known to be computationally intractable enough to provide the basis for public

key encryption by which banks records and passwords are kept safe. Although the brain ingeniously uses massively parallel computation, there is as yet no systematic way to boot strap an arbitrary number of parallel computations together in a coherent manner.

However, we may be able to harness the superposition of all the possible states in a single wave function. If we can arrange a wave function to represent all the possibilities in such a computation, superposition might give us the answer by a form of parallel quantum computation. A large number could in principle be factorized in a few superimposed steps, which would otherwise require vast time-consuming classical computer power to check all the possible factors one by one. Suppose we know an atom is excited by a certain quantum of energy, but only provide it a part of the energy required. The atom then enters a superposition of the ground state and the excited state, suspended between the two like Schrödinger's cat. If we then collapse the wave function, squaring it to its probability, as in $P=\phi^*\phi$, it will be found to be in either the ground state or excited state with equal probability. This superimposed state is sometimes called the 'square root of not' when it is used to partially excite a system which flips between 0 and 1 corresponding to a logical negation.

Supposing we want to factorize a large number. We devise a single quantum system in two parts. The left part is excited to a superposition. Suppose we have a collection of such atoms which effectively form the 0s and 1s of a binary number - 0 in the ground state and 1 in the excited state. If we then partially excite them all they represent a superposition of all the binary numbers - e.g. 00, 01, 10 and 11. The right half is designed to give the factorization remainder of a test number taken to the power of each of the possible numbers in the left. These turn out to be periodic, so if we measure the right we get one of the values. This in turn collapses the left side into a superposition of only those numbers with this particular value in the right. We can then recombine the reduced state on the left to find its frequency spectrum and decode the answer. As a simple example, you are trying to factorize 15. Take the test

number $x = 2$. The powers of 2 give you 2, 4, 8, 16, 32, 64, 128, 256 ... Now divide by 15, and if the number won't go, keep the remainder. That produces a repeating sequence 2, 4, 8, 1, 2, 4, 8, 1 ... with period $n = 4$ we can use this periodicity as an 'interference pattern' to figure $x^{n/2} - 1 = 2^{4/2} - 1 = 3$ is a factor of 15. Quantum parallelism solves all the computations simultaneously.

The essential principles of this calculation may pass over into a general problem solving paradigm. Key is the idea that measurement of part of an entangled system may enable the whole system to collectively solve a problem connecting its entangled parts.

Nevertheless, although it may be able to solve some intractable problems by parallel superposition, (Deutsch 1985, Calude and Pavlov 2002), quantum computing alone may not solve the deeper problems of the open environment. Many critical decisions a living animal has to make to survive are not simply a matter of computation because many problems of survival are intrinsically unstable. Each strategy tends to be matched by a competing strategy in another organism, so that a predator may choose a less likely path for the very reason that the prey may be more likely to take it knowing it is safer in computational terms. These many options may not be able to be decided on by optimizing computationally on past histories, as illustrated by neural net 'over fit' errors, when circumstances change. Survival depends more on intuitive anticipation and paranoia taken to a hair-trigger, when the tiger is about to strike, rather than brute-force computation. This is where the evolutionary value of subjective consciousness begins to become apparent. It is thus insufficient to replace a computational model of brain function, as exemplified by 'artificial intelligence', with a form of quantum consciousness which is simply a reflection of quantum computation through non-local molecular automata or other mechanisms. Although quantum computation might act more quickly, avoiding the gazelle becoming stranded catatonically at the cross roads because of computational intractability, it still doesn't go any way to solving the questions of free-will and creative choice, nor does it compensate for the perfidy of the predator. Raw conscious anticipation is the key. Attentiveness and hunch in the shadow of paranoia is the best survival strategy.

Intentional generation of novelty and unpredictability for its own sake is also key to survival in many species, and strongly manifest in *Homo sapiens*. A pivotal aspect of novelty in our own context is that, in all species, decisions are not just made for survival but to express reproductive fitness. Geoffrey Miller (2000) in "The Mating Mind" has suggested that the development of human culture is an indicator of reproductive fitness in which both sexes are 'running while standing still' in a genetic race generated through novelty, music art, story-telling as well as resourcefulness and protection. This theme is further developed in "Sexual Paradox" (Fielder and King 2004). All of these features also need explaining and involve diversity and complexity generation which no computational model, quantum or otherwise, focussing on a fixed 'solution' can generate.

Quantum computing on its own does not solve the problem of 'will' involved in decision-making when many choices are available, several of which may be successful to varying degrees. The capacity to make a decision, given many options is pivotal. To explain free choice, it is also necessary to explain all the manifestations of non-computational complexity, such as the creativity which enables a new musical theme, or an art form, or other innovation to be created. None of this complexifying behaviour is explained by any form of computation which seeks a single optimal outcome or even a specific heuristic array of options. Creative variety is the essence of human diversity and our success as a species. Neither does quantum computing alone indicate why we experience a subjective impression of free-choice central to the exercise of subjective consciousness. In the Hameroff-Penrose OOR model, *reduction* of the wave function is regarded as *orchestrated* and *objective* and is thus independent of the conscious will of the experimenter. If intentional consciousness is only a retrospective reflection of an orchestrated objective collapse, it still has no evolutionary role in terms of selective advantage.

We thus need to explain not just how computation might be accelerated in quantum consciousness, but the origin of will in the subjective affecting and in effecting physical outcomes. We need to deal with dynamics in which many choices are available, not one computational solution, quantum or otherwise, and to explain how 'free will' can achieve real physical choices, and the endless variety of novelty which we associate with living systems and particularly with human culture. We need to consider not only computation but creativity - how the symphony emerges from the composer.

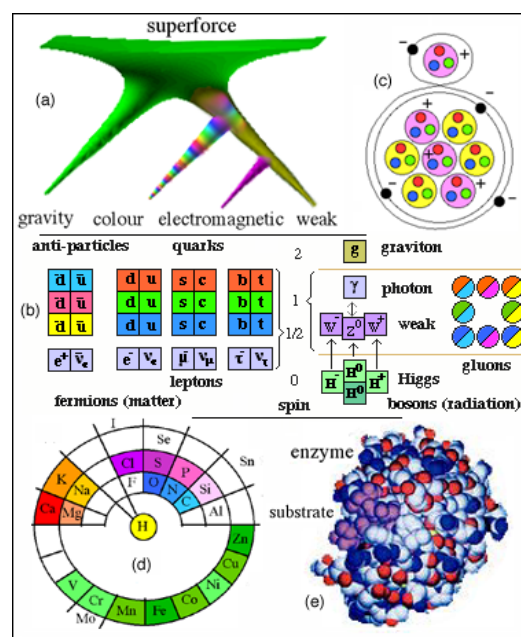
Fig: 15 (a) Cosmic symmetry-breaking as a fractal generator of life (King 1987, 2002).

The four forces of nature emerge from a single unified field theory, probably a 10 to 12 dimensional superstring or membrane theory based on supersymmetry - a pairing between the bosons and fermions, which cancels the infinities that would otherwise result in the theory. (b) The standard model showing the key fermions making up matter and bosons making force and radiation. Added to the 4 dimensions of space-time, the dimensions of the internal symmetries of colour, charge-flavour and the Higgs particle give a strong hint of the grand unification. (c) Because the resulting fermions are highly charge asymmetric they associate to form the hierarchical structures of atomic and molecular matter. The non-linear charge interactions result in a cascade of chemical bonding effects, generating higher molecular fractal structures, leading to organelles, cells and tissues. The bioelements form a key symmetry-breaking interaction among the principal orbital types.

10: The Cosmic Primality of Membrane Excitation

Rather than a molecular accident, the emergence of life can be modeled as a tree of critical cosmological quantum bifurcations, or splittings, interactively between quantum features emerging from the interaction of the atomic and molecular structures which arise in turn as complex asymmetric hierarchical structures from cosmic symmetry-breaking itself, fig 15. The non-linear nature of charge interactions results in a succession of bonding effects, from strong covalent and ionic bonds, through, H-bonds, polar and hydrophobic interactions, to van der Waal's effects. Cooperative weak bonding results in globally-interactive enzyme structures, fig 15(e) and in fractally increasing scales, molecular complexes, organelles, cells, tissues and organisms.

The central bifurcation tree, fig 15(d) is an interaction of the $1s$ orbital of H with the $2sp_3$ hybrid orbitals of C, N, and O as most strongly covalent multi-bonding elements. Secondary bifurcation of polarity between C, N, and O in order of increasing electronegativity in relation to H generates the polar non-polar bifurcation in which the phase division leading to the lipid bilayer membrane and ion-based excitation arises. H_2O becomes the optimal formative substrate in terms of its diversity of quantum modes (reflected in high specific heat), and diverse ionic and polar structures, giving rise to the interactive properties which make the polar-hydrophobic phase bifurcation of protein enzymes, fig 15(e), nucleic acid base stacking and lipid membranes, fig 17(b), and hence excitable cells possible.



Subsequent orbital bifurcations divide alkali and alkaline earth metal ions according to ionic radius, secondary involvement of second row elements in S-S weak covalency, PO_4^{3-} dehydration energy and Cl^- ions. Subsequently the d-orbital catalysis of the transition elements completes the orbital symmetry-breaking interaction. This bifurcation pathway leads directly to polypeptides, nucleotides and membranous lipid structures as complexity polymers, with RNA and monomers such as ATP having a central formative replicative role.

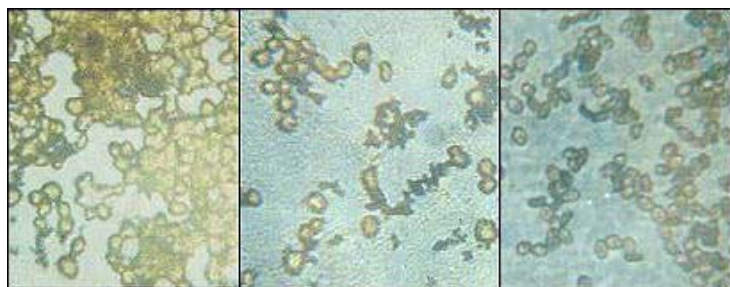


Fig 16: Left and centre: Microcellular formations generated by the author from HCN and HCHO (King). Right: Spores of a psilocybe species at the same magnification for size comparison.

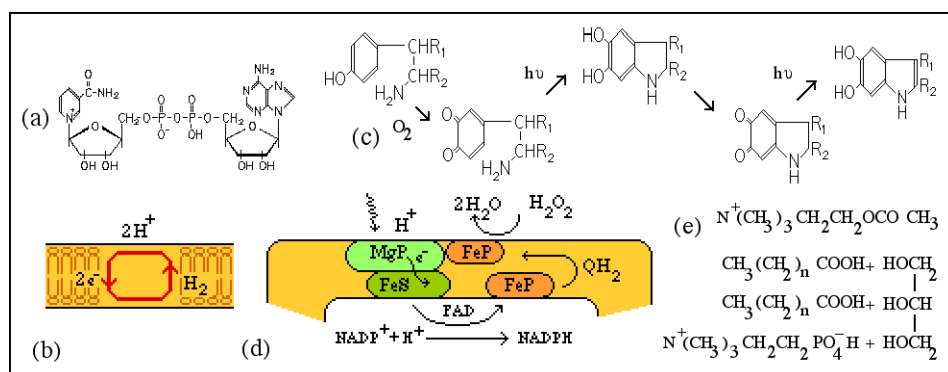
All life as we know it is dependent on maintaining a distinct internal micro-environment as an open far-from-equilibrium thermodynamic system (Glansdorff and Prigogine, Agladze et. al. 1984, Epstein et. al. 1983), through the topological closure of the cell. Viruses for example all depend on cellular life. The structure of the bilayer membrane is a direct consequence of the polarity bifurcation. The formation of amphiphilic lipid-like molecules, joining a linear non-polar hydrocarbon section to an ionic or H-bonding polar terminal,

leaves 2 degrees of freedom for layer formation. Backing of the non-polar moieties to one another, fig 17(b), completes the bilayer. Cell structure can then arise directly from budding of the bilayer, as illustrated in budding in several types of prebiotic reaction medium. Microcellular structures are abundant in many origin of life syntheses, fig 16. The use of cytosine diphosphate CDP associated with choline, inositol and lipids in membrane construction is consistent with membrane formation in the RNA era along with the ubiquitous energy molecule the nucleotide adenine triphosphate ATP. The structure of typical biological lipids such as phosphatidyl choline display a modular structure consisting of fatty acid, glycerol, and substituted amine, linked by dehydration and involving phosphate, fig 17(e).

The existence of the membrane as a non-polar structure leads to segregation into ionic and non-polar reaction phases. Ion transport is essential in maintaining the concentration gradients that distinguish the cytoplasm from the external environment and thus must develop in the earliest cellular systems (MacElroy et. al. 1989). Ion transport is a source of significant electronic effects, because the membrane under polarization is piezo-electric and is capable of excitation in the presence of suitable ions. Model systems using the simple 19 unit oligopeptide Na^+ ionopore alamethicin and artificial membranes display action potentials (Mueller and Rudin 1968). Similar results have been reported for microcells produced by prebiotic techniques containing light irradiated chromophores (Przybylski and Fox 1986), demonstrating that such effects are fundamental to the quantum architecture of lipid membranes (King 1990). Four groups of non-polypeptide neurotransmitters: acetyl-choline, catecholamines (epinephrine and dopamine), serotonin and histamine are all amines, the latter three being derived from amino acids tyrosine, tryptophan and histidine by decarboxylation. Two others are amino acids and thus also contain amine groups. This may represent a fundamental chemical bifurcation between basic amines and the acidic phosphate groups in the lipid membrane. Alamethicin also has glutamine amides located in the core of the pore (Fox and Richards 1982). The catecholamines are linked to indoles such as serotonin by a prebiotic pathway, fig 17(c).

Ion transport, the membrane and excitability appear to have a common progenitor in the phase transition to ordered water gels (Pollack 2001) with negatively-charged proteins, under ion gradients which reject Na^+ and attract K^+ , the latter leading to a compact ordered water phase transition leading to a stable gel phase cytoplasm without the need to impose a structurally unstable membrane and ion transport mechanism at the birth of the first cell to maintain a far from equilibrium thermodynamic limit cycle.

Fig 17: (a) NAD structure permits linkage of other energies to a redox bifurcation. (b) H^+ and e^- transport linked by H_2 in membrane due to insolubility of e^- and solubility of H^+ . (c) Prebiotic link between catecholamines and indole via quinone-type photoreduction. (d) Hypothetical form of primitive electron transport as a non-equilibrium limit cycle. (e) Acetyl-choline and phosphatidyl choline compared. Phosphatidyl choline lipid stacks tail to tail as shown in the clothes pegs (b).



The proton is soluble in water to form the hydrogen ion H^+ , but the electron is not, unless attached to another group such as a protein. This causes a physical linkage between the polarity bifurcation and the charge bifurcations associated with electron and proton transfer, fig 17(b) mediated by H transport through quinone reduction, (c). Despite the complexity of modern electron transport in photosynthesis and respiration, there is considerable evidence that membrane electrochemistry could have arisen before translation produced coded enzymes. There is a consistent basis for the existence of many of the components of electron transport during the RNA era. The nucleotide coenzymes provide evidence for this system emerging in the RNA era. Nicotine and flavin adenine dinucleotide NAD, FAD, a nucleotide-bound Mg/Fe-porphyrin ring similar to B_{12} , a cysteine-bound FeS group (Hall et. al. 1974), possibly based on glutathione (g-glutamyl-cysteinyl-glycine) and quinones would provide all the key components of electron transport in an RNA dependent but protein-free form, fig 17(d) (King 1990). The Fe-S-centre has also been cited a basis for prebiotic metabolism. Both porphyrins and quinones have obvious prebiotic syntheses and the primal role of nucleotide coenzymes has already been discussed. Secondly, membrane structure and the solubility differences between the electron and proton guarantee a link between electron and hydrogen ion transport fundamental to quantum symmetry-breaking. Electron transfer does not in principle require the complex coded active sites required to catalyze specific molecular transformations. Model systems using Fe-porphyrins and imidazole can couple oxidative electron transport to phosphorylation (Brinigar et. al. 1966) and photo activated Mg-porphyrin to phosphate (Goncharova and Goldfelt 1990, Lozovaya et. al. 1990). These would initially have used H_2S as a substrate rather than the higher splitting energy of H_2O .

These primal features give a basis for the occurrence of excitable membranes associated with cells as an interactive manifestation of cosmic symmetry-breaking. While this doesn't solve the hard problem, it does go some way towards a description in which the cel-

lular excitability we do associate with consciousness does have a possible cosmological status in physical terms, rather than being an idiosyncratic result of biological evolution alone. We thus next look at the ways evolution may have selected for subjective consciousness.

11: Chaotic Excitability and Quantum Sensitivity as a founding Eucaryote Characteristic.

The evidence of the preceding section suggests that chaotic excitability may be one of the founding features of eucaryote cells dating from the purely replicative RNA era, before coded protein translation (King 1978, 1990). The Piezo-electric nature and high voltage gradient of the excitable membrane provides an excitable single cell with a generalized quantum sense organ. Chaotic sensitive dependence would enable such a cell to gain feedback about its external environment, rather than becoming locked in a particular oscillatory mode. Excitation would be perturbed by a variety of modes - chemically through molecular interaction, electromagnetically through photon absorption and the perturbations of the fluctuating fields generated by the excitations themselves, and mechanically through acoustic interaction. Such excitability in the single cell would predate the computational function of neural nets, making chaos fundamental to the evolution of neuronal computing rather than vice versa. Key chemical modifiers may have been precursors of the amine-based neurotransmitters which span acetyl-choline, serotonin, catecholamines and the amino acids such as glutamate and GABA, several of which have a primal status chemically. The use of positive amines may have chemically complemented the negatively charged phosphate-based lipids in modulating membrane excitability in primitive cells without requiring complex proteins. It is possible that chaotic excitation dates from as early a period as the genetic code itself and that the first RNA-based cells may have been excitable via direct electrochemical transfer from light energy, before enzyme-based metabolic pathways based on protein translation had developed.

The sense modes we experience are not simply biological as such but more fundamentally the qualitative modes of quantum interaction between molecular matter and the physical universe. They thus have plausible cosmological status. Vision deals with interaction between orbitals and photons, hearing with the harmonic excitations of molecules and membrane solitons or piezo-electric excitons, as evidenced in the action potential. Smell is the avenue of orbital-orbital interaction, as is taste. Touch is a hybrid sense involving a mixture of these. The limits to the sensitivity of nervous systems are constrained only by the physics of quanta, rather than biological limits. This is exemplified in fig 13(c) by the capacity of retinal rod cells to record single quanta, and by the fact that membranes of cochlear cells oscillate by only about one H atom radius at the threshold of hearing, well below the scale of individual thermodynamic fluctuations and vastly below the bilayer membrane thickness. Moth pheromones are similarly effective at concentrations consistent with one molecule being active, as are the sensitivities of some olfactory mammals.

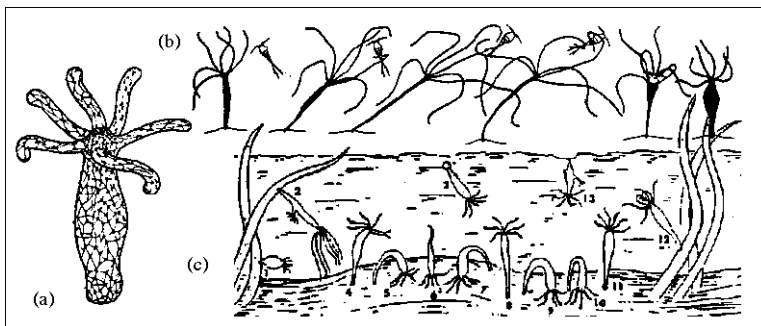


Fig 18: Hydra poses a dilemma for theories of cognitive development based on neural net organization rather than the complex adaptability of individual neurons. Hydra can reassemble ectoderm and endoderm if turned inside out and has a disseminated neural net (a) with no global structure, except for a slight focus around the mouth. Nevertheless it can coordinate eating in a similar manner to an octopus (b) and possesses more diverse types of locomotion than animals such as molluscs and arthropods which have structured ganglia. These include snail-like sliding, tumbling, inch-worm motion and use of bubbles and surface films.

The very distinct qualitative differences between vision, hearing, touch and smell do not appear to be paralleled in the very similar patterns of electrical excitation evoked in their cortical areas. If all these excitations can occur

simultaneously in the excitable cell, its quantum-chaotic excitation could represent a form of cellular multi-sensory *synaesthesia*, which is later specialized in the brain in representing each individual sense mode. Thus in the evolution of the cortical senses from the most diffuse, olfaction, the mammalian brain may be using an ultimate universality, returning to the original quantum modes of physics in a way which can readily be expressed in differential organization of the visual, auditory, and somatosensory cortices according to a single common theme of quantum excitability. This is consistent with cortical plasticity which enables a blind person to use their visual areas for other sensory modes.

It is thus natural to postulate that, far from being an epiphenomenon, consciousness is a feature which has been elaborated and conserved by nervous systems because it has had unique survival value for the organism. We are thus led to an examination of how chaotic excitation may have evolved from single-celled animals through the early stages represented by Hydra, fig 18, with its diffuse neural net, to the complex nervous systems of metazoa. We have seen how chaotic excitation provides for exploration of phase space and sensitivity to internal and external fluctuations. However the conservation of consciousness may also involve features expressed only by chaotic systems which are fractal to the quantum level.

It is a logical conclusion that the conscious brain has been selected by evolution because its biophysical properties provide access to an additional principle of predictivity not possessed by formal computational systems. One of the key strategies of survival implicated in brain dynamics is anticipation and prediction of events (King 1978, 1991, Basar et. al. 1989, Llinás 1987, MacLean et. al. 1991). Computational systems achieve this by a combination of deductive logic and heuristic calculation of contingent probabilities. However quantum non-locality may also provide another avenue for anticipation which might be effective even across the membrane of a single cell, if wave reductions are correlated in a non-local manner in space-time.

12: Models of the Global-Molecular-Quantum Interface

The question of free-will in a quantum uncertain universe led several of the early researchers of quantum physics to propose that the brain may be in some way utilizing the uncertainty of individual quanta that appears to violate causality at the foundation of physics (Lockwood 1989), to give rise to a quantum uncertain brain state consistent with free-will. Eddington (1935), for example noted that the uncertainty of position of a synaptic vesicle was large enough to be comparable with the width of the membrane, making synaptic release potentially subject to quantum uncertainty. Walker (1977) noted quantum tunnelling in synaptic transmission and Eccles (1986) noted the relation between mental events, neural events and quantum probability fields.

As noted in section 7, many aspects of synaptic release are highly non-linear, with many feedback loops involved in the biochemical pathways. A single vesicle excites up to 2000 ion channels, so a smaller fluctuation could set off a critically-poised ion channel and trigger a chain reaction of excitation. Voltage gated ion channels, fig 19(b), display fractal kinetics (centre) consistent with a quantum fractal model of protein conformational dynamics, illustrated for myoglobin in fig 13(b). Ion channels, such as that for acetyl-

choline display non-linear (quadratic) concentration dynamics, being excited by two molecules, consistent with chaotic dynamics at level of the the ion channel, which brings us to the realm of kinetic quantum chaos, fig 13(d).

Fig 19: (a) Synaptic vesicle release (Kandel et. al. 2000) and a diagram of the synaptic bulb. (b) Bacterial K^+ ion channel, fractal time kinetics of a voltage-gated K^+ channel (Liebovitch et. al. 1987, 1991) (c) Microtubules and the quantum computation hypothesized in the OOR model of Hameroff and Penrose (2003). (d) Scarring of the wave function of a quantum stadium indicates quantum suppression of chaos (Gutzwiller 1992).

To mount an effective solution to the hard problem requires making a connection between subjective consciousness and the physical world which has mutual explanatory power. The functionally closest phenomena to subjective consciousness we know of are global electrochemical brain processes which appear to be 'holographically' distributed, chaotic, and potentially relate to the binding problem of the central theatre of conscious attention through phase coherence. The most promising avenue, given what we have discovered about the quantum world is to look for a bridge between global phase coherences and those we associate with quantum entanglement and transactions. This raises the enticing possibility of linking the paradox of conscious will with the paradox of reduction of the superposition of quantum states to a physical history, thus providing a complementary view of the mystery the hard problem presents both from physical unpredictability and from subjective intentional decision-making.

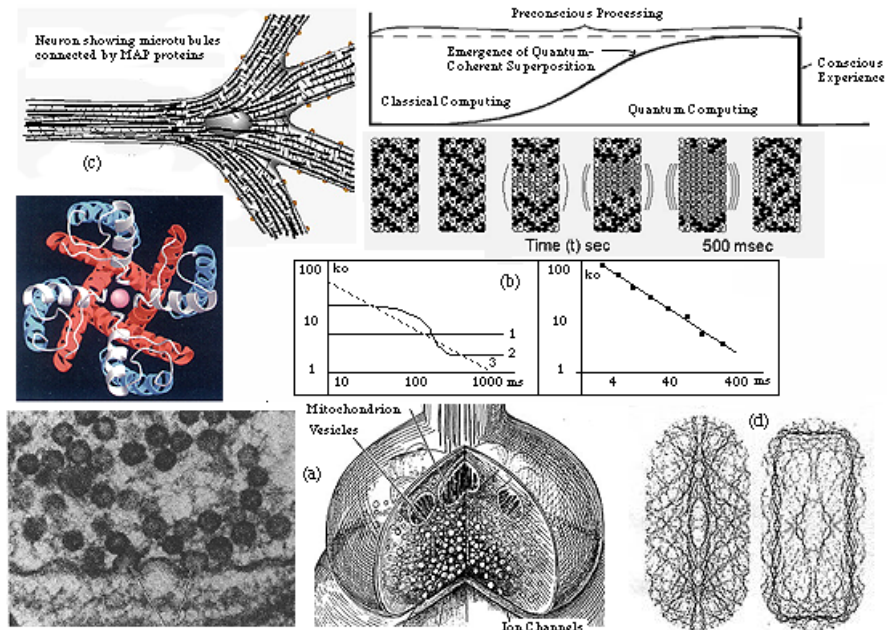
The fractal dynamics model proposes that the conscious state corresponds to phase coherent, temporally edge-of-chaos, excitations of coupled regions of the cortex, capable of entering a critically poised unstable state if faced with conflicting stimuli which cannot be resolved from learned experience. This would in turn enable quantum fluctuations at the molecular level to become an unstable 'watershed' which tips the global state towards a resolution. The fractal model uses the molecular processes of synaptic vesicles and ion channels currently believed to be pivotal in supporting active conscious states. Such a model enables instability at the quantum level to become amplified when the global brain state is critically-poised, in a way which could be possible even though the corresponding excitations are distributed across the cortex. The situation could in principle enable global excitations to be considered as 'inflated' quanta - either simple harmonic excitations or solitons, and phase coherence of global brain states to thus be interpreted as coherent quantum states.

The model of Hameroff and Penrose seeks a more specific mechanism in the microtubules of the neuron, fig 19. In particular they have noted that tubulin exists in two forms and could thus enter a quantum superposition of states. They thus envisage tubulin acting as a quantum cellular automation, interleaving between classical and quantum computational states. However microtubules are extensively involved in transport of essential molecules and whole organelles, as well as cytoskeletal architecture and synaptic growth and it is unclear they have a direct role in the fast forms of excitation of the electrochemical states we associate with conscious awareness. Generally when a single cellular system serves two critical, yet differing functions, evolution by gene duplication is likely to occur, so that both characteristics can be selected for independently. It is hard to see how the microtubules can be both involved in active transport and at the same time performing quantum calculations essential to the organism without potential conflicts of interest. These considerations do not apply to membrane excitation and synaptic transduction, which are already directly connected to excitability.

In the OOR model, consciousness is a passive result of a quantum computation which occurs in the pre-conscious state and is resolved objectively by a self-energy splitting of the gravitational centres of mass of the superimposed states in 'objective reduction' and conscious awareness emerges only subsequently, based on the outcome. Effective quantum computation of even simple problems, such as Shor's algorithm (Brown) for factoring a number, involve complex boundary constraints, including the capacity to Fourier transform one part of a quantum 'register' to represent periodicities in the superimposed states of the other part. It is unclear the microtubular automation can be configured to do this at the same time as serving the active transport of molecules and organelles. The Penrose and Hameroff model suggests the neuron can very rapidly alternate quantum computing with normal function by temporarily isolating the microtubules from the membrane through disassociating the linking MAP proteins (to avoid quantum decoherence effects). This means the quantum computation is isolated from the global brain state during the quantum computation cycle. The quantum computation phase would thus be fragmented at the cellular level and could not correspond to the subjectively conscious state.

Quantum computing is subject to decoherence because any quantum interaction with the outside world except the measurement itself disrupts the superposition of states by interacting with it. By contrast, transactional supercausality incorporates contingent interaction foci, in developing the complexity of the subquantum system, and would thus be robust to decoherence.

The fractal model envisages chaotic and unstable processes penetrating the quantum level in a way which minimizes decoherence because of the self-coupling of the brain state to a restricted class of global excitations. A variety of closed quantum systems which correspond to classical chaos, including nuclear dynamics, the quantum stadium and magnetically-perturbed high energy orbitals display inhibition of quantum chaos in phenomena such as scarring of the wave function fig 19(d), in which periodic repelling orbits 'reclaim' the probability distribution. However quantum-kinetic interactions in an open molecular system (Gutzwiller 1992) do appear to retain the attributes of chaotic instability, fig 13(d). Unlike the OOR model the transactional model we investigate next envisages subjectively conscious decision-making associated with a global dynamical criticality as capable of participating in 'anticipatory' collapse of the wave function and thus actively changing subsequent brain dynamics.



13: Quantum Mind and Transactional Supercausality

Recapitulating on our ideas of transactions we note the following points:

1. Since the first ideas linking quantum uncertainty and free-will were proposed, the non-local space-time spanning manifestations of uncertainty have become more apparent and given rise to the concepts of quantum non-locality and entanglement. A key example of this is the pair-splitting experiment, fig 6, in which a single quantum event releases two particles in the same wave function. If the state of either is measured, the particles' complementary spins or polarizations then become immediately correlated in a way which an exchange of local information limited by the speed of light cannot achieve.
2. The space-time properties of quantum phenomena also have a peculiar hand-shaking potentiality, in which future can affect past as well as past affect future. In fig 5 is an illustration of the Wheeler delayed choice experiment on a cosmic scale in which the route taken by a photon around a gravitational lens can be determined after it has already passed, by rearranging the detection apparatus at the end of its path, reinforcing the notion of future-past hand-shaking. The concept is also fully consistent with quantum field theory formulations as exemplified by Feynman diagrams, fig 4, which themselves can be time reversed, resulting for example in inter-conversion between positrons and electrons.
3. These paradoxes are resolved by the transactional interpretation, fig 7. In this description each contingent emitter of a quantum sends out an offer wave and each contingent absorber sends out a confirmation wave. In reduction of the wave function the interrelationship of all these together throughout space-time collapses (possibly sequentially) into a match-making pairing of real interactions between paired emitters and absorbers as in fig 7(a). The decision-making process results in collapse of the wave function of many possibilities to the actual unique real quantum event. This becomes an interference between one emitter and one absorber superimposing to form the real particle travelling between. In the transactional interpretation, section 5, the absorber, such as my eye looking at a distant star is thus as essential to the transaction as the star which long ago emitted the light. In this view of quantum mechanics there is then a sense in which any quantum emitter is implicitly aware of the future existence of the absorber by the very act of engaging the transaction.
4. The force field is explained through virtual particles (such as the photon) appearing and disappearing through uncertainty. Such particles must necessarily link an emitter and an absorber. The theory of virtual and real particles demonstrates that real and virtual particles are in-principle indistinguishable. If we oscillate the electromagnetic field we elicit a radio broadcast. Virtual photons generating the electromagnetic field have become real ones telling us the news. If the universe emerged from a single wave function all real particles may also be entangled. Even if the universe expands forever and some quanta, such as photons, are disseminated into space, causing a permanent disparity between emitters and absorbers, the kinds of excitons we naturally associate with phase correlations in global brain dynamics are all transient excitations, both emitted and absorbed by the brain and its neurons as boundary conditions as an integral part of dynamical systems feedback.

We have discussed the idea that chaotic excitation was a primal phenomenon which occurred in the first cells, even as the metabolic pathways were becoming established. Chaotic excitation leads to a multi-quantum-mode sense organ responding to external perturbations of the environment by sensitive dependence. The idea is that this sense organ then found that through the exchange of transactional hand-shaking with its own emission and absorption states, a form of quantum anticipation of its own immediate future, resulted. This anticipation then proved to have significant selective advantage for the organism and thus became fixed in evolution as the sentient conscious brain, complementing computational capacity with transactional anticipation through the chaotically fractal central nervous system.

An evolutionary explanation for the role of subjective consciousness intervening in the states of the brain emerges if the brain uses unstable processes and nervous systems can access the laws of quantum non-locality to enable a form of temporal anticipation of pivotal survival value, which would hence be strongly selected as a trait. This could effect global brain states if they are critically poised or have chaotic sensitive dependence. The hard problem then exerts a complementarity between entangled quantum states along with their corresponding contingent transactions, and subjective states, in which conscious choice becomes physical action partly through collapse of the wave function - the component that corresponds to the 'free' component of will not determined by initial conditions or computational constraints. Even if the universe expands forever and some quanta such as photons are disseminated into space, the kinds of excitons we naturally associate with phase correlations in global brain dynamics are all transient excitations both emitted and absorbed by the brain and its neurons as boundary conditions.

The transactional process closely parallels known techniques of quantum computation (Brown 1994) using a superposition of states as boundary condition rather than the finite number of real particles exchanged in transactions. The use by the brain of complex excitons may make it sensitive to an envelope of states spanning immediate past, present and future (Libet 1989) - the anticipatory 'quantum of the conscious present'. We can model the evolving brain dynamic as a complementation between two processes, an ordered process of computation based on the 'initial' conditions forming a skeleton defining the ordered context and a chaotic, uncertain complement. It is thus possible for the brain to utilize all the prevailing contexts in coming to a decision and yet involve some free choice in the outcome. Such excitons might have restricted interactions which would isolate them from quantum decoherence effects (Zurek 1991) as illustrated by quantum coherence imaging (Samuel, Warren) and would also serve to ensure transactional handshaking occurred. The ordered aspect of the dynamic would be a function of initial conditions but the complementary chaotic, uncertain regime would involve inflated future states through transactional handshaking. The uncertainty in the transition from chaos to order representing, perception, or cognitive 'eureka,' corresponds to an inflated reduction of the wave function. The physical model of historicity and the subjective experience of conscious intentional will thus coincide.

The 'binding problem' - how sensory experiences being processed in parallel in different parts of the cortex are bound together to give the conscious expression we associate with our integrated perception of the world - has no direct solution in terms of being hard-wired to some collection point - the ultimate seat of consciousness. Every indication is that consciousness is distributed and bound together by non-linear resonances in the brain which is exactly what we would expect in a situation self-resonances were being used as part of a transactionally super-causal solution to the perception-cognition dilemma.

The problem of consciousness is consummated by the question of free will. What is the function of subjective consciousness if it is only brain states and not the subjective aspect which effect our future physical states? Put in reverse, if subjective consciousness has any evolutionary advantage then it can manifest only by perturbing in some way the physical causality of brain processes. This is the problem of intent. Everyone who sets foot into the world invests in the principal of personal autonomy, that we have subjective control over our physical circumstances. All questions of legal responsibility hinge on it. Yet this implies mind affecting matter, something which mechanistic science struggles to deny. In the transactional model of perception, intention, and will, subjective consciousness enters into the picture as the inner complement of the quantum non-local hand-shaking process which violates the causality of initial or former states determining future states, which we associate with the Newtonian universe and temporal

determinism. This occurs as a consequence of special relativity and the fact that the boundary conditions of collapse include future contingent absorbing states.

Since the quantum transaction is a fundamental interpretation of all quanta, it is general to all quantum interaction. Its manifestation in resolving the fundamental questions of interaction with the physical world thus adopts a cosmological dimension, in which the sentient conscious brain becomes a central avenue for the expression of subjectivity through quantum non-locality in space time.

At the same time, the brain has been evolving towards a type of universality expressed in flexible algorithms for multi-sense processing and modeling, which experiencers of synaesthesia can witness are capable of coexisting in one multi-sense perception mode. A huge cosmological question is now raised. Is evolution simply adventitious accident, or is it part of the way the quantum universe explores its own phase space of possibilities in reaching towards a universal expression of the quantum entangled physical universe. In a quantum universe we have the dilemma of the many-universes problem. How does reduction of the wave packet result in one history or another occurring?

Transactional supercausality explains the cat paradox, fig 3, by interlacing contingent emitters and absorbers across space-time in a hand-shaking to form a complex subquantum system whose outcomes are naturally distributed according to the wave amplitude because they are the result of bifurcations of offer and confirmation waves dependent on their relative amplitudes. Reduction of the wave function corresponds to a particular matching of emitter and absorber for one exchanged wave-particle. Determining which part of the wave function a particle appears in is converted into the combinatorial one of which emitter and absorber pair are matched up. One can model the transition from many-to-many to one-on-one in terms of a non-linearity in which pairs become 'mated' in sequence. However this process cannot be resolved causally based on initial conditions because of the hand-shaking, leaving a loophole which only the 'anticipatory' mind and not computation per se can resolve. The many probability multiverses thus become resolved from superimposed multiverse super-abundance by hand-shaking across space-time sequentially, reducing the packet of all possible emitter-absorber connections to a sequence of 'happy marriages' as illustrated in fig 7(a).

The transactional principle also teaches us that modeling the interior domain of the quantum entanglement even if it can be understood as an interactive sequence of emitter-absorber reductions, will only give indeterminate predictions if only past boundary conditions are defined. It also shows us how symmetric hand-shaking time occurring in reduction fits with the sequential arrow of time defined by real, retarded, positive energy particles. The universe, thus becomes experientially historical through the uncertainty of free choice and perception itself in distinguishing the perceived from the uncertain background. Napoleon does not win the Battle of Waterloo, but Briatain wins Trafalgar, despite the feigned uncertainty of Nelson's blind eye. The same goes for all the hopeful monsters of evolution that never came to be. Quantum non-locality thus appears to have a method through space-time hand-shaking of determining which one of the multi-verses hovering in the virtual continuum will actually manifest. The role of consciousness as a cosmological process appears to mediate effectively between the world of the cosmic subjective, represented in physics as quantum non-locality, with the uniqueness of historicity, which never fully converges to the statistical interpretation of the cosmic wave function, because each change leads to another, throughout cosmic epochs.

This leads to a deep question shared by all human cultural traditions from the dawning of shamanism, through Vedanta to the Tao and even in the Judeo-Christian prophetic tradition, that mental states of awareness and subsequent physical happenings are interrelated by an anticipatory principle. If historicity is interactive with both the quantum realm and the existential condition, what are the consequences for science, society and cosmology itself? The description of reality here suggests that the physical universe has a complement - the subjectively conscious existential condition. Such a view both of the cosmological role of evolution to sentience and the brain as an interface between the cosmic subjective and the physical universe puts us right back into the centre of the cosmic cyclone in a way which Copernicus, Galileo, Descartes, Leonardo and Albert Einstein would have all appreciated.

Consciousness is then not just a globally-modulated functional monitor of attention subject helplessly to the physical states of the brain, but a complementary aspect to physical reality, interacting with space-time through uncertainty and quantum entanglement in a manner anticipated by Taoist (Wilhelm 1951) and Jungian ideas of synchronicity (Jung 1952). The same considerations apply to the use of chance oracles such as the I Ching, and the Hebrew Urim and Thummim, both of which use chaotic processes to divine an uncertain outcome. It is also possible to model hunches or premonitions as perceptions of partially collapsed contingent transactional ensembles, making certain perceived outcomes more likely than they would have been had no the perception occurred. The anthropic cosmological principle (Barrow and Tipler 1988) declares that possible universes are constrained by the existence of observers. In the weakest terms the anthropic principle ensures laws of nature compatible with the complexity of life. In stronger forms the existential nature of the universe is partially dependent on the existence of conscious observers. In transactional super-causal forms, conscious perception is resulting in the collapse of multiverses to the historical physical universe we experience. These observations illustrate anthropic aspects of the subject-object complementary hard problem model.

Although subjective consciousness, by necessity, reflects the constructive model of reality the brain adopts in its sensory processing and associative areas, this does not fully explain the subjective aspect of conscious experience. Conscious experience is our only direct avenue to existence. It underlies and is a necessary foundation for all our access to the physical world. Without the consensuality of our collective subjective conscious experiences as observers, it remains uncertain that the physical world would have an actual existence. It is only through stabilities of subjective conscious experience that we come to infer the objective physical world model of science as an indirect consequence. For this reason, subjective consciousness may be too fundamental a property to be explained, except in terms of fundamental physical principles, as a complementary manifestation to quantum non-locality, which directly manifests the principle of choice in free-will in generating history.

14: Complementarity and the Sexuality of Quantum Entanglement

This cosmology is intrinsically sexual and gives rise to cosmological prisoners' dilemma paradoxes similar to those of sexually antagonistic coevolution in which an attempt to mount a description based on only one aspect results in impasse (Fielder and King 2004). This sexuality is manifest in wave-particle complementarity and successive complementarities in physics from advanced and retarded solutions, through boson-fermion complementarity. It is also manifest in subject-object complementarity.

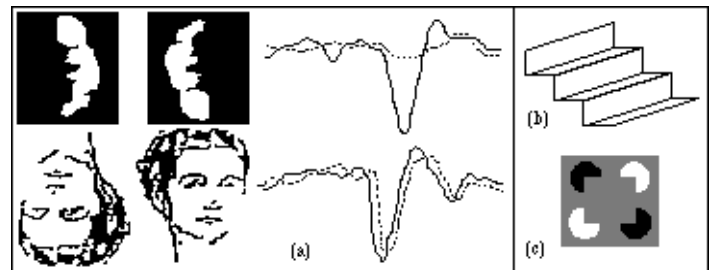
Subject-object complementarity is different from either panpsychism or Cartesian duality. The subjective distinction is described as complimentary to the physical 'loophole' of quantum uncertainty and entanglement, just as the wave and particle aspects of the quantum universe are complementary. Subjective and objective are interdependent upon one another with neither fully described in terms of the other. Furthermore, the transactional interpretation is intrinsically sexual in the sense that all exchanges are mediated through entangled relationship between an emitter and an absorber in which reduction of the wave function is a match-making sequence of marriages. This sexual paradigm is not simply an analogy, but is a deep expression of the mutual complementarity and intrinsic relationship manifest in the existential realm, physically and subjectively and between.

Extrapolating, the theory suggests the evolution of gendered recombinational sexuality, as it is found in biology in the metaphyta, is not simply an analogy with quantum complementarity, but is an emergent expression of the same complementarity principle. The single ovum, by necessity, is driven to seek fertilization through a solotonic wave of excitation which extends across the membrane. The multiple sperm, by contrast, are particulate packets of molecular DNA, without a cellular cytoplasmic contribution. Thus biological sexuality is utilizing quantum complementarity in the symmetry-breaking of gender.

In Tantra, the subject-object relation is an intimate sexual union, which, in its retreat from complete intimacy, spawns all the complexity of the existential realm. In the Taoist view the same two dyadic principles are the creative and receptive forces which in their mutual transformation give rise to all the dynamic states of existence. In Taoist thought, the cosmological principle is manifest in three phenomena, chance, life and consciousness, the very phenomena appearing in physical terms in quantum physics, evolution and brain dynamics. The transactional principle clearly establishes the marital dance of emitter and absorber as the foundation of historicity - the collapse of the infinite shadow worlds of multiverses into the one line of history we experience in life, evolution, consciousness and social and natural history.

Randomness remains a scientific mystery, explained ultimately in cosmological terms by quantum entanglement. The source of the scientific concept of randomness lies in theories, such as probability theory, statistical mechanics, and the Copenhagen interpretation of quantum mechanics which draw generalities from an incomplete knowledge of the system. However the source of supposedly random events in the real world lies either in highly unstable systems, which themselves may draw their uncertainty from the quantum level, or directly from the phenomena of reduction of the wave function under the probability interpretation. The transactional approach seeks to explain the sub-stratum of entanglement in a deeper interaction. This complex system could provide an ultimate explanation for the origin of randomness.

Fig 21: (a) Correspondence between brain states and subjectively perceived differences, is illustrated by the differing evoked potentials (averages of many recordings triggered by the same stimulus) when an inverted face is easily recognized as below, from the ambiguous image above. However the differing electrical potentials are qualitatively quite distinct from the differing subjective experiences in the two cases. Conscious experience cannot thus be reduced to brain states. Right: Visual illusions stimulate neurons that code explicitly for illusory contours (c), and mutually-interfering 3-D perspectives (b).



15: The Hard Problem: Subjective Experience, Intentional Will and Quantum Mind Theories

This paper proposes that the existential realm is a complementarity between subjective consciousness and the objective physical universe, of a founding cosmological nature. It advances a basis for natural selection of subjective awareness through a quantum entangled form of anticipation independent from computation as such. This presents a unique solution to the hard problem, not by attempting to explain subjective consciousness through objective brain states (the 'classical' error), but by elaborating a theory based on the complementarity between subjective consciousness and physical brain states, in which two key features are complementary views of existential reality as are wave and particle in the physical realm. These are manifest in the subjective aspect in conscious perception and intentional will and in the objective aspect in physical indeterminacy accompanied by reduction of the wave packet and the consequent historicity of the universe collapsing the quantum superabundance of multiverses to the physically historical world we experience.

In this view, subjective awareness is not identifiable with quantum entanglement but is complementary to it. Through chaotic instability and its fractal interaction with quantum uncertainty, a loophole is created in the physical description which allows subjective consciousness to have anticipatory selective advantage. This advantage is in turn given expression in the physical world through the capacity to intend, or 'will'. Neither is willing performed exclusively by the subject, for if a person's mind is already made up either by prejudice or by the logic of the circumstances, we are not discussing the 'free' aspect of will, but rather when they are making a genuine choice in spite of all the prevailing circumstances, even by hunch or intuition. Here intentional will is not any kind of specific drive possessed or directed by the organism, but the very capacity for subjective experience to, in turn, affect the physical universe and the future potentialities it may perceive, by an act of free-will. Subjective consciousness transforms incoming sensory and other forms of perception into the outgoing expression of creative consequences in intentional action. The freedom of will also means it is not entirely under ordered conscious control. We depend on a founding sense of personal autonomy to be able to act as sane individuals, without which we might all become catatonic or robotic automata. Intentional will is a mystery, both from the objective physical description, and from subjective existence. Just as uncertainty and unpredictability open the loop hole making free-will possible in the quantum universe, so the subjective aspect of will remains potentially as free of internal conditioning by drive or ego as it is potentially free of becoming completely conditioned by the circumstances of the physical world. In so far as we, as sentient conscious individuals, treat love and will as mysteries in their own right, so they become the subjective complement of an integrated expression of quantum non-locality and an entanglement which permeates the entire universe. In applying our free will, we each contribute collectively to the collapse of the infinite possibilities of the multiverses before us into a beneficent or sterile outcome. Just as the choice is ours at all points to enhance or diminish the diversity and abundance of life, so our world history becomes one of abundance or poverty.

We also have to consider how sensory information which may be pre-conscious achieves a level of consensual arousal e.g. through 'phase coherence' sufficient to draw attention to itself and become a fully fledged conscious experience. As Libet (1989) has noted, this may involve backward time referral of a conscious experience to its first pre-conscious manifestation.

The transactional perspective stands unique among quantum theories in providing an explanation for anticipatory consciousness which can effect the future of the physical universe through will. The Copenhagen interpretation, being essentially a theory of our knowledge, rather than the universe itself, can say nothing on this question of interactivity between subjective and objective aspects. Many worlds interpretations, having no process of collapse provide no mechanism whatever for consciousness to interact to influence the physical future. The Bohm pilot wave theory being a semi-quantum theory with a classical underpinning in the quantum potential likewise remains a purely objective description, which also has specific problems dealing with situations which can generate new quantum degrees of freedom such as a high energy photons creating a particle anti-particle pair. Penrose and Hameroff's (2003) OOR model likewise provides an objective reduction process driven in the limit by gravitational decoherence (the gravitational self-energy between the differing mass distributions of the outcomes), which permits subjective consciousness (or the transition from the pre-conscious state) only to reflect the objective reduction, and thus cannot explain how intentional conscious can effect the physical universe.

Hameroff and Penrose concentrate on the microtubule as a possible basis for quantum computation using two states of the tubulin

monomer, in the form of a quantum cellular automation, because it displays convenient automata-like structure. Certainly this is an interesting hypothesis and the possible involvement of microtubules in conscious states is a significant area of research, however the hypothetical process requires the isolation of microtubules to avoid decoherence, possibly through de-linking of MAP protein connections with the excitable membrane. This effectively reduces any form of quantum consciousness to collections of isolated cell interiors, preventing a direct feedback between the electro-dynamical global brain resonances we identify with active conscious states (e.g. in the 40 Hz region) and quantum non-locality. Microtubules possess many interesting properties, including possible solitonic interactions. It has also been suggested microtubular proteins might possess topological quantum computing properties (Freedman et. al. 2002) of non-commutative anyons (Kitaev 2003), which would be robust to quantum decoherence (Zurek 1991). However their primary functions are transport of essential chemicals and components such as vesicle and maintaining structural integrity of graduated processes such as synaptic adaption and long term potentiation.

What is really needed is a quantum mind theory capable of linking the fast electro-dynamical resonances we associate with active conscious states directly to an anticipatory form of quantum non-locality. The supercausal version of transactional quantum theory, which allows for mutual collapse of an entangled transaction to specific real connections between emitters and their future absorbers, is unique in providing such a possibility. The use of chaos and fractal dynamics provides mechanisms to inflate quantum uncertainties and the use of wave coherence in global brain states forms a direct basis for exciton exchange between emitters and absorbers consisting of immediate past and future brain states, thus linking them into a handshaking resonant system.

16: Consciousness and Neurocosmology

The diversity of wave-particles resulting from symmetry-breaking of the four fundamental forces, the weak and colour nuclear forces, electromagnetism, and gravitation, finds its final interactional complexity, in which all forces have a common asymmetric mode of expression, in complex molecular systems. It is thus natural that fundamental principles of this quantum interaction may be ultimately realized in the most delicate, complex and globally interconnected molecular systems known - those of the conscious brain. The brain may be one of the few places where the supercausal aspects of wave packet reduction can be clearly manifest, as a result of its unique capacity to utilize entanglement in its dynamics. Although other unstable systems, from the weather to axionic dark-matter condensates (Ryquist) may also display, or amplify, features of non-locality, it is difficult to conceive of a physical system which could in any way match the brain as a potential detector of correlations and interrelationships within the domain of quantum mechanics. Cosmology is not simply a matter of vast energies, but also quantum rules. In these rules of engagement, more fundamental even than symmetry-breaking, the stage appears to be set for the emergence of sentient organism as the culminating manifestation in complexity of quantum interaction. In this sense the conscious brain may be the ultimate inheritor and interactive culmination of the quantum process at the foundation of the universe itself. This is the consummation of cosmology, not in the alpha of the big-bang, nor in the omega of finality but in the sigma of its interactive complexity, fig 22(c).

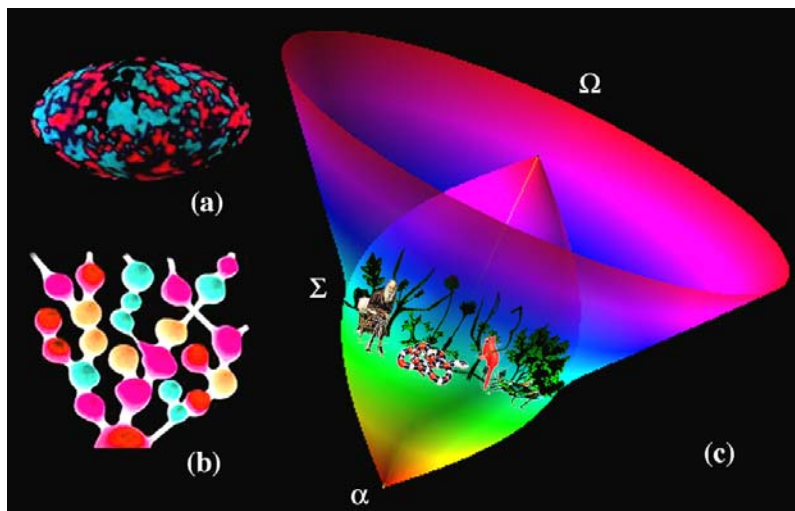


Fig 22(a): The cosmic background - a red-shifted primal fireball. This radiation separated from matter, as charged plasma condensed to atoms. The fluctuations are smoothed in a manner consistent with subsequent inflation. (b) Fractal inflation model leaves behind mature universes while inflation continues. (c) Darwin in Eden: "Paradise on the cosmic equator." - life is an interactive complexity catastrophe resulting from force differentiation representing the Σ of interactive complexity rather than the α cosmic origin or the Ω of final culmination.

The deepest question which can be posed about cosmology is precisely that of the hard problem: What is the relationship between the existential observer and the universe at large? What is the relation between conscious subjectivity and the objective physical world? This is a question which has plagued philosophers and scientists from the early Greeks through Bishop Berkeley and Descartes to David Chalmers' (1995, 1996) description of the 'hard problem in consciousness research' as a fundamental philosophical chasm which can only be crossed through a greater

description of reality.

Despite the advances of modern scanning techniques such as PET (positron emission tomography) and fMRI (functional magnetic resonance imaging) and electro- and magneto-encephalographic studies, a chasm still remains between the brain states under a researchers probe and the subjective experiences of reality we depend on for our awareness of the physical world. This comes on top of a fundamental complementarity upon which we depend for our existence. Although we live as biological organisms, raise families, navigate our lives and perform our science on the assumption of the existence of the physical world, we access physical reality only through our subjective sensory experiences. Without the direct veridical access we have to subjective experience, there would be no conscious 'observers'. It remains unclear under these circumstances that one could establish that the physical universe would exist in any objective 'sense'.

Ironically a purely objective physical world description considers only brain states, leaving subjective consciousness to the perilously ephemeral status of an epiphenomenon, or not existent at all. However the physical world is really a consensual stability property of our conscious experiences, despite the fact that we are physical organisms whose consciousness appears to depend on our remaining alive. We can both consciously agree that the table is made of wood, or that we will bleed if cut, so the subjective aspect is capable of representing the objective. The objective is capable in turn of 'incorporating' the subjective in terms of uncertainty in the physical. A fully cosmological theory thus has to encompass both realms.

This access to the subjective is profoundly augmented by a variety of subjective states, some of which have no direct correlate in the physical world, yet can be commandingly real to the observer. Firstly consciousness is constructive, and fills in details to generate a subjective description of reality which can often lead to peculiar results as illustrated by visual illusions, fig 21. More significantly we have states of meditative trance, psychedelic hallucination and the intense phases of dreaming. Although various tests can be made by the astute subject to distinguish dreaming from waking reality, the very fact of dreaming as an alternative veridical reality raises a deep question about the nature of the everyday world we perceive. Is it nothing but an internal dream state anchored by

additional stability constraints provided by sensory input? If we are actually witnessing exclusively and only our internal model of reality, what then is the manifest nature of the physical world?

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