Dual-Time Supercausality (1989) Physics Essays **2/2** 128-151

DUAL-TIME SUPERCAUSALITY

Chris C. King
Department of Mathematics and Statistics
University of Auckland, New Zealand
Submitted 5th September 1988.

ABSTRACT: This article explores models of causality of the physical universe which extend beyond the usual quantum and classical descriptions. To facilitate discussion of this topic, a brief review of relevant areas of modern physics is included.

Although mathematical logic is not directed in time, the causal description of the physical universe is classically performed in terms of ***temporal determinism****, an initial-value problem in which subsequent states are determined through the action of differential equations, thus avoiding the paradox of effects preceding their causes. Quantum mechanics has reduced this description to the status of a* ***stochastic-causal*** *theory, in which individual future states of a system are not predictable because the probability interpretation of the wave function prevents a complete knowledge of a single reduction of the wave packet.*

The ***transactional interpretation*** *of quantum mechanics provides a basis for examining the workings of stochastic causality in terms of time-symmetric advanced and retarded waves. Cosmic* ***symmetry-breaking*** *provides a contrasting description in which time-directed phenomena derive their explanation. Dual-time supercausality replaces the stochastic model with one in which two complementary causal processes,* ***symmetric-time*** *and* ***directed-time*** *are operating. The mode of interaction of these avoids temporal paradox in the time-directed description, and also explains why quantum mechanics provides an incomplete stochastic model.*

An important role for supercausal processes in the structural evolution of the universe is proposed, including the emergence of biosystems, biological evolution, and consciousness.

1 : CAUSALITIES AND SUPERCAUSALITIES

Since the development of calculus and the Newtonian model of the universe, the evolution of dynamical events has been described through the directional application of time as a parameter. The evolution of a classical system can in principle be causally described in terms of the initial conditions and the differential equations governing its action. In the classical Laplacian universe, the initial conditions and the dynamical equations taken together completely specify the ongoing state at subsequent times. We will refer to this model as ***temporal determinism.***

The classical Hamiltonian and Lagrangian dynamical equations are both expressed as differential equations expressing generalized coordinates in terms of increasing time, where $\mathcal{L} = T - V$ and in the case of a potential, $\mathcal{H} = T + V$, giving the total (T kinetic & V potential) energy :

$$\frac{d}{dt}\left(\frac{\partial \mathcal{L}}{\partial \dot{q}_i}\right) - \frac{\partial \mathcal{L}}{\partial q_i} = 0 \quad i = 1, \ldots, N \tag{1.1}$$

$$\mathcal{H} = \sum_i p_i q_i - \mathcal{L} \qquad \frac{\partial \mathcal{H}}{\partial p_i} = \dot{q}_i \qquad \frac{\partial \mathcal{H}}{\partial q_i} = -\dot{p}_i \tag{1.2}$$

The essential features of this description are:
(1) The spatial coordinates are expressed as differential functions of increasing time, and are completely determined by the differential equations and the initial conditions.
(2) The energy and momentum are exactly specifiable simultaneously with time and position.
(3) Space and time are independent parameters, and independent of the parameters of energy & momentum.

Relativity introduces specific changes into this scenario, because the interdependence of spatial and temporal dimensions leads to natural negative energy solutions in which the temporal direction of evolution is reversed:

(1) Although the temporal order of events is preserved under a Lorentz transformation with sub-luminal relative velocities, and the evolution of a positive-energy relativistic system along time-like world lines has the same directed causal description as classical physics, the relation below between relativistic energy and momentum (c = 1)

$$E^2 = \mathbf{p}^2 + m^2 \quad \text{leads immediately to dual energy solutions} \quad E = \pm\sqrt{\mathbf{p}^2 + m^2} \tag{1.3}$$

in which the negative energy solution has reversed temporal behavior in space-time.

(2) The planes of spatial simultaneity in the Newtonian view give way to the topology of space-time in which the light cone is divided into disjoint advanced $\mathcal{A}$ and retarded $\mathcal{R}$ regions forming the absolute past and future of O. A time-like world line as shown in 1,2,3 below has its time sequence preserved under Lorentz transformations, but space-like separations, such as 4,5 do not. Consequently transformations involving superluminal exchange, although permitted by the Lorentz transformations lead to temporality-reversing causality violations in which an event can contradict its own past causation (see fig 12).

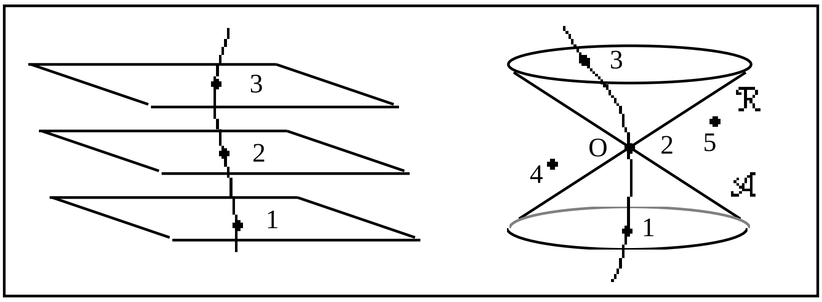


Fig 1: Newtonian planes of simultaneity and the light-cones of space-time.

Quantum Theory introduces further key changes in the form of relationships between energy-momentum and space-time parameters, which prevent simultaneous description of two conjugate variables and result in the probability interpretation and a stochastic view of causality. In particular the transformations:

$$E \rightarrow i\frac{\partial}{\partial t} \quad \mathbf{p} \rightarrow -i \qquad (1.4)$$

result in energy-momentum being equivalent to a time-space interval measurement (of frequency-wavelength),

resulting in the uncertainty relations $\Delta E \, . \, \Delta t \sim \frac{h}{2\pi} \quad \Delta \mathbf{p_x} \, . \, \Delta x \sim \frac{h}{2\pi}$ (1.5)

The above transformations convert the Hamiltonian energy expression (1.3) into a wave equation

$$(\partial^2/\partial t^2 - {}^2 + m^2) \phi = 0 \qquad (1.6)$$

which can be expressed in covariant 4-variable notation $\left(\partial_\mu \partial^\mu + m^2\right) \phi = 0$ (1.7)

with elementary solutions: $\phi_{+,k} = (2\pi)^{-3/2} e^{\, i\, (\mathbf{k.x} \, - \, \omega \mathbf{t})}$

$$\phi_{-,k} = (2\pi)^{-3/2} e^{-\, i\, (\mathbf{k.x} \, - \, \omega \mathbf{t})} \qquad (1.8)$$

where $\omega = (k^2 + m^2)^{1/2}$ (1.9)

As above, one solution travels in each direction in space-time, forming **retarded** (the usual) and **advanced** solutions.

This quantization has two key effects, the dynamics is stratified into sets of eigenvalues, and the quantum transformation between these states involves the probabilistic consequences of wave-particle duality - the occurrence of a particle which can only be predicted probabilistically in terms of the wave equation according to:

$$P = \phi^* . \phi \qquad (1.10)$$

While we can appreciate the effects of wave-interference of many photons forming an interference pattern, we cannot predict the trajectory of any one of the photons involved.

Relativity and quantum theory thus have two distinct effects on the classical description of the universe, one introduces **bi-directional determinism**, associated with positive and negative energies, and the other breaks down the determinism of kinetic-causality into a sequence of probabilistic interactions which only gain causal regularity under the repetition of events to form classes or ensembles of repeated events - **stochastic causality**.

Quantum mechanics violates classical causality because the future states can be defined only in terms of probabilities by 1.10. Although the evolution of the state vector under the wave equation is fully deterministic, reduction of the wave packet, can be described only in terms of the expectations over many repeated events, i.e. ensembles. We thus arrive at a dual theory in which deterministic processes are interleaved with probability reductions.

The statistical interpretation poses a very serious problem for the causal description of the universe with increasing time, as only averaged behavior is described, and the theory does not specify the state or trajectory of a given quantum with precision. This has been the subject of controversy since the development quantum mechanics, because the theory appears incomplete in the sense that it predicts only a probability while *de facto* the universe makes a choice and selects one event type.

The subsequent difficulty in developing a unified description of quantum mechanics and relativity may hinge on the problems involved in conceptually integrating these temporal effects into a unified causal description.

The aim of dual-time supercausality is to replace a single-principle causality with a two-fold causality in which two dual components have complementary modes of interaction. Broadly-speaking, the model involves dual modes of action of the time parameter, as follows:

(1A) Symmetric-Time. This mode of action of time involves a mutual space-time relationship between emitter and absorber. Symmetric-time determines which, out of the ensemble of possibilities predicted by the probability interpretation of quantum mechanics is the actual one chosen. Such a description forms a type of *hidden-variable* theory explaining the selection of unique reduction events from the probability distribution. We will call this bi-directional causality **transcausality**.

(1B). **Directed-time**. Real quantum interaction is dominated by retarded-time, positive-energy particles. The selection of temporal direction is a consequence of symmetry-breaking, resulting from energy polarization, rather than time being an independent parameter. The causal effects of multi-particle ensembles result from this dominance of retarded radiation, as an aspect of symmetry-breaking.

Dual-time is thus a theory of the interaction of two temporal modes, one time-symmetric which selects unique events from ensembles, and the other time-directed which governs the consistent retarded action of the ensembles. These are not contradictory. Each on their own form an incomplete description. Temporal causality is the macroscopic approximation of this dual theory under the correspondence principle. The probability interpretation governs the incompleteness of directed-causality to specify unique evolution in terms of initial conditions.

Because description of this dual-causality requires models from several branches of modern physics, it is necessary to provide a concise description of these ideas. Although these are all well-established notions they are included to guarantee the understanding of the basis of the model.

Origins of Time-Asymmetry

Quantum mechanics is founded on dual vectors spaces in which each *bra* $\langle\phi|$ is conjugate to the *ket* $|\phi\rangle$. If $A^\dagger$ is the *Hermitian conjugate* of a linear operator A, satisfying $A^\dagger.|\phi\rangle = \langle\phi|.A$, then we have the dual relation between forward and inverse amplitudes: $\langle\phi|A^\dagger|\psi\rangle = \langle\psi|A|\phi\rangle^*$ where * is the complex conjugate. (1.11)

In the case that we are considering the time-evolution of a system, the state vector is described through the *evolution operator* $U(t, t_0)$:

$$|\phi(t)\rangle = U(t, t_0)\,|\phi(t_0)\rangle \qquad (1.12)$$

where $U(t+dt,t) \equiv 1 - \frac{i}{h}H.dt$ is derived from the differential change in the Hamiltonian H, as defined by the *Schrödinger Equation*

$$i\,h\,\frac{d}{dt}|\phi(t)\rangle = H\,|\phi(t)\rangle\,. \qquad (1.13)$$

Hence U is unitary, giving $U^\dagger.U = 1$. Consequently the reversed evolution is described in terms of the conjugate.

Time reversibility is usually expressed in the *Quantum principle of microreversibility*[1]:
Given a system in a state $|\phi\rangle$ at t_1 the amplitude w of finding the system in state $|\psi\rangle$ at t_2 is given by

$$w = \langle\psi\,|\,U(t_2, t_1)\,|\,\phi\rangle \qquad (1.14)$$

where $U(t_2,t_1) = e^{-iH(t_2 - t_1)}$ is the evolution operator for Hamiltonian H:

Consider the transformation K reversing the signs of time, momentum and spin (i.e. $t \to -t$, $\mathbf{p} \to -\mathbf{p}$, $\mathbf{r} \to \mathbf{r}$, $\sigma \to -\sigma$), composed with complex conjugation. Using K, we can define the reverse amplitude

$$w_{rev} = \langle\phi\,K^*\,|U(t_2, t_1)|\,K\,\psi\rangle \quad \text{that } K|\psi\rangle \text{ will be transformed into } K|\phi\rangle. \qquad (1.15)$$

From the reality of H, it follows that $U(t_2,t_1) = K^*.\ U^*(t_2,t_1).K$ and hence the probabilities in the forward and reversed direction are equal. This means that the microreversibility of classical systems carries through to quantum systems. Although magnetism violates this principle, the addition of charge conjugation, renders quantum phenomena reversible with the exception of a few notable cases, such as the K^o meson outlined below.

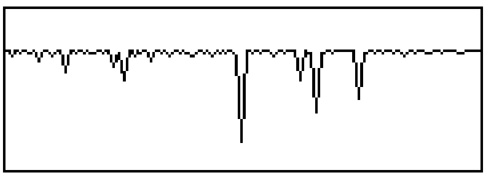


Fig 2: Entropy fluctuations in an isolated closed system.

The classical statistical mechanical treatment of the arrow of time also leaves no definitive indication of the directedness of time. Although the second law specifies increasing entropy with increasing time, Poincare recurrence shows that an isolated system will enter every state including states of arbitrarily low entropy over a time period which may be exceedingly long (e.g. $10^{10^{23}}$ secs)[21]. Although these states have low probability, the treatment of fluctuations to a low entropy state becomes fully time symmetric, in which situations where entropy is increasing correspond to the aftermath of rare fluctuations as shown in fig 2.

The difficulty of fulfilling a program causally describing the state of the universe with increasing time leads to a general consideration of the source of the arrow of time in general - *i.e. what aspects of the universe are responsible* *for the directed evolution of time?*

(1) Time-asymmetric quantum phenomena. The violation of charge-parity (CP) symmetry in quantum systems The neutral K_o meson, and its antiparticle $\bar{K}_o$ both decay into a pair of π mesons

$$K_o \rightleftharpoons \pi^+ + \pi^- \rightleftharpoons \bar{K}_o$$

The rapid decay of the component $K_1 = K_o + \bar{K}_o$ into π-mesons, subsequently leaves the remaining component $K_2 = K_o - \bar{K}_o$ which does not follow the same decay. However subsequently there is a small amplitude for conversion of some of the K_2 back to K_1 resulting in a K_L which is not matter-antimatter symmetric, since it contains differing components of K_o and $\bar{K}_o$. Thus the reaction $K_L \rightarrow \pi^- + e^+$ is preferred over the mirror-image $K_L \rightarrow \pi^+ + e^-$. Since the K_o has quark constituents $(d,\bar{s})$ and the $\bar{K}_o$ $(\bar{d},s)$, this implies that the reaction $\bar{d} + s \rightarrow d + \bar{s}$ should be directed in time. Similar considerations are used to explain the preponderance of matter over anti-matter. This is one outstanding CP-violating system displayed by the fundamental forces, but it is just one manifestation of a more fundamental scheme of symmetry-breaking which has become a keynote for understanding the relations between the forces.

(2) The cosmological evolution of the Universe from the big bang.
The global behavior of the Universe is very obviously oriented in time. The big-bang, and its variant scenarios such as cosmic inflation all involve non-steady-state descriptions arising from a singularity or super-fluctuation. The symmetry-breaking of the forces of nature immediately subsequent to the origin makes it possible for such structures as stars and galaxies to maintain their energetic processes, giving rise as a consequence, both to the continuing phase of entropy production on all scales, and to the evolutionary structures such as living systems the two most obvious manifestations of time-directedness. This time-directed cosmology represents the global manifestation of the same symmetry-breaking process that we see manifest at the quantum level.

(3) The evolution of conscious observers - the Anthropic arrow.
There is a third arrow which both defines us as observers and is also responsible for the most elaborate causal systems in the Universe, the time-directed evolution of living systems. While this at first appears to bear little relation to the first two, being founded in statistical mechanical models of Darwinian evolution, the origin and evolution of life arises from an intimate connection between the quantum and the cosmic. Living systems are the ultimate hierarchy of causal stability structures that culminate from the interaction of the quantum and cosmological symmetry-breaking sequences. The molecular-electromagnetic structures of living systems are made possible by the nucleosynthetic pathways of the nuclear forces. The importance of observers as boundary conditions for the evolution of the universe on a cosmic scale has also been cited in the Anthropic principle[3,4].

2: SYMMETRIC-TIME AND THE TRANSACTIONAL INTERPRETATION

Just as with the Klein-Gordon equation, the Dirac equation for the spin-$^1/_2$ electron:

$$\left[\gamma^\mu (i\,\partial_\mu - e\,A_\mu) - m\right] \psi = 0 \qquad (2.1)$$

allows for negative-energy advanced solutions representing negative-energy positrons. In fact charge conjugation and time-reversal independently transform the equation into the one satisfied by charge conjugate of e or time-reversal of the potential A_μ respectively.

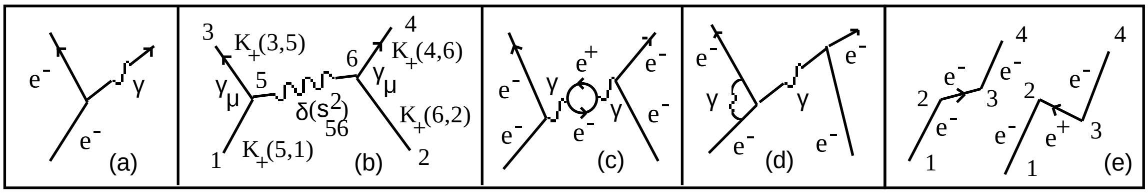


Fig 3: (a) The quantum potential approach must determine an exact trajectory for an emitted γ, as well as e^-.
(b) Feynman diagram for first-order exchange of a single photon between electrons (see text).
(c,d) Higher-order diagrams for electromagnetic interaction do not involve a single type of photon interaction consistent with a unique trajectory, but a coherent sequence of interaction types.
(e) Electron scattering and positron anihilation are both explained in the same diagram.

The Feynman space-time approach[5,6] extends this description into a quantum field theory description which is time-symmetric when viewed in terms of a negative energy anti-particle. The approach is succinctly demonstrated in the first-order diagram of Fig 3(b) in which two electrons interact through the exchange of a virtual photon. The propagation kernel for the pair is

$$K^{(1)}(3, 4; 1, 2) = - e^2 \iint K_{+a}(3,5)\, K_{+b}(4,6)\, \gamma_{a\mu}\gamma_{b\mu}\, \delta_+(s_{56}^2)\, K_{+a}(5,1)\, K_{+b}(6,2)\, d\tau_5\, d\tau_6 \qquad (2.2)$$

where the γ are variants of the Pauli spin matrices for the two electrons, the Dirac δ function represents the discrete interaction of the virtual photon over relativistic interval $s_{56}^2 = t_{56}^2 - r_{56}^2$ and the K_+ are propagation kernels for electrons a and b to be carried according to:

$$K_+(p,q) = \sum_{\text{pos } E_n} \varphi_n(2)\, \bar{\varphi}_n(1)\, e^{(-i E_n (t_2 - t_1))} \quad \text{for } t_2 > t_1 \quad (\text{ +ve energy electron travelling forwards in time })$$

$$(2.3)$$

$$= - \sum_{\text{neg } E_n} \varphi_n(2)\, \bar{\varphi}_n(1)\, e^{(-i E_n (t_2 - t_1))} \quad \text{for } t_2 < t \quad (\text{ -ve energy positron travelling backward in time })$$

where E_n and φ_n are the eigenvalues and eigenfunctions for the Dirac equation. Since these kernels describe the *amplitude* to go from p to q they refer to wave probabilities rather than single events. The integral over all such interactions also covers interactions by all possible photons via the δ. The combination of retarded and advanced solutions permits common descriptions of positron and electron processes (fig 3(e)).

A further interpretation of quantum mechanics, developed out of Wheeler-Feynman absorber theory, has the capacity to resolve many outstanding quantum paradoxes, and although consistent with orthodox interpretations has the potential to develop a succinct and far-reaching supercausal description. Absorber theory was developed as a theory of classical electromagnetism using time-symmetric fields, which was consistent with experiment because, despite utilizing both retarded and advanced solutions for the emitter and absorber, the subsequent interference effects reduced by virtue of the absorption conditions to the usual retarded description[2,7]. Cramer[8] has used these ideas to develop a corresponding quantum description called the *Transactional interpretation of quantum mechanics.*

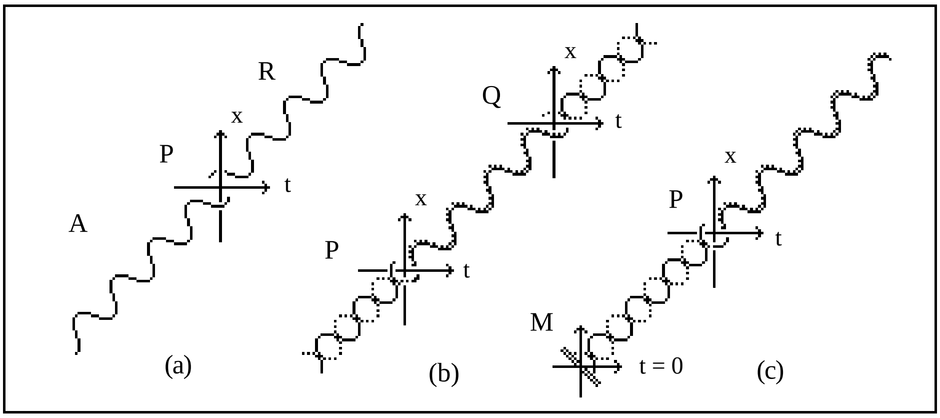


Fig 4: (a) Advanced and retarded waves, (b) Emitter-absorber transaction, (c) Reflecting boundary condition at origin of the universe results in retarded radiation.

The basic components of an absorber-emitter transaction are shown in fig 4. The space-time diagram for advanced and retarded waves (a) applies to both absorber and emitter in a time symmetric manner. The emitter issues an *offer* wave, which is a complex waveform and carries no self-energy, because the positive energy of the retarded wave R is exactly balanced by the negative energy of the advanced component. The absorber responds with a similar *confirmation* wave, as in (b). The phase differences between the advanced and retarded solutions now result in destructive interference of the two waveforms, except for the interference of the retarded 'offer' wave and the advanced confirmation wave, which result in a single real wave from the interference of two complex ones. This is illustrated in the figure below, where offer & confirmation waves are shown for non-commuting polarizing filters.

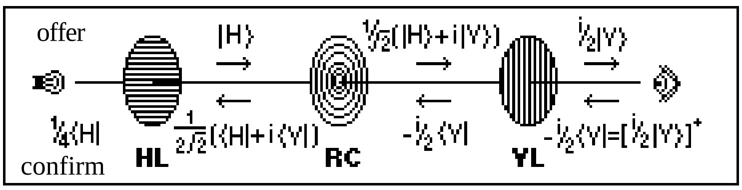


Fig 5: Non-commuting polarizing filters in the transactional interpretation

The development of quantum mechanics has depended on conjugate wave functions in such formulas as 1.10 and

$\langle x \rangle = \int \Psi \;\; \underline{X} \, \Psi \, dv$ for the expectation of a variable x represented by an operator $\underline{X}$ under $\underline{X}\Psi = x\Psi$.

Why such a description has involved both, complex quantities, which would normally be regarded as unphysical, and the product of the wave function and its conjugate, which effectively interconverts retarded and advanced waves suddenly becomes clear. The conjugate wave function represents the confirmation wave or its variants from potential absorbers, while the original represents the offer wave of the emitter.

A second type of transaction (c) above could explain the dominance of retarded radiation in the current universe in terms of interference by a reflecting origin at t=0, the alpha point[9]. If this initiated retarded radiation of the first high-energy quanta, unstable equilibrium between the advanced and retarded forms of radiation would have resulted in a bifurcation of the quantum arrow of time. Subsequent inflation (see later) and consequent high-energy particle production as the true vacuum was created from the symmetrical force configuration would then explain the thermodynamic arrow of time in terms of the creation of high-probability multi-particle states in the sense of Boltzmann's H-theorem.

The transactional interpretation is intrinsically non-local, because a transaction is established *atemporally* across space-time in a way which spans both space-like and time-like intervals. If we imagine watching a distant galaxy, the photons emitted near the beginning of the universe establish the transaction only because eons later, our retina is present to act as the receiver. The transaction integrates all potential absorption events without regard to the order in time, because the backward light cones of all potential absorbers travel back simultaneously to the emission vertex irrespective of the delay before absorption. However the transactional interpretation has the very odd implication that *future* states of the universe, which can only exist as probabilities, form the actual boundary conditions determining the transaction.

3: COSMOLOGICAL SYMMETRY-BREAKING

The integral description of the forces of nature appears to require their derivation from a common quantum superforce. The emergence of gravity, the nuclear forces and electromagnetism from a single force requires the development of theoretical schemes which explain how the initial symmetry of a unified superforce has resulted in diverse forces with distinctive structures. Since gravitation is coupled to the structure of space-time, the topology of space-time may also be an aspect of symmetry-breaking.

There are two basic theoretical tools to explain fundamental force integration, the first associates the forces with fundamental symmetries of nature. Symmetry-breaking is then explained through the non-zero polarization of key fields at minimum energy. The second describes nature through a higher-dimensional space-time. Symmetry-breaking is then associated with the compactification of all but 4 dimensions.

(a) Gauge theories with Broken Symmetry. These derive fundamental forces in terms of local gauge symmetries. Global symmetries such as phase rotations, the Poincaré group (Lorentz transforms + translations), and internal nuclear symmetries give rise to forces (electromagnetism, gravity, weak, & colour force) when the symmetries are made local. A further symmetry, supersymmetry relates integer-spin bosons which freely superimpose to form radiation fields to fermions, which associate only in pairs and form particulate matter. The symmetries of the theory can become hidden because the minimum energy configuration has a non-zero field [1,10,11]. This results in symmetry-breaking in which some particles gain a positive, real mass.

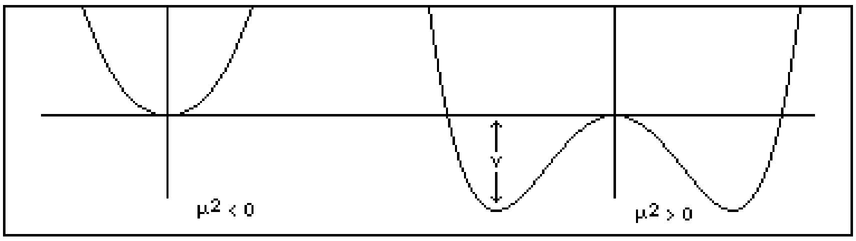


Fig 6 : The potential functions of the scalar field ψ.

Given a Lagrangian for a real scalar field ψ, $\mathbf{L} = (\partial^\mu \psi)(\partial_\mu \psi)/2 - V(\psi)$ (3.1)

with even potential function $V(\psi) = \mu^2 \psi^2/2 + |\lambda| \psi^4/4$ two cases may be distinguished:

(a) $\mu^2 > 0$ (ordinary symmetry) Firstly the Lagrangian is converted to a Hamiltonian on cells of length ε by taking $L = \int \mathbf{L}(x,t)\, dx = \int [\, (\partial\psi/\partial t)^2/2 - (\partial\psi/\partial x)^2/2 - V \,]\, dx$ (3.2)

and substituting $q_i = \psi(x_i,t)$ $p_i = dq_i/dt$ under quantization $x_i - x_{i-1} = \varepsilon$

L ¾→ $\epsilon \sum_i [\, p_i^2/2 - \epsilon^2 (q_i - q_{i-1})^2 - \mu^2 q_i^2/2 + |\lambda| q_i^4/4$ (3.3)

which has Hamiltonian $H = \epsilon \sum_i [\, p_i^2/2 + \epsilon^2 (q_i - q_{i-1})^2 + V(q_i)\,]$ (3.4)

the minimum energy configuration has $q_i = q_{i-1}$ & $V(q_i) = 0$. Taking small oscillations around the vacuum state,

$H \sim \epsilon \sum_i [\, p_i^2/2 + \mu^2 q_i^2/2\,]$ corresponding to a free particle of mass$^2 = \mu^2 > 0$. (3.5)

(b) $\mu^2 < 0$ (broken symmetry) The potential $V(\psi)$ now has minima at $\psi = +/- (-\mu^2/|\lambda|)^{1/2} = +/- v$. (3.6)
If v is picked as new vacuum state $\psi \to -\psi$ is now a symmetry of **L** but not v. Now the shifted field $\psi' = \psi - v$ has vacuum $\psi' = 0$ with shifted potential $V'(\psi') = -\mu^2 [\, \psi'^2 + \psi'^3/v + \psi'^4/4v^2 + \mu^2/4|\lambda|\,]$ (3.7)
giving Hamiltonian

$H \sim \epsilon \sum_i [\, p_i^2/2 - \mu^2 q_i^2/2 - \mu^4/4|\lambda|\,]$ corresponding to oscillations with mass$^2 = -\mu^2 > 0$. (3.8)

The description of the Higgs mechanism shows that both the resulting particles, the Goldstone boson and the photon inherit <u>real mass only</u> for both real and imaginary values of the parameter μ. For example in the case of a U(1)-invariant Abelian gauge field with Lagrangian

$$\mathbf{L} = 1/2\, (\mathbf{D}^\mu \varphi)^* (\mathbf{D}_\mu \varphi) - \mu^2/2\, \varphi^* \varphi - |\lambda|/4\, (\varphi^* \varphi)^2 - 1/4\, F^{\mu\upsilon} F_{\mu\upsilon} \quad (3.9)$$

where $\mathbf{D}_\mu = \partial_\mu - iq A_\mu$, $F_{\mu\upsilon} = 1/iq\, [\, \mathbf{D}_\mu, \mathbf{D}_\upsilon\,]$

For $\mu^2 > 0$ we get 1 massless photon and two scalars $\varphi^{+/-}$ with mass$^2 = -\mu^2 > 0$

In the case of broken symmetry, the shifted fields $\varphi = e^{i\xi/v}(v+\eta)$ $v + \eta + \xi$ produce the Lagrangian

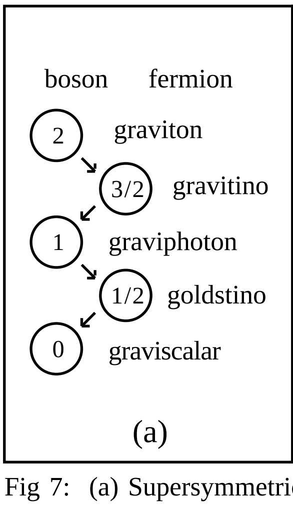
$$\mathbf{L} = \mu^4/4|\lambda| - 1/4\, F^{\mu\upsilon} F_{\mu\upsilon} + q^2 v^2 A'_\mu A'^\mu + 1/2\, (\partial^\mu \eta)(\partial_\mu \eta) + \mu^2 \eta^2 \quad (3.10)$$

under the gauge transformations $A_\mu \to A'_\mu = A_\mu - 1/qv\, \partial_\mu \xi(x)$, $\varphi \to \varphi' = e^{i\xi(x)/v} . \varphi(x) = v + \eta$

and this results in a massive vector field A'_μ with mass$^2 = q^2 v^2 > 0$ and a η-field with mass$^2 = -2\mu^2 > 0$.

Spontaneous symmetry breaking has a common scheme of minimization of a real positive energy potential for both real and imaginary values of μ. The effect of this is that only real masses are permitted and tachyons are excluded.

The weak-electromagnetic relationship can thus be explained in terms of the massive symmetry-breaking of the W and Z bosons compared with the photon (see (b) below). Such a scheme also gives rise in the SU(5) unification scheme to massive X bosons which would interconvert quarks and leptons and would explain the preponderance of matter over anti-matter through CP-violation. By contrast, nuclear particles gain mass because they are energetic bound states of massless quarks and gluons under the colour force. Symmetry-breaking also provides predictions concerning the supersymmetric partners of the graviton. The graviphoton and graviscalar have been theorized as small-scale participants in second order modifications to the gravitational force currently being investigated, because, unlike the fermionic gravitino and goldstino, their mass may be small enough to permit interaction over distances of ~100m. Further fields, such as the milli- or super-weak may be required to explain effects such as CP-violation.



	d^r_{right}	d^g_{right}	d^b_{right}	e^+_{right}	$\bar{\upsilon}_{rgt}$
d^r_{right}	*	G_{rg}	G_{rb}	$X^r_{-4/3}$	$X^r_{-1/3}$
d^g_{right}	G_{gr}	*	G_{gb}	$X^g_{-4/3}$	$X^g_{-1/3}$
d^b_{right}	G_{br}	G_{bg}	*	$X^b_{-4/3}$	$X^b_{-1/3}$
e^+_{right}	$X^{\bar{r}}_{4/3}$	$X^{\bar{g}}_{4/3}$	$X^{\bar{b}}_{4/3}$	$\gamma + Z_0$	W^+
$\bar{\upsilon}_{rgt}$	$X^{\bar{r}}_{1/3}$	$X^{\bar{g}}_{1/3}$	$X^{\bar{b}}_{1/3}$	W^-	Z_0

(b) $* = G_1 + G_2 + \gamma + Z_0$

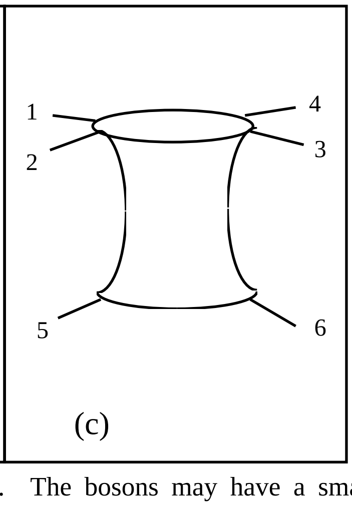


Fig 7: (a) Supersymmetric partners of the graviton include bosons and fermions. The bosons may have a small mass permitting observable second-order gravitational effects.
(b) The SU(5) scheme unifies weak and colour forces with electromagnetism. The X particles would interconvert quarks and leptons and if violating CP-symmetry could explain the preponderance of matter in the universe.
(c) A gravitational (closed-loop) superstring removes anomalies in particle interaction.

(b) <u>Kaluza-Klein Theories and Superstrings</u>. These theories describe the divergence of the other forces from gravity by using a higher dimensional space-time including spinorial dimensions, in which all but the four dimensions of space-time have compactified into closed curves on the Planck scale (10^{-35} m). Supersymmetry has recently been incorporated into string theories in which point particles are replaced on the Planck scale by quantum strings which can have infinitely many vibrational & rotational modes, in addition to those states made available by compactification. Open strings joining end to end correspond to Yang-Mills type interaction via spin-1 bosons, while the excision of closed loops resembles the spin-2 exchanges of gravitons. The original string theories formulated for the nuclear forces caused problems, because they generated inconsistencies in the form of tachyonic solutions in the ground state except in particular dimensions. For bosons this was 26 dimensions and for fermions

10. Each higher state results in an increase of spin by one unit.

The requirement for 26 dimensions emerges from requiring relativistic covariance when in the theory, the commutator

$$[M^{i-}, M^{j-}] = 2/p^2 \sum_{m=1} \Big[m\big(1 - 1/24\,(D-2)\big) + 1/m\big(1/24\,(D-2) - \alpha(0)\big) \Big] (\alpha_{-m}^{i}\alpha_{m}^{j} - \alpha_{-m}^{j}\alpha_{m}^{i}) \quad (3.11)$$

must vanish, leading to $D = 26$ and $\alpha(0) = 1$.

Subsequently, Green & Schwartz[12] have produced supersymmetric 13 string theories in which the ground state has zero mass in a ten dimensional space-time, which also give anomaly-free calculations for the symmetry groups SO(32) and $E_8 x E_8$. The 32-dimensional requirement comes from the cancellation of the 32 Möbius 6 vertex open-string diagrams with the untwisted one (which includes one 32 factor as a result of its free inner end). The even-twist diagrams do not contribute anomalies because they correspond to a closed string (gravitational) connection between the vertices on either side of the twists (see above (c)). "Heterotic" string theories have also been developed on closed strings where the 26-dimensional boson fields and 10-dimensional fermion fields represent the clockwise and anticlockwise wavefronts. Successive compactification of 26 to 10 and 10 to 4 would result in our usual world view. To date no scheme has been devised which successfully selects this 4-D compactification from other dimensionalities. These theories result in massless ground states, and positive mass excited states as a result of positive energy.

(c) The Cosmological Perspective: In the big-bang model, within the Planck epoch, 10^{-35} sec, the universe was smaller than the wavelength of its mass energy. Subsequently at the Compton epoch, the universe was still smaller than the wavelength of its constituent particles. The universe is thus described from a singular origin under which conditions were shrouded within the quantum nature of the universe.

Inflationary theories[14,15], explain many aspects of early cosmic evolution in terms of the dynamical process of symmetry-breaking itself. The description begins with a universe cooling below the temperature at which the nuclear and gravitational forces are symmetrical. This super-cooling results in an anti-gravity regime caused by the negative pressure associated with the field-energy of the field responsible for the Higgs mechanism, which explains the expansion of the universe to near-parabolic form. The negative pressure is confirmed by the collapse of the 'false' symmetrical vacuum into the lower-energy true-vacuum. This releases the latent heat of fusion in the form of high-energy normal particles creating the 'hot' early universe. Defects in the local orientation of symmetry-breaking have been proposed involving points (magnetic monopoles), cosmic strings and domain walls. In such a scheme, the global properties of the universe could result from a single quantum fluctuation of a symmetrical state.

Both these scenarios provide a framework in which a supercausal theory could play a key part in the formative evolution of the universe. Because the universe appears to generate its complexity out of a state which is a fluctuation of a quantum totality, in the end its entire description could become the evolution of a hidden variable theory into the quantum-mechanical scheme of the fundamental forces.

The *anthropic principle* in astronomy[3,4] provides a basis for a description involving time-inverting boundary conditions, because it considers the constraints which are necessary on the laws of the physical universe to enable it to have observers. Many relations arising from symmetry-breaking such as the precise ratios of the nuclear and electromagnetic coupling strengths and masses must be confined within quite delicate constraints if molecular structures and stellar lifetimes are to be capable of supporting biochemistry. Anthropic arguments have been used to explain several relationships between fundamental constants for which there is no ready explanation from symmetry or conservation laws. These are deemed to result from the fact that only in a universe with such relationships is life and hence (conscious) observers possible. This amounts to a form of natural selection of observable universes. Such selection is normally regarded as an example of Bayes formula in probability Nominally the other universes may exist, but are never observed. However the transcausal interaction of symmetric-time and interaction with the conscious observer could also play a role in selection at the level of quantum fluctuation.

Stephen Hawking[16], has developed a time-symmetric cosmology in which the quantum state of the universe is described by a path-integral over metrics that are compact without boundary, which is CPT invariant and has initial and final boundary conditions both in a state of high order. It has been proposed that a global reversal of the arrow of time could result during the contracting phase of such a closed universe, although Don Page[17] has subsequently pointed out that any individual classically observable component of the wave function may not have this symmetry.

(d) The directed-time model:

(1) The initial fluctuation forming the universe establishes directed-time through the formation of a positive-energy retarded universe. All subsequent symmetry-breaking phenomena take place in terms of directed-time, and so from this perspective evolve with increasing time from an initially isotropic symmetric state.
(2) As a consequence, the causality of directed-time describes causes as preceding effects in the form of initial conditions.
(3) The description of single quanta occurs only on a statistical basis, because transactional collapse is determined through symmetric-time.

4: A MENAGERIE OF HISTORICAL THEORIES: Quantum mechanics is an inherently stochastic theory. Since the development of the probability interpretation of the wave function (1.10), physics has been dealing with theories in which specification of initial or other boundary conditions appears to leave the eventual state of the system as a probability distribution rather than an exact physical solution.

Schrödinger's cat paradox of fig 8 expresses the problem in a well-known example. A quantum mechanical system is set up so that a reduction of the wave packet B within time-interval A has a non-zero probability of exciting a detector C and subsequently causing a cat F in a closed box to be killed by a macroscopic device D,E (a silenced gun or poison flask). Any quantum system can be used such as a radioactive decay or an interference pattern for which individual photons can be detected. In the quantum mechanical system we have a superposition of two possibilities, one in which the cat has died and the other in which it lives. By contrast in the world of the experiment, the observer H upon opening the box containing the cat, finds with certainty that only one result has occurred. Although in quantum mechanics only the **probability** of an outcome can only be determined, the real world appears to include a procedure for making a unique choice in each event which I will call the **principle of choice**. If God is not, in Einstein's words "playing dice with the universe," this mechanism of choice remains to be elucidated.

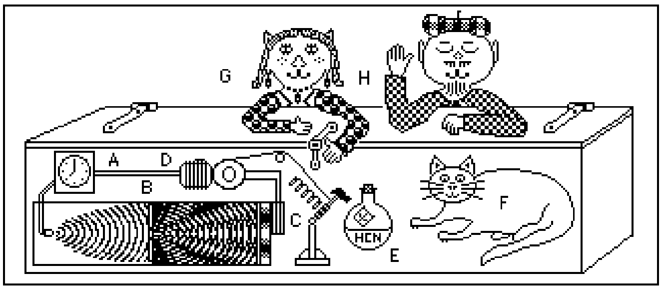


Fig 8: Versions of the Schrödinger cat paradox. (Some cats are more equal.)

Several interpretations cite the consciousness of the observer as the key element causing collapse. Hence in the cat paradox the wave function remains uncollapsed until the experimenter H opens the box. Wigner's friend is a version of the cat paradox in which an assistant G reports on the result, establishing that unless the first conscious observer collapses the wave function, there will be a conscious observer in a multiplicity of alternative states, which is also a drawback of the many worlds view (see below). In a macabre version the conscious assistant is the cat. Heisenberg suggested representing the collapse as occurring when the system enters the domain of thermodynamic irreversibility, i.e. at C. Schrödinger suggested the formation of a permanent record e.g. D, E. Quantum logic is also cited as an explanation[18]. According to the Copenhagen interpretation, it its not the system which collapses, but only our knowledge of its behavior. The state vector is then not regarded as a real physical entity at all, but only a means of describing our knowledge of the quantum system, and calculating probabilities.

In the standard quantum mechanical description[1], we associate with a physical system S a Hilbert state-space H. The state of the system is represented by a unitary state vector $| \psi(t)$ in H which evolves in time according to the Schrödinger equation, (1.13). An observable quantity A is represented by a self-adjoint operator with a complete orthonormal set of eigenvectors $\{ | \psi_r \}$. The probability that an observation of A at time t will give the eigenvalue ψ_r is then

$$\sum_j | \psi_r | \psi(t) |^2 \qquad (4.1)$$

if we restrict ourselves to non-degenerate eigenvalues. Before measurement the state vector is $\psi(t)$, and afterwards it is one of the eigenvectors ψ_r.

The Copenhagen interpretation of quantum theory consists of four key postulates:

(1) The direct consequences of the uncertainty principle - wave-particle duality and the impossibility of simultaneous projection of conjugate variables.

(2) The probability interpretation $P=\phi^*.\phi$, and the application of predictivity only to statistical ensembles.

(3) The concept of complementarity , system-apparatus as a whole unit, uncertainty as a physical property rather than a property of measurement.

(4) The concept of the state vector, and its collapse as representing changes in our state of knowledge of the system, rather than a physical property.

Several other interpretations have also been formulated. In Everett's 'many worlds' interpretation, the universe is described by a vector like $| \Psi$ which never collapses, but evolves into an increasing number of branches through successive couplings. The universe is then described as splitting into an increasing number of probability branches in which all possibilities are realized in future states. This can be seen via measurement theory which describes the interaction between the system observable $\mathbf{s}$, and an apparatus observable $\mathbf{A}$[19]. For convenience, we would think of $\mathbf{s}$ as having discrete eigenvalues s and $\mathbf{A}$ as having continuous ones A. When measurement takes place, the apparatus will record a change to the *disturbed* operator $\mathbf{A}^+$ which depends on the *undisturbed* system $\mathbf{s}$. The system will now however be in state $\mathbf{s}^+$. If, prior to the measurement, the apparatus and the system are uncorrelated, these are independent i.e.

$$| \Psi = | \psi . | \Phi \qquad (4.2)$$

where Ψ represents the combined system and ψ, Φ the state vectors of the system and apparatus in Hilbert space.

When a measurement takes place, the vector $|\Psi\rangle$ must now be expanded in terms of the basis $|s, A^+\rangle$ giving

$$|\Psi\rangle = \sum_s \int |s, A^+\rangle\langle s, A^+|\Psi\rangle\, dA = \sum_s c_s |s\rangle|\Phi[s]\rangle \qquad c_s = \langle\psi|s\rangle \qquad (4.3)$$

We can describe $|\Phi[s]\rangle$ as the states of the system *relative* to $|s\rangle$. The traditional solution to the measurement problem is to presume that $|\Psi\rangle$ collapses into one of the basis vectors $|s\rangle.|\Phi[s]\rangle$ with probability $w_s = |c_s|^2 (\sum_r |c_r|^2)^{-1}$, but then the outcome remains indeterminate.

As the vector $|\Psi\rangle$ stands, no irreversible process has occurred, as the state of the system-apparatus is still a linear combination of basis vectors, leading to questions of how collapse and the arrow of time emerges from the quantum description. The original state vector has now been expanded into a sum of branch terms, all of which according to Everett become branch universes. In fig 9(c) the observer at the square has separated from past branches, but will split into each of the future branches.

Various attempts have been made to unearth a deeper logic underlying the formalism of wave mechanics which would form a basis for subquantum phenomena. De Broglie [20] and subsequently Bohm [21,22] have advanced interpretations of the wave function in which a real particle is "piloted" by a quantum potential which acts in addition to any other potential. This is easily derived from the Schrödinger equation as follows:

$$i h\, \partial\psi/\partial\tau = -h^2/2m\, \nabla^2\psi + V\psi \qquad (4.4)$$

writing $\psi = R \exp(iS/h)$, $P = R^2$

we have $\partial P/\partial t + \mathrm{div}(P\, \nabla S/m) = 0$

and $$\partial S/\partial t + (\nabla S)^2/2m + V + Q = 0 \qquad (4.5)$$

where Q is represented as an additional quantum potential, under which

$$Q = -h^2/2m\, (\nabla^2 R/R) \qquad (4.6)$$

The particle is then constrained to move under the guidance of the wave in a way which synchronously represents the global influence of the wave on the particle. Because the quantum potential consists of a quotient of factors involving R, its variation does not diminish with distance, enabling interactive effects between particles to remain strong at great distances. DeBroglie has extended the description to a covariant form derived from the Dirac equation, in which the particle is piloted by an averaging of the four components of the Dirac wave function.

Bohm et. al. have also extended the treatment[23] to include creation and annihilation of quanta through Auger-like interactions in which energy is transferred for example from an excited atomic electron e^- to a bound particle, which then escapes with kinetic energy representing the energy surplus of the excited electron over the particle's binding energy. Since there is no net change in the particles present, the entire interaction can be described in terms of quantum potential interaction, without reduction of the wave packet. The hidden trajectory of the particle then becomes a succinct and appropriate measure determining which of the possible outcomes will result.

If the wave function of the atomic electron is $\psi_0(\mathbf{x})\, e^{-iE_0 t}$ and that of the particle is $\varphi_0(y,t)$, thus resulting in a combined wave function $\Psi_0 = \psi_0(\mathbf{x})\, e^{-iE_0 t}\, \varphi_0(y,t)$ which through interaction becomes $\psi_f(\mathbf{x}).e^{-iE_f t}$, then the

combined wave function becomes $$\Psi_f = \psi_0(\mathbf{x})\, e^{-iE_0 t}\, \varphi_0(\psi,\tau) + \int_0^t \alpha(t',t)\, \psi_f(\mathbf{x})\, e^{-iE_f t}\, \varphi_f(y,t-t')dt \qquad (4.7)$$

where the term α is calculated using time-dependent perturbation theory. We are thus dealing purely with the effects of the quantum potential on each particle. Bifurcation theory is then invoked to explain the realization of possible outcomes, such as the electron exciting or failing to excite the particle, in terms of bifurcation of the trajectories into two channels, one in which interaction occurs and the other not. In situations where many possible outcomes occur, a richer set of bifurcations of the trajectories results in separation of possible states into wave functions which eventually separate and cease to overlap with the original wave function, thus becoming distinct outcomes, which may become distinguished subsequently by macroscopic irreversible processes. Such a mechanism could explain many types of particle interaction, particularly if quarks and leptons could all be explained in terms of one class of truly fundamental preons such as the rishon scheme[24] (e^- = TTT, υ = VVV, 3 quark colours TTV TVT VTT etc.).

The treatment of interaction with a field is a more complicated version of the same scheme. For example in absorption of a photon from an electromagnetic field, an initial Fock state of the field with one quantum of excitation is converted to the ground state. However here the interaction does not involve specific trajectories for the photon, which is represented as a superposition of normal modes of a real field which is defined at each point in space-time in the same manner as a particle resulting in a super-wave function $\psi(\ldots \varphi(\mathbf{x},t) \ldots)$ over all values $\varphi(\mathbf{x},t)$ of the field φ.

The combined wave function is now $\Psi_f = \Psi_o^f \psi_o(\xi - \xi_o) + \sum_n \int_0^t \alpha_n(t',t)\, \psi_n(\xi, t-t')dt'\, \Psi_o^f,$ (4.8)

where the photon is described as a packet of normal modes $\Psi_o^f = \sum_k f_k q_k \exp\left[- \sum_k k' q^*_{k'} q_{k'} \right]$ (4.9)

which does not involve a specific trajectory for the photon as a particle. In fact, Bohm maintains that it is not possible to make a causal description of a field such as electromagnetism in which there are well-defined particle trajectories, because the field transforms as a tensor between reference frames, while any real trajectory must transform differently as a vector... i.e. in general there are no conserved four-vectors whose time component is positive-definite.

Comparison with Feynman's space-time treatment gives a more structured explanation, in the fact that the field is determined by the coherent action of a sequence of higher-order diagrams, each representing a particle interaction whose amplitude results in a non-unit probability, fig 3. It is the *integratedset* which transforms correctly, rather than a single vector particle trajectory. An exact trajectory in terms of the original e^- in higher-order diagrams, such as 3(c,d) is impossible since intermediate states involve additional particle pairs. Particle-antiparticle anihilation provides a good test case, because almost any particle type can be produced, involving more degrees of freedom than stipulated by the initial trajectories of the anihilating particles.

$$e^+ + e^- \rightleftharpoons \gamma \rightleftharpoons \text{quark + antiquark etc.}$$

A complete quantum potential scheme requires the extension of the approach to include full description of the trajectories of all virtual particles in field exchange, and the creation of new quanta and their exact trajectories using the other trajectories at a creation vertex as boundary conditions. It remains doubtful whether the quantum potential approach can give a coherent explanation of the creation of new trajectories including such specifically quantum attributes as particle spin, and whether the boundary conditions are initial conditions, or rather the transactional boundary conditions over space-time.

A second hidden variable theory developed by Bohm and Bub[25] attacks the collapse of the wave function. In this theory, a dual space is appended to the Hilbert space which provides the domain for variation of the collapse. Consider a system whose wave function can be represented as a vector in 2 dimensional Hilbert space, such as a spin 1/2 particle.

The vector $|\psi\rangle = \psi_1 |S_1\rangle + \psi_2 |S_2\rangle$ (4.10)

normalized so that $|\psi_1|^2 + |\psi_2|^2 = 1$, where S_1, S_2 is a basis in which the operator of the spin observable is diagonal is associated with a dual vector

$$\langle\mu| = \mu_1 \langle S_1| + \mu_2 \langle S_2|.$$

ψ is presumed to vary both with the Schrödinger equation and with the equations

$d\psi_i / dt = \gamma\,(R_i - R_j)\,\psi_i J_j \quad i = 1,2 \quad j = 2,1 \quad \text{where } R_i = |\psi_i|^2 / |\mu_i|^2, \quad J_i = |\psi_i|^2$ (4.11)

Since the R_i increase to 1 or decrease to zero in the resulting equations

$dJ_i / dt = 2\gamma\,(R_i - R_j)\,J_i J_j$ (4.12)

depending on whether or not $R_i > R_j$ initially, ψ tends to either S_1 or S_2. By choosing a random distribution on the unit Hilbert hypersphere for μ, statistics conforming to $P_i = |\psi_i|^2$ result. The attachment of the dual space has the appealing property that it is variation in the dual space which determines the nature of each selection in the original. Bohm in his paper pointed out that other process of selection in the dual space would also permit collapse of the wave packet. The idea could be extended to infinite-dimensional spaces as occur in position measurements enabling the probability distributions of varied wave functions from orbital electrons to diffraction patterns to be treated in terms of distributions in a dual Hilbert space.

This treatment has been expanded into a covariant form by Longtin & Mattuck[26]. In this description, the collapse process suffers the usual time dilation when viewed in another Lorentz frame, if we assume that the dual vector transforms in the same manner as the state vector .

Von Neumann and others [27,28] have attempted to use the principles of quantum mechanics to prove that no dispersion-free states can exist in a quantum mechanical system, which hence cannot be described in terms of an exact hidden variable theory. Von Neumann's theorem and its refinements all appear to have loopholes which allow hidden variable theories to violate their premises and hence render the theorems inapplicable. The theorems exploit the fact that an observable is a linear operator and its expectation values are also linearly related, to prove the inconsistency of dispersion-free states. Bell, Bohm and others have all produced counter-examples based on the fact that single collapses produce eigenfunctions, which unlike the expectations are not linearly related. The validity of theorems of this type do not hold in models where the expectation is defined jointly by the system and its "measuring apparatus".

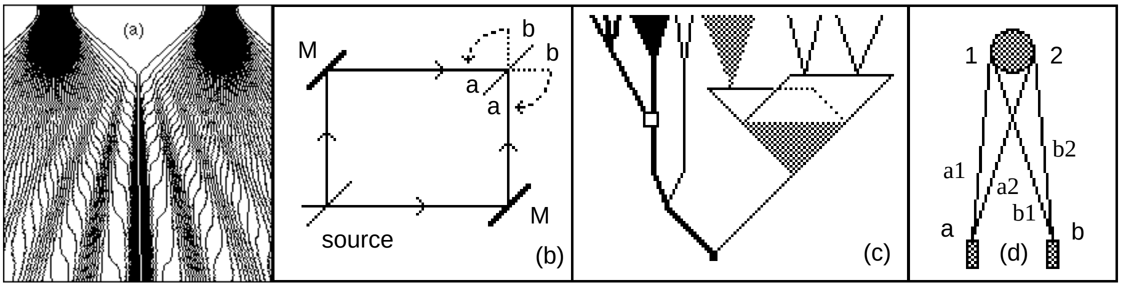


Fig 9: (a) Quantum potential trajectories for two-slit diffraction, (b) The delayed choice experiment (c) Everett's many worlds interpretation involves branching histories in which discrete or continuous eigenvalues generate probability universes, (d) Hanbury-Brown Twiss experiment in which interference from incoherent sources is measured using the product of counts from two separate detectors.

We can also examine how the Quantum potential approach stands in the light of the transactional interpretation. Under a complete scheme where all interactions have causal trajectories, the quantum potential approach is unchanged by the inclusion of advanced waves since a negative energy particle travelling on an advanced wave will follow the exact time reversed trajectory of the corresponding positive energy particle travelling on the retarded wave. The approach is thus fully consistent with the transactional viewpoint, in such a way that the same deterministic solution is represented by both retarded and advanced solutions. However the problem dealing with quantum field trajectories leads to a loophole in the causal description.

5: PAIR-SPLITTING EXPERIMENTS AND OTHER QUANTUM PARADOXES.

Bell's theorem and the resulting experimental tests have become a subject of keen interest because they have important bearing on the relationship between relativity and quantum theory. The ideas were first put forward in a *Gedankenexperiment* of Einstein, Rosen and Podolsky, but it was not until the advent of Bell's theorem that an experimental test became possible[27,28,29]. Bell's theorem applies to locally realistic hidden variable theories, and demonstrates a divergence between their predictions and quantum mechanics. Realism asserts that the physical universe has well-defined properties independent of observers. Locality or local Einsteinian causality postulates that once two particles have separated no information can be transmitted between them at a speed faster than light.

The discrepancy can be seen easily in the case of a spin measurement on each of two spin-1/2 particles, which are initially in a common singlet state with opposite spins and subsequently separate.

Let $A_{\mathbf{u}}$ and $B_{\mathbf{v}} = \pm 1$ be the result of spin measurement of the particles along directions $\mathbf{u}$ and $\mathbf{v}$. The quantum mechanical prediction for $A_{\mathbf{u}}.B_{\mathbf{v}}$ is then $E(\mathbf{u},\mathbf{v}) = \langle\psi|\sigma_1.\mathbf{u}\ \sigma_2.\mathbf{v}|\psi\rangle = \mathbf{u}.\mathbf{v}$ (5.1)
simply the dot product of the directions, which will vary with $\cos(\theta)$. As a special case in both theories, we have the deterministic $E(\mathbf{u},\mathbf{u}) = -1,$ (5.2)
By contrast, let Λ be a space of states for a hidden variable parameter λ upon which a probability distribution function ρ can be defined. Let this have unit norm i.e. $\int_\Lambda d\rho = 1$ (5.3)

A deterministic hidden variables theory is defined to be local if for all $\mathbf{u}$, $\mathbf{v}$

$$(A_{\mathbf{u}}.B_{\mathbf{v}})(\lambda) = A_{\mathbf{u}}(\lambda).B_{\mathbf{v}}(\lambda) \quad \mathbf{u}, \mathbf{v}, \lambda \qquad (5.4)$$

Thus after separation, the result of measurement of A depends only on $\mathbf{u}$ and λ but not $\mathbf{v}$ and vice versa.

For such theories, the expectation is $E(\mathbf{u},\mathbf{v}) = \int_\Lambda A_{\mathbf{u}}(\lambda).B_{\mathbf{v}}(\lambda)\, d\rho$ (5.5)
By (5.2) we have that $A_{\mathbf{u}}(\lambda) = B_{\mathbf{u}}(\lambda)$ and hence

$$E(\mathbf{u},\mathbf{v}) - E(\mathbf{u},\mathbf{w}) = -\int_\Lambda \{ A_{\mathbf{u}}(\lambda).A_{\mathbf{v}}(\lambda) - A_{\mathbf{u}}(\lambda).A_{\mathbf{w}}(\lambda) \}\, d\rho$$
$$= -\int_\Lambda A_{\mathbf{u}}(\lambda).A_{\mathbf{v}}(\lambda) \{ 1 - A_{\mathbf{v}}(\lambda).A_{\mathbf{w}}(\lambda) \}\, d\rho$$

Since A, B = ± 1 and so $|E(\mathbf{u},\mathbf{v}) - E(\mathbf{u},\mathbf{w})| \le \int_\Lambda \{ 1 - A_{\mathbf{v}}(\lambda).A_{\mathbf{w}}(\lambda) \}\, d\rho$ (5.6)
Hence by (5.3) $\le 1 + E(\mathbf{v},\mathbf{w})$ (5.7)
The discrepancy now becomes apparent, because if we pick $\mathbf{v}$ and $\mathbf{w}$ to be rotations in a plane of $\mathbf{u}$ by $\pi/3$ & $2\pi/3$ then in the quantum mechanical interpretation $\mathbf{u}.\mathbf{v} = \mathbf{v}.\mathbf{w} = -1/2$ and $\mathbf{u}.\mathbf{w} = +1/2$, and so 5.7 would become $1 \le 1/2$ which is clearly a contradiction. Similar results for photon polarization are shown in fig 10(b).

Subsequently Clauser[28] and other workers developed an experimental technique which has demonstrated that the Bell's inequality and hence the locality assumptions from which it is derived are violated and that the quantum mechanical predictions are valid. The experiment consists of causing two particles with complementary spin (or polarization) to become separated as above. In locally realistic theories, each of the two particles has defined and opposite spins from the time of their separation, but the observers are only able to measure the total spin and the spin relative to a chosen axis. A limit on the transfer of information faster than light then results, by Bell's theorem, in a limit in the correlations between the detector statistics when measurements are made at an angle θ. By contrast, quantum mechanics predicts the sinusoidal variation based based on the projection operators above in 5.1. This is consistent with the interpretation that the spin orientation of each particle is undefined until one of them is measured, when the other is immediately determined to be complementary. However there is a degree of inconsistency in such a description, because the time ordering of a 'simultaneous' measurement can be reversed through relativistic motion in other reference frames, resulting in inconsistent alternative descriptions of the collapse, (although no ambiguity in the predictions concerning observable quantities). Similar results hold for many-particle states[30].

A more recent version of the experiment by Alain Aspect[31,32,33] has refined the technique to demonstrate that the same correlation is observed, even when the detector's orientations are varied at speeds which prevent the transfer of information at the speed of light between them. The same correlations are measured but under conditions where pseudo-random switching is made between the detectors too rapidly to permit the transfer of information about the orientation angle between the two arms of the apparatus, see fig 10(c).

The Aspect experiment does not permit the transfer of a signal or message across space-like intervals. To see this one needs only to look at the data from one end of the apparatus, which is a random string of 0's and 1's. The correlation between the sets of data can only be recognized when both are coincident. To bring the data together requires a further light signal, resulting in a positive time interval between the registration of one set of data and the comparison with the other. This remains positive even if the apparatus components are in relative motion because the sum tachyon time (negative) + photon time (positive) is always positive. Furthermore, an experimenter cannot manipulate the apparatus (e.g. by selectively repolarizing half the particles) at one end so as to cause the other end to become structured. Various attempts have been made to construct such transmission schema and all have so far contained critical flaws.

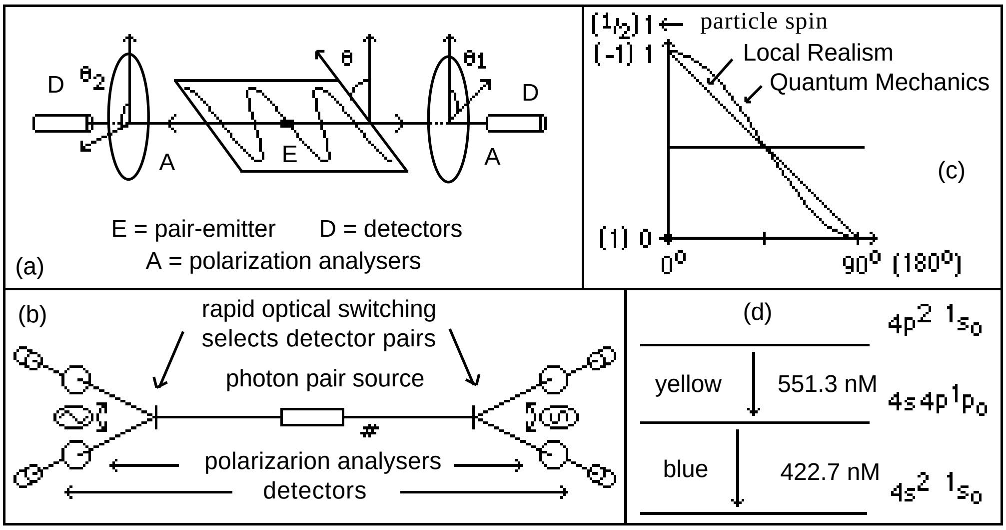


Fig 10: The experimental arrangement of the pair-splitting experiment for photons.

Mackintosh & Jensen[34] have demonstrated that even using non-collapsing momentum-measuring interactions, the conditions required to make a measurement at one end coincide with the destruction of phase coherence between the particles under the uncertainty relations. If a mirror is used to measure the momentum by recoil, the resulting uncertainty of its position equals one wavelength. By contrast we could try to measure the polarization of one component by delaying it through a reflected path and then recombining the wavefronts into coherence while using coincidence counting later to test the polarizations, however we must then have a path difference $\Delta l > \tau c \sim 1.4$ m where τ 4.5 x 10^{-9} is the lifetime of the calcium excited state, but the extension of the photon is also τc and so the wavefronts cannot overlap. Herbert[35] has also attempted to use a laser on one arm of the apparatus to clone one of the photons to produce a particle distribution on one side which would reflect the linear or circular polarization of the other. Unfortunately the scheme requires all of the cloned photons to have the same polarization state as the initial one, and the possibility of doing this violates the basic linearity properties of quantum theory.

The Aspect experiment presents in an interesting way a dilemma that applies quite generally ... if the disturbance to the wave aspect resulting from collapse can only be transmitted at the velocity of light, then it should be possible to witness spurious double-particle creation from spatially extended waves, on the basis that the probability function would not immediately become zero at space-like intervals. This non-locality of the *first* kind is normally distinguished from the above non-localities of the *second* kind, because it can be explained away by describing the wave function as representing only our state of knowledge under the Copenhagen interpretation.

A possible measure of synchronous collapse in biochemistry is illustrated as follows. A long heterocyclic (carbon-nitrogen) polymer P can become excited through a lone-pair electron on a N atom at one end of the molecule entering a delocalized π-orbital which runs the length of the molecule. Two other molecules interact with P. A molecule A becomes weakly bonded to the π-orbital when it is in the excited state and a second molecule B is bound weakly via the doning nitrogen when one electron of the pair is absent (excited state also).

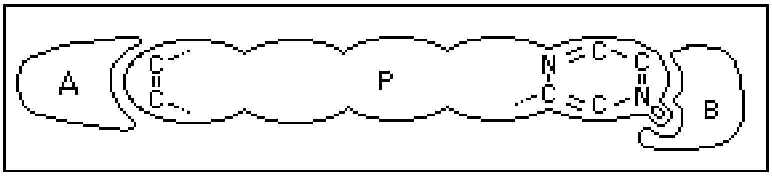


Fig 11 : A Heterocyclic *Gedanken*- molecule

Dexcitation of the π−orbital would result in release of both A and B from opposite ends of the molecule. B registers that an electron has entered N while A registers from the other end of the molecule that the π−orbital has collapsed. However the average lifetime of the π after removal of A will cause a delay, and this delay will increase with the length of P because the energy levels will be closer together in a longer molecule.The use of an independent particle approximation gives energy values $E - Eo = 2 A \cos (\pi S / (2N + 1))$ $S = 1, . . . N+1$ which for a $\pi \rightarrow \pi$ will tend to 0 with increasing N, but for an $n \rightarrow \pi$ will tend to $E - E_n$ = const.

A second quantum paradox can be seen in Wheeler's delayed choice experiment, fig 9(b). A split beam traverses two different routes before being recombined in a partially silvered mirror. Measurements at **a** result in a measurement of whether a particle traversed path 1 or path 2 while measurements at **b** determine the phase difference of the paths. Wheeler points out that it is as if by choosing **a** or **b** we can determine *after* the photon was moving along the separated parts of the path whether it went along only one path or both. The quantum potential approach results in a form of realism about the particle which requires it to traverse only one of the paths while the wave traverses both. After mixing at the mirror, the waves result in a quantum potential which forces the particle distributions to reflect the phase difference. The same realism applies to a two-slit diffraction experiment as shown in the trajectories of fig 9(a).

A third paradox called Renninger's negative-result experiment plays havoc with the notion of collapse being associated with irreversible or permanent changes and reinforces the potential role of a conscious observer. A single quantum is emitted from a source at t_0. A hemispherical detector to the left at d_1 will detect the quantum at t_1 with probability $^1/_2$, otherwise it reaches a more distant detector to the right at time t_2. Thus if the experimenter does not observe a scintillation by t_1 he will know with certainty that the wave function has collapsed to one with only a right-hand velocity component. The failure to detect anything thus appears to trigger the collapse.

Finally we have the Hanbury-Brown Twiss type of experiment typified by using the product of count rates from two separated detectors a & b if Fig 9(d) to measure the interference of incoherent light emitted from two sides of a distant star. This is normally used to measure the central interference peak and develop a measure of the angular width of the star, but it also illustrates a situation in which the concept of a unique photon trajectory receives some testing, since each detector in principal receives a photon which constitutes two half-photons, one from each side of the star.

The power of the transactional interpretation is illustrated by its capacity in a single stroke to resolve several if not all of the outstanding paradoxes of quantum mechanics:

(a) The pair-splitting experiment is resolved by the boundary conditions determined by the backward light-cones of the two detectors which meet at the original emission focus. Because these must have aligned polarization for the pair-emission to establish a transaction, the correlation is maintained non-locally without requiring a superluminal signal between the absorbers. The correlations are established retrospectively in time at the source by the joining negative phase components (see fig 13(a)).

(b) The Wheeler delayed choice experiment is also neatly explained, because the differing arrangements of the detectors result in different configurations of confirmation wave which either establish transactions in which a photon travels through one, or through both paths of the apparatus. The delayed choice arrangement illustrates the strong influence that future states of the universe can have on current transactions.

(c) The Renninger negative-result experiment does not involve contradictory interpretation because of the *atemporal* nature of any transaction. A transaction with the nearer screen will occur with non-zero probability which will be recognized if it occurs by t_1. If it has not occurred by t_1 , then the other transactions at the second screen are inevitable but a transaction is completed only by t_2 and no collapse occurs at t_1.

(d) The Hanbury-Brown Twiss effect also provides an interesting example of a transaction whose boundary conditions invove contributions from more than one retarded and advanced wave at both absorption and emission foci, leading to the idea that two half-photons, one from each side of the star are assembled at each detector, fig 9(d). The explanation of this arrangement in terms of unique quantum potential trajectories would have to involve interference of the empty section of one wave function with the the other one in a similar manner to the delayed choice experiment.

(e) The cat paradox is partially resolved because there is no longer any confusion over *when* the wave function collapses. The emitter-absorber transaction is extended over space-time and the wave function is only deemed to collapse once the transaction is established with the absorber. However the transactional interpretation does not explain the principle of choice. The probability interpretation remains in the form of the confirmation waves of the potential absorbers which must collapse over space-time to a single emitter-absorber transaction. The probabilities are now a function of future states, which are themselves potentially a subject of unresolved transactions, adding a recursive dilemma to resolving the single-collapse transaction.

6: TACHYONS AND CAUSALITY-VIOLATION

The notion of simultaneous collapse suggests examining how synchronous events are transformed by special relativity. Faster-than-light particles, or tachyons do not in fact violate the Lorentz transformations for velocity-time and energy-momentum provided they are confined exclusively to superluminal velocities[36].

The Lorentz transformations $(c=1,\ \gamma=(1-v^2)^{-1/2})$

$$x_2 = \gamma .(x_1 - v.t_1) , \qquad y_2 = y_1, \qquad t_2 = \gamma.(t_1 - v.x_1) \qquad (6.1)$$
$$u_{2x} = (u_{1x} - v) / (1 + u_{1x}.v), \qquad u_{2y} = u_{1y} / \gamma. (1 - u_{1x} .v)$$

remain valid for velocities u>1 (i.e. c) but not in 4 dimensions[37,38] for $v > 1$.
The energy and momentum $E = \gamma.m$ and $p = \gamma.m.v$ can be modified for v>1 to give real expressions:

$$E = i. \mu / (v^2 - 1)^{1/2} = i \gamma \mu, \quad p = \mu v / (v^2 - 1)^{1/2} = i \gamma \mu v, \quad \text{for } \mu = i \qquad (6.2)$$

Superluminal solutions are interesting in that the time order of events can actually become reversed for different observers, and because the energy tends to zero at infinite velocity, although the momentum does not.

The wave properties of tachyons appear to prevent them from forming a complete set of eigenfunctions which will sum to a Dirac delta function. If we consider the analogue of the Klein-Gordon equation for imaginary mass,

$$(\nabla^2 - \partial^2/\partial t^2 + \mu^2) \psi = 0 \qquad (6.3)$$

elementary solutions are
$$\psi_{+,k} = (2\pi)^{-3/2} e^{i (\mathbf{k}.\mathbf{x} - \omega \mathbf{t})}$$
$$\psi_{-,k} = (2\pi)^{-3/2} e^{- i (\mathbf{k}.\mathbf{x} - \omega \mathbf{t})} \qquad (6.4)$$

but in this case
$$\omega = \pm(k^2 - \mu^2)^{1/2} \qquad (6.5)$$

and so we must restrict $\mathbf{k}$ by the condition $| \mathbf{k} | \geq \mu$ to keep ω and hence the energy real. Hence when we look for the usual completeness relation

$$\sum_k \psi_{+,k} (\mathbf{x}, t=0).\ \psi_{-,k} (\mathbf{x}, t=0) = \delta^3(\mathbf{x-x'}) \qquad (6.6)$$

we have instead only the sum for $| \mathbf{k} | \geq \mu$. The eigenfunctions thus do not form a complete set.

The situation regarding the energy of tachyons is interesting, in the light of Feynman's approach to negative energy states by reversing the time direction of the solution. The changes in the sign of the velocity in one dimension correspond to reversals of the sign of energy and of phase. Consider a Lorentz transform with velocity $\mathbf{v}$ along the x-axis. The energy transforms as

$$E' = \gamma.(E - \mathbf{p}.\mathbf{v}) = \gamma.E .(1 - v u) \qquad (6.7)$$

similarly the time transforms as
$$t' = \gamma.(t - v x) = \gamma.t.(1 - v u) \qquad (6.8)$$

and the frequency as
$$-\omega' = \gamma.(-\omega - \mathbf{k}.\mathbf{u}) \qquad (6.9)$$

hence both the energy and phase direction change sign when the reversal of the relative velocity in one dimension causes a time reversal of the travel. Hence the roles of creation and annihilation operators a(k) and a'(k) are then exchanged, violating the usual commutation relations for bosons.

$$[a(k),a'(k')] = \delta^3(k - k') \qquad [a(k),a(k')] = 0 \qquad (6.10)$$

This exchange of roles of creation and annihilation renders the particle number non-invariant because a tachyon emitted to infinity is converted to a tachyon absorbed from infinity. This problem is solved in the transactional view by the pairing of absorbers and emitters.

The existence of tachyons as real particles involves logical contradictions. Ordinary Lorentz transformations can result in the reversal of the velocity of a tachyon, and hence change the logical order of the events connecting two observers. This permits contradictory situations where an observer can emit a tachyon and receive the same tachyon before it was emitted, enabling logical paradox if for example the observer emits the tachyon only if he doesn't receive it. This dilemma can be partially resolved by associating the backward time direction with the negative energy solution, however sequences involving three or more interactions can have the property that all the tachyons have positive energy retarded waves, as in fig 12 [39].

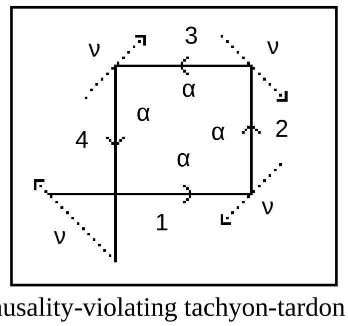


Fig 12: Causality-violating tachyon-tardon interaction.

The existence of imaginary mass particles would require a mechanism for their creation from other, possibly massless states using one of the unified field theories. The form of the major theories of cosmic symmetry-breaking shows why tachyonic solutions may be eliminated. The minimum potential configuration of the Higgs mechanism guarantees that for both real and imaginary values of μ, the resulting particles have exclusively real mass. Although string theories originally had tachyonic ground states, current theories have zero-mass ground states and real-mass positive energy excited states. Thus, while tachyons could in-principle occur, no mechanism appears to exist for their generation during cosmic symmetry-breaking. Rather than using additional particles such as tachyons, the natural course is to use the advanced solutions of the conventional particles to develop a transcausal theory.

7 : TRANSACTIONAL TRANSCAUSALITY AND DUAL-TIME

We define a hidden variable theory to be ***transcausal*** if:

(1) The predictions of the theory are relativistically covariant.

(2) The expected value E of an observable A on collapse of the wave-packet is a single-valued function

$$E = E(A, S) \qquad (7.1)$$

where S is a 'context' set of quantum-mechanical or hidden-variable parameters spanning a relativistic interval which includes space-like intervals. E thus defines an exact value for each single reduction event.

(3) The statistical distribution of values $E(A)_S = (\psi, A\psi) = \int \psi^* A\psi \, d\mathbf{x}$ (7.2)

i.e. the <u>statistical</u> predictions of the theory agree with those of quantum mechanics.

These conditions place a general bound on theories which define unique reduction events using information from a space-time interval. Examples could either use exotic particles such as tachyons or alternatively establish transcausal interaction using the twin advanced and retarded solutions of conventional particles. Although the statistical convergence of transcausal theories would not give rise to causality violations at the quantum level, such violations could appear in the hidden variable description, and would then effectively prevent the reduction of a transcausal theory to a temporally deterministic one. Any attempt to decompose the theory into directed-time interactions would involve temporal paradox, because of time reversals in the causal chain required to describe the global process from the view of any single observer. Such theories would extend the description of present into a function of a space-time interval and allow for a kind of bootstrapping, in which the context determining each reduction event includes future states of other locations in the universe. Transcausal hidden variable theories could thus become "non-existence" theories in which the unravelling of the causal sequence would become impossible below the quantum level because of paradoxical time reversal. This provides an interesting example of Bohm's idea[40] of *implicate* and *explicate* order in which the implicate order underlying wave-particle reduction becomes paradoxical when an attempt is made to unfold it into explicate order.

We now return to the definition of dual-time supercausality as expressed in (1A) & (1B) at the beginning of the paper. The definitions of symmetric-time and directed-time and their complementary relation now become clear:

(7A) Symmetric-Time. Relativistic quantum mechanics contains dual solutions in which a conventional retarded particle is equivalent to an advanced negative-energy anti-particle. The advanced and retarded waves corresponding to these form a quantum hand-shaking transaction between the emitter and absorber whose boundary conditions consist of all contingent emitters and absorbers which could also interact with each wave function. The solution to the boundary condition is the selection of just those quanta which are actually exchanged. Because the boundary conditions span the space-time region containing the exchanged quanta, they cannot form a set of initial conditions, and hence not be solved in terms of directed time.

(7B) Directed-Time. Cosmological symmetry-breaking gives rise to a preponderance of retarded positive-energy particles, because the universe must contain non-zero real energy to form an action. The real positive-energy interactions in the universe are thus necessarily retarded, and give rise to a time-directed causality in all the interactive consequences of symmetry-breaking. This time-directedness is manifest both at the quantum level, resulting, for example in an excess of matter over anti-matter, and on the cosmological scale resulting in star and galaxy formation and the retarded evolutionary scheme of biological systems.

The relationship between these modes does not involve contradiction in directed-time. The symmetric selection events are beyond specification in terms of symmetry-breaking time, since they include future states as boundary conditions. Hence the most complete theory possible in terms of symmetry-breaking time is the probability interpretation of quantum mechanics. The potential paradoxical nature of symmetric time is confined to the sub-quantum domain and hance unavailable to directed-time to cause a paradox.

The incompleteness of directed-causality manifests in terms of the probability interpretation of quantum mechanics. Symmetric-time, because it deals with choices in the subquantum domain is confined to being a hidden-variable theory. All combinatorial choices made under symmetric-causality are consistent with the quantum probability interpretation of directed-causality. The correspondence principle projects the total description onto the directed-aspect, resulting in macroscopic temporal determinism. Access to the internal structure of symmetric time is made very difficult because the configuration of an experimental apparatus is defined in terms of retarded particles and displays data only at the quantum level.

In the transactional interpretation, we have the collapse being determined across space-time by the action of the boundary conditions on the confirmation waves arising from the contingent absorbers. The transactional interpretation provides for a non-linear wave transient acting at the emission & absorption vertices determining the collapse dynamics of the event, in a form which I will call **transactional transcausality**. In the figure below, (a) shows the transaction for the pair-splitting experiment. There is no need for a superluminal interaction to connect the absorption events A1 & A2 because their retrospective light cones intersect at the emission vertex in space-time. It doesn't matter which one if A1 & A2 are first or which is deemed to collapse the paired wave function, because the transaction is established across the space-time of the entire light cone from E.

If we apply the same treatment to the resolution of the collapse dynamic of all contingent confirmation waves by all contingent absorbers, we have a similar effect. Regardless of the time or position of a given contingent absorption event, the contingent confirmation waves all arrive simultaneously at the emission vertex, and in the case of a single particle event are resolved by the boundary conditions into a single transaction. One way of describing this resolution is through a non-linear transient in the total confirmation wave. Because this is established both prospectively and retrospectively it would result in a supercausal description of the collapse dynamic. Such a transient must be consistent with the probability norm, rather than a simple bifurcation favoring the maximal contributor.

In a fully time-symmetric description, we should also consider the corresponding resolution at the potential absorber between the offer waves of the emitter and the other contingent emitters (dotted lines in fig 9(b)). The probabilities associated with each of these would be

$$P_{ea} = |\ \psi_e(\ r_a,t_a)\ |^2 \qquad (7.3a)$$

$$P_{ae} = |\ \psi_a(\ r_e,t_e)\ |^2 \qquad (7.3b)$$

I.e. the probabilities determined by the offer wave at the absorber as opposed to the confirmation wave at the emitter. However under situations such as non-commuting polarizing filters, the correct transactional description would be as the product of the conjugates

$$P_{e|a} = \psi^*_e(\ r_a,t_a).\ \psi_a(\ r_e,t_e) \qquad (7.3c)$$

requiring the mutual establishment of the transaction by emitter & absorber.

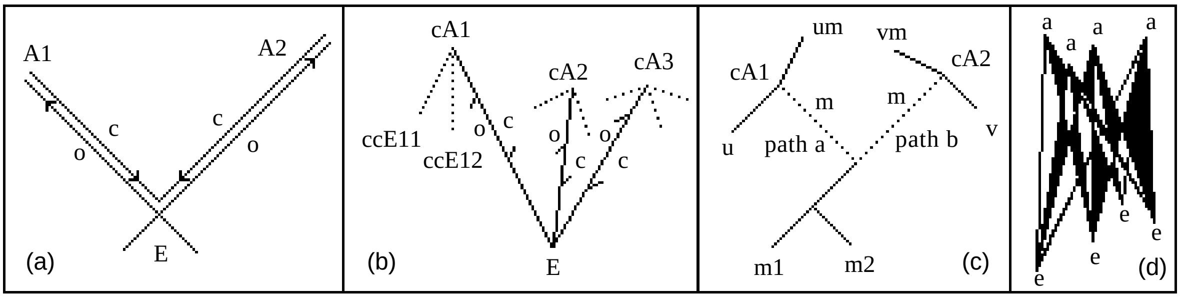


Fig 13: (a) Retrospective light-cones of the absorbers join at the emission vertex in the pair-splitting experiment.
(b) Confirming waves of contingent absorbers are resolved at the emission vertex in a one-particle transaction.
(c) A polymerization reaction involving emission & contingent absorbers of a molecular intermediate m.
(d) Enfolding of contingent offers & confirmations into a spliced space-time interaction (compare fig 3(c)).

The transactional interpretation has significant consequences which point to a deep time-reversing property of the universe which bears an interesting relation with the anthropic principle in astronomy:

(i) Retrospective realization: Suppose I look through a telescope at the distant borders of the currently known universe at a galaxy whose image originated, say 4000 million years ago. Then the absorption of a photon from the perceived smudge also confers a realistic boundary constraint on its previous emission at some time near the origin of the solar system. The particular transaction cannot be established by the emitter during the early stages of the universe without the *real* existence of the observer at a much later date across the space-time interval. The universe must produce a *real* future absorber, myself peering through the telescope, rather than another hypothetical Everett branch in which I never existed, or never looked through the telescope at all. The emission of the photon at this early date has become causally linked with an absorber that cannot come into real existence until a vast process of evolutionary change has been completed involving many intermediate transactions.

In this sense there may be an important difference between the transactional and standard interpretations in that the usual probability interpretation considers only the probabilities of the offer wave without applying the boundary conditions of the real absorbers at a future time. Successive predictions indiscriminately include all Everett branches. By contrast, the transactional view includes only those *real* absorbers in the future light cone of the offer wave, thus acting as a filtering device to specify the subset of those potential absorption events which form the *real* future contingent absorbers.

(ii) Directed- time recursion.
Since the future absorbers of a given emitter may themselves be defined through other transactions which are not

completed at the time of observation, transactional collapse involves a regress in terms of boundary conditions which are themselves defined through the probability dynamic of other potential transactions. Thus in terms of directed-time, nothing can be predicted until "the universe is complete and time comes to an end". I would call this the **final transcausal principle** in directed-time.

It is at this point that the practical-minded physicist may well ask *"Isn't this violating Occam's razor by providing a theory that drags the whole universe into the act, so that nothing is explained until the history of universe is complete?"* The most coherent reply that can be made to this is simply *"If nature has chosen this path, physics will necessarily reflect it in a theory which is causally open in the manner that the probability interpretation of quantum mechanics appears to be".* There is already strong evidence from the inflationary scenario that the universe may come to be viewed essentially as a single quantum fluctuation in which the negative field energy of the Higgs force is balanced by the total mass-energy of the constituent particles. A natural extension of this view is to regard all interactions as virtual, both because each particle must be both emitted and eventually absorbed, and because the form of each reduction is connected to all other reductions in this super-fluctuation.

(iii) Space-time assimilation: The transactional view manifests all contingent absorber responses at a single point in space-time, regardless of when or where the absorption process occurs, by assembling at the emission vertex (and similarly for absorption) a superposition of all the confirmation waves which have responded to the offer throughout space-time. We saw that the Aspect experiment could be explained by the two separate absorbers placing a mutual constraint on the emitter, illustrating that the advanced waves also have a formative influence on the emission process, and in a way which results in a transcausal relation between spin orientations. Similar considerations apply to the resolution of a transaction among contingent and supercontingent foci.

(iv) The twin-dice dilemma: The transactional approach also makes a further complication to Einstein's notion of God playing dice with the universe. In the Copenhagen interpretation of quantum mechanics, each reduction of the wave packet represents only an ensemble of possibilities each of which is consistent with the predictions of quantum mechanics as an outcome. Thus any of the possible single reduction events can happen without inconsistency. God could then be described as being hypothetically free to decide which one in particular is chosen by throwing a (possibly infinite-dimensional) die or by any other means that are consistent with averaging to the probability distribution. The Bohm-Bub theory of the collapse of the wave-packet and the empirical supercausality described above illustrate that a variety of processes could vary the relations between such outcomes while remaining consistent with the predictions of quantum mechanics.

The transactional interpretation however adds a global set of relationships with far-reaching consequences to this schedule. We now have a more complex balancing act for God. In the transactional view he must juggle not only one set of dice, but two, and in such a way as to resolve,without contradiction a mutual set of potentialities which spread recursively throughout space-time. The reason is this. As well as the emitter deciding that out of all possible absorbers *this* is the one, the absorber must decide that and of all emitters, *that* is the one, as shown in lines ${}_{cc}E^{11}$, ${}_{cc}E^{12}$ if Fig 13(b). Thus all super-contingent emitters and absorbers and indirectly just about any equivalent interaction in the universe could be involved. We can of course eliminate this dilemma by insisting that it is only the retarded probability P_{ea} which is involved in the dice throwing, however this returns us to a *stochastic-causal* theory, because we cannot use the future states as part of the boundary condition determining a unique reduction choice. We thus have a theory which looks *stochastic-causal* from a given reference frame, because it lacks the essential component of information emerging from the future in terms of the absorber waves, which however would become supercausal when viewed over the entire space-time interval involved. The ergodic variation of outcomes arises from the variation in this *future* aspect under repetition of the experimental context under consistent *retarded* conditions.

(v) Spliced Space-time.
Because Everett's description is concerned with the state vector, and hence the transactional process of measurement, it falls within the domain of symmetric-time. From the transactional viewpoint, it is thus equally relevant to consider prior states of the universe which lead up to the absorption event. One can thus equally consider advanced-splitting in which past probabilities are resolved in a unique emission event. The transactional apporoach, by resolving probabilites over space-time, effectively splices advanced and retarded Everett branches into a realized combinatorial interaction, by selecting which absorbers and emmitters interact with which. This results in a **spliced space-time** structure as in (d) where past and future events enter into a mutual collapse dynamic, determining each individual transaction by an integrative process throughout space-time, which avoids Everett's multiplicity dilemma, fig 3(c).

Transactional transcausality has an interesting interpretation in molecular systems where each molecule, or molecular state must be regarded as the product of a transaction, in which precursors such as m1 & m2 emit intermediate m which is subsequently absorbed by interaction, for example with u or v as in fig 9(c). The transaction thus lasts the lifetime of the molecule, and the potential absorbers are the molecules with whom the state m will eventually react. The absorbers are thus determined by the probability paths resulting from kinetic encounters during the lifetime of the molecule. The complexity of a molecule makes the description of it in terms of a single quantum entity difficult. Really we should divide the wave function of the molecule between the low energy states which may be changed along the path and the higher energy structures which determine the emission & absorption events.

Thus: $$(m) = \phi(m).\Phi\Psi(m) \qquad (7.4)$$

where $\phi(m)$ is the low energy component and $\Phi(m)$ is the wave function preserved through the lifetime of m. This means that in a polymerizing system, the collapse dynamics of intermediate creation is a function of the more complex potential products, in addition to the products being kinetically derived from the intermdiates.

Such a description lies in a sense outside the domain of quantum mechanics because it is asking a different question, namely: *Which one of the many histories permitted by the predictions of quantum mechanics is going to be the actual one which takes place?* For this reason, it is likely to apply more to processes of an evolutionary nature in which one out of a large number of possible histories are selected by a feedback process, but these will also be very difficult to test in a reproducible form.

8 : THE INTERNAL STRUCTURE OF SYMMETRIC-TIME

Transactional transcausality returns us to a reconsideration of space-like interactions, because although it assembles information about the whole contingent absorber set at the emission vertex and vice versa, the principle of choice is not solved. A global constraint is required to link the choices not only at emitter and absorber, but also the contingent and super-contingent emitters and absorbers to which they are related. We will only briefly explore this uncharted area.

Any attempt to model transactional collapse as a non-linear transient of the superimposed confirmation waves must also conform to the probability interpretation, requiring a Hilbert state-space description to represent the possibilities. This suggests appending a dual space to space time, or its extended dimensional version, which unlike Kaluza-Klein theories may have a dimensionality dependent on the particular transaction type, and which requires a global solution over each contingent set. The von Neumann collapse process as in 4.3 might then become a multistage transient involving a sequence of intermediate stages, based on the combinatorial relations between contingent emitters and absorbers, in which space of eigenvalues is reduced successively through subspaces to a single eigenvalue.

$$\sum_r c_r |\psi_r\rangle \rightarrow \sum_s c_s |\psi_s\rangle \rightarrow \ldots \rightarrow |\psi_s\rangle \qquad (8.1)$$

(1) Internal symmetries and Pseudo-stochastic theories. It is possible to mount an empirical approach to discovering relationships between collapse events. We will merely examine pointers to how dual causalities might be modelled in a manner consistent with the probability interpretation. We have seen that the data from each end of a pair-splitting experiment behaves individually as random data which conforms to the probability interpretation. However, when the data is compared at both ends, the *correlation* between the individual sets of data becomes apparent. The data at each end appears random because it is *encrypted* through the wave function of the pair. We can extend this reasoning to look for internal symmetries in the collapse process which might connect the collapse of many wave functions across a space-time interval through correlations between their individual statistics. Internal symmetries might for example relate indistinguishable particles, all wave functions in a given class, (e.g. all N_7 nitrogens of the adenine molecule), or in a more restrictive scheme, all equivalent interactions in which a given measurement relationship occurs (such as all interactions between a given enzyme and its substrate). Alternatively they may relate contingent sets in a transaction.

Such a theory would describe the dual vector as $\langle \psi(t) | = f (\{ \langle \psi_j(t) | : j \quad J \})$ (8.2)
where J is a class of dual vectors bearing an internal symmetry with the original, ψ . In the case of transactional transcausality the internal symmetry is the space-time splicing of super-contingent transactions. I.e. all the contingent emissions and absorptions which are indirectly connected to ψ as described in fig 13(d).

The obvious constraint that must be placed on such a symmetry is that it should approximate the probability interpretation to first order. A deterministic function is termed *pseudo-random*, if a sequence of values satisfy suitable non-periodicity, chi-squared or other test criteria generally satisfied by a random distribution. A complex dual process may be consistent with quantum-mechanics simply by virtue of its pseudo-randomness, despite having a unique selection property over space-time. We will call such a theory **pseudo-stochastic**.

The Bohm-Bub theory illustrates mathematically that wave-particle reduction can be determined by a dual logic which is independent of the quantum event, and might be varied on the dual space while remaining consistent with quantum mechanics. What is now required is to construct supercausalities which also display the interconnectedness required to solve the transactional boundary-value problem consistently among a large-number of wave-particle reductions. Such a causally open description is similar to the description of biological processes as open thermodynamic systems which do not reach equilibrium because they gain net free energy from external radiation.

One simple example is as follows. If all the spin-1/2 measurements in the universe were described by a single dual wave function in which the phase angles were identical, or were $2\pi s/n : s = 1, \ldots , n \quad n$ = no of wave functions. Then, like the pair-splitting experiment, each individual measurement would return random data, but all would be correlated. However, we do not expect these to be causally related in the manner of the carefully prepared photons of the pair-splitting experiment. Nevertheless they could be related, subject to a transform in a dual space. This is consistent with a transactional picture in which all contingent absorbers are related by being capable of a similar measurement process through the absorption of the same particle type at comparable energies.

We now superimpose on this solution other means of variation in the phase angles, defined in a *transform space* dual to the physical context, in the same manner as the Bohm-Bub dual Hilbert space. As long as the manner of variation between the components of the transform space is complex, a pseudo-random interaction could result. For example if the phase angle between two spin-1/2 measurements was determined by projecting one coordinate of a compactified space in which dual particles corresponding to each measurement are in kinetic interaction. The phase angle would then have a Brownian motion characteristic, despite having deterministic laws of motion. We could distinguish this behavior because over very short time intervals the phase relationships would not vary significantly because the Brownian path length would be small. If the dual particles were tachyons, the dual space would become paradoxical and the path length would converge to the probability description. The aim here is not to produce a serious physical theory, but simply to illustrate that a variety of supercausal mechanisms could reproduce the stochastic behavior of wave-particle reduction.

Similar models could be developed around a continuous or discrete dynamical system in the dual space. The most important step is developing an exclusion principle which will guarantee unique transactions from the contingent emmitter and absorber sets.

In the transactional interpretation, it is natural to look for such a link in terms of photon exchange. One region in which this is at least plausible is the molecular fingerprint region of the infra-red. Fred Hoyle has pointed out the close correspondence between the emission spectra of HCHO (and HCN) clouds[41] in the galaxy and the infra-red spectrum of e.g. carbohydrates such as wood. If molecular radiation in such a region is partially coherent in the sense that a molecule can emit several correlated low energy photons, then their absorption would also be correlated, resulting in a form of signature radiation that could influence the course of molecular polymerizations, and which could also be dynamically linked through relations in the dual space.

Experimental testing of such theories depends on looking for anomalies in the supposed random relationships between measurements which would be causally-independent in the standard interpretation. The essential difference between such theories and the standard interpretation would be that causally-unrelated collapse events may display higher-order correlation through a symmetry or global transform. Many of the most interesting instances might then occur where complex quantum-mechanical systems have unusual collapse events whose wave functions might be fewer in number and related only to similar equally complex systems in other parts of the universe. One interesting example of such systems are the molecular systems associated with biological evolution.

Another application of pseudo-stochasticity is in the brain. One ideal way of performing an experimental test of pseudo-stochasticity is to develop an apparatus with parrallel application of an unstable quantum phenomenon under redundant circumstances where unexpected higher-order correlations between the systems could occur. The parallel circuitry and resonance modulation of neuronal networks in the brain provide an ideal example of such a detector which could be tuned to react unstably to statistical anomalies in the output of its own neurons.

(2) Contracausality & Quantum Psychology. A second supercausal model , **contracausality**, describes the universe as a pair (P, M) where P is the physical universe, and M is a dual 'universe' whose properties, dependence on time etc., remain to be established. The Bohm-Bub theory of section 4 illustrates such a dual theory in the context of the collapse process, but in this case the random (or other) nature of the theory remains to be specified on the dual Hilbert space. In *solipsistic contracausality*, P is a class of stability structures on M. In such a model no explanation of the dynamics of M is possible from theories based on P because causally it is P which is derived from M.

One way of treating such a duality would be to decompose the pair (P,M) into subsystems corresponding to the *meta-system* and the *meta-observer.* Such a dual model is attractive because it provides a fundamental role for consciousness, and free-will as direct manifestations of the 'principle of choice' which makes the difference between a stochastic causality and a universe which is able to make a unique choice for each reduction event.

Contracausality is a refinement of quantum theory in which mind-body duality is fundamental. The 'mental' attribute selects each wave-particle reduction uniquely in a manner consistent with the probability interpretation when averaged over many events. This is an extension of Wheeler's view of wave-packet reduction being dependent on the conscious interaction of the observer.

Quantum psychology describes conscious attributes as a fundamental aspect of the wave-particle. *Quantum-consciousness* is precisely the ability of a quantum system to determine future states of the universe through reduction of the wave-packet. The mechanism cannot be described until all transactions are complete at the culmination of the universe, but is manifested directly through the principle of choice. It corresponds to the selection of some Everett branches over others, based on the retrospective resolution of contingent absorbers. The consciousness of a wave-particle system results in a unique choice in each reduction event.

Quantum-consciousness has two complementary attributes, **sentience** and **intent**:

(a) **Sentience** represents the capacity to utilise the information in the advanced absorber waves and is implicitly transcausal in its basis. Because the advanced components of symmetric-time cannot be causally defined in terms of directed-time, sentience is complementary to physically-defined constraints.

(b) **Intent** represents the capacity to determine a unique outcome from the collection of such absorber waves, and represents the selection of one of many potential histories. Intent addresses the two issues of free-will and the principle of choice in one answer . . free-will necessarily involves the capacity to select one out of many contingent histories and the principle of choice manifests the essential nature of free-will at the physical level.

In a structurally unstable or chaotic macroscopic process, quantum-consciousness may become amplified through stochastically uncertain processes, resulting in a macroscopically-conscious process. A particular example of such a molecular system is the excitable membrane at threshold, where a bimolecular lipid layer is polarized so that any action potential will ramify i.e. unstable equilibrium, making the entire system sensitive to the interaction of a single quantum. The coupling of large collections of neurons into larger unstable systems finally results in the cooperative quantum-consciousness, we associate with the consciousness of the human brain. *Sentience* then addresses the fact that there is an additional subjective aspect to conscious experience which transcends the physical. We *see* in addition to our brains registering a visual cortex response. This inner cinema could be described as a simulation process, but the duality between the brain structures and the subjectively percieved events remains unbridged. *Intent* by contrast manifests the consequences in terms of the *principle of choice* - the free-will of the observer.

Life then becomes a direct expression of the physical nature of the universe as the evolutionary aspect of quantum-consciousness. The so-called prebiotic regime preceding the development of the nucleic acid code is then just one evolutionary phase and the development of the genetic code is a product of life rather than life a phenomenon arising from nucleic acid replication. Evolutionary models then require modification to include this effect. To utilise quantum-consciousness, prebiotic processes must include structurally-unstable phases in their development. The lack of a single consistent model for the prebiotic pathway to date supports such an unstable origin.

Because intent provides a basis for solving the principle of choice, it raises difficult questions of initial and final causes. Causally it explains little until the omega point when the universe is complete. The idea that one future is unilaterally determined leads to the issue of *fatalism* that the future states of the universe are already defined, irrespective of the notion of free-will. This is incorrect because they are never defined in a given reference-frame and become determined only over a space-time interval. This gives rise to the central causal paradox of quantum-consciousness which is that of using future contingent states to produce a non-contingent decision. Because this is using the future to determine itself, it has an essentially unstable character in every reference frame. The ultimate issue of which future states are going to arise becomes a recursive paradox. This paradox is resolved in quantum-psychology because sentience and intent remain causally indeterminate in any reference frame, and are mutually interdependent, and the completion is attained only through their interaction.

9: STOCHASTIC UNCERTAINTY

The complementation between symmetric and directed time underlies a similar relation between quantum and statistical mechanics. However there is an intrinsic difference between the probability interpretation of quantum mechanics and the probabilities associated with statistical mechanical arguments. Their relation is illustrated in an interesting way in the first such problem to be resolved, Planck's law for black-body radiation.

$$I(\omega) = \frac{\hbar\omega^3}{p^2 c^3 \left(e^{\hbar\omega/kT} - 1 \right)} \qquad (9.1)$$

$$e^{-\hbar\omega/kT} \overset{(i)}{=} e^{-\Delta E/kT} \overset{(ii)}{=} \frac{N_{exc}}{N_{grd}} \overset{(iii)}{=} \frac{\bar{n}}{\bar{n}+1} \qquad (9.2) \qquad\qquad \bar{n} = \frac{1}{\left(e^{\hbar\omega/kT} - 1 \right)} \qquad (9.3)$$

Here the critical "cutoff factor" 9.3 is derived in 9.2 through three associated steps: Einstein's law $E = h\upsilon$, the statistical-mechanical exponential for excited populations, and the Bose scattering probabilities. Since the Bose scattering is identical mathematically to the modes of a harmonic oscillator, the end result 9.1, depends critically on the statistical-mechanical formula (ii) for excited populations, despite the fact that it was quantization of the oscillators by (i) that made the formula possible.

This illustrates how quantum and statistical mechanics become interfused in a single description. In dealing with populations, statistical mechanics applies the averaged behavior of many interactions, each of which could in principle be described in a more exact model by defining the kinetic parameters of each member of the population. For example in dealing with an ideal classical gas, a statistical mechanical description could in principle be replaced by a kinetic simulation of the population using conservative mechanics. The thermodynamic arrow of time arising from the H-theorem is a product of this probability description and applies as much to a classical gas with exact reversible kinetics as to a quantum system (fig 14(a)). By contrast, the uncertainty principle is in its foundation unpredictable. Thus the distinction between the statistical-mechanical and quantum-mechanical probabilities is that the latter involves *essential* probability in the sense that the description is in its foundation stochastic.

It is in fact the *essential* probability of quantum theory that indirectly provides the processes of statistical mechanics with a basis in uncertainty . For example it is the quantum mechanics of measurement which prevents the Maxwell's demon from selectively channelling the high and low energy molecules in a diffusion barrier to violate the second law of thermodynamics. However this role for quantum mechanics means that it is Heisenberg uncertainty that always provides the stochastic parameters underlying the supposed statistical behavior of molecular and other ensembles. We will call this aspect **stochastic uncertainty**.

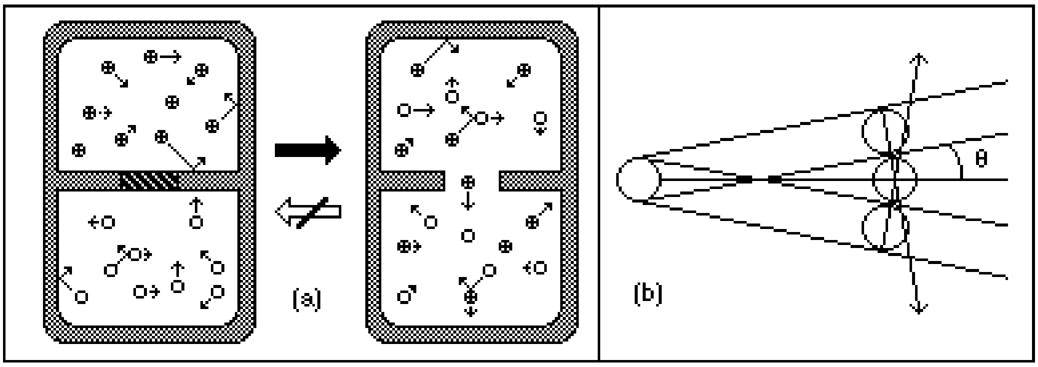


Fig 14 (a) Probabilities in thermodynamic arrow apply equally to quantum and reversible classical systems.
(b) Amplification of the uncertainty of scattering angle through diffraction of the wavefront of the particle.

If we return for a minute to the ideal gas, we can estimate the contribution made by spreading of the wavefront to the statistical mechanics of particle motion. In particular one can define the *indeterminacyradius* of a particle as the distance travelled before the diffraction of the particle is twice the particle diameter, as in fig 14(b), resulting in complete uncertainty of the direction in the elastic collision. In particular, at 300 K the average kinetic energy of molecular hydrogen is 0.04 eV and the speed is 2,200 m/sec. The wavelength is thus .18 nm, greater than the Bohr diameter of .105 nm. Thus the *indeterminacyradius* is the order of magnitude of the atomic diameter . The diffraction of thermal neutrons in the crystalline silicon interferometer exploits this correspondence. Thus the gas could just as well be a liquid or solid.

Since the wavelength varies inversely with the square root of the molecular weight of a molecule at a given temperature, we can make a realistic estimate of the *indeterminacyradius* of an amino acid in aqueous solution as follows. The average molecular weight is approximately 120. The wavelength is thus $.18/\sqrt{120} = .017$ If we take the length of an amino acid as .36 nm and use the formula $\sin(\theta) = +/- \lambda/w$ to estimate the angle θ of fig 14(b) using a .15 nm diameter of a water molecule as w, we find $\sin(\theta) = .017/.15$ or $\theta = 6.5^{o}$. Thus in .36 nm the uncertainty of position would be .0408 approximately the Bohr radius. The uncertainty will thus become complete after a few kinetic encounters.

Correspondingly, we can define the *indeterminacy time* required for Heisenberg uncertainty to randomize a molecular population. For molecular hydrogen the probability-time is $(1.05 \times 10^{-10}) / 1{,}100 \sim 10^{-13}$ sec. The figure for an amino acid is $\sim 10^{-12}$ sec. This means that arguments based on the random positions, energies etc. of molecules actually derive their essential randomness from quantum indeterminacy. Similarly, if $\Delta E.\Delta t \sim {}^{h}/_{2\pi}$ is used with ΔE at weak bond energies of ~1 kcal/mole gives $\Delta t \sim 10^{-14}$ sec. Both estimates reflect times for such processes as exciton transfer, fluorescence, and relaxation times in the range 10^{-14} - 10^{-12} sec.

These probability effects of quantum mechanics do not appear specifically in such formulas as 9.1, because statistical mechanics already presumes a random treatment of individual particles. The quantum indeterminacy is thus accounted for in the uncorrelated profile. However they have important implications for the relationship between hidden variable theories and complex molecular processes such as occur in unstable biochemical systems.

The conventional view of biochemical processes uses mass-action in terms of reaction rates and dynamical equilibria. However there are many examples of processes in molecular biology where either the number of molecular species converges to one (e.g. nucleic acid operations where sequence copies are unique or repeated relatively few times) or where the amplification of an unstable process permits a single molecular encounter or other quantum fluctuation, in principle, to trigger an instability (e.g. a neurotransmitter activating a neuron which is at the threshold of excitation). On a longer time scale, evolutionary processes arise out of the statistical-mechanical *milieu* as feedback systems based on random events (e.g. mutation and natural selection). Any hidden-variable theory which replaces the probability interpretation (1.10) could thus have far reaching implications in biological systems, evolution, cosmological processes, and the origin of life.

10 : APPLICATIONS TO EVOLUTIONARY PHENOMENA

All evolutionary phenomena share a common causal dilemma in which the complexity of the system at later times exceeds that at earlier times. Thus in a fundamental sense, the initial conditions fail to contain enough information to causally prescribe the subsequent states. Realistic theories of evolutionary phenomena are essentially dual theories in which an algorithm is applied to a process involving random events. Darwinian evolution is a typical example in which random genetic mutation generates a pool of deviant arrangements, most of which are deleterious. The few advantageous mutations are subsequently preserved by the replicative process, because organisms carrying the characteristic have a heightened probability of survival. The evolution of the gene pool is then presumed to be guaranteed by occasional errors of fidelity within the reproductive process of its individuals. This picture is little altered if the fixation of neutral mutations is also taken into account - i.e. the 'neutralist' position.

The duality between the probability interpretation of random events and the causal process is thus shared by quantum mechanics and Darwinian evolution. In effect, each of these stochastic theories is projecting the total dual-time process on to the directed-time aspect. Since we have seen from section 9 that the underlying substrate for random molecular events is Heisenberg uncertainty, a connection between hidden variable theories and evolutionary processes, although indirect, could complement the existing picture of evolution as a stochastic-causal process. As with the quantum theory, this would not involve refuting evolutionary theory, but would extend its description to account for the replacement of random processes by globally-coherent pseudo-random ones. The experimental test of such differences would be exceedingly difficult, because as soon as reproduceable circumstances are invoked, we are again dealing with averaged results and the predictions will converge to those of quantum mechanics.

We will say that a system *converges to stochastic equilibrium* if its evolution depends on wave-particle reductions which are repeated sufficiently for the probability interpretation to well-approximate the behavior of the system. A physical system in statistical-mechanical (e.g. thermodynamic or chemical) equilibrium is in stochastic equilibrium. However evolutionary systems may fail to converge to stochastic equilibrium because each step in an evolutionary chain changes the context of subsequent events so that potential repetitions do not have the same context. In such an evolutionary system, convergence will depend on the exchange of information between chains, as is the case with sexual recombination. Even with sexual recombination acting as a partial mixing factor, a single advantageous mutation in an allele can result in assimilation by an entire population, guaranteeing the stochasitc instability of the gene pool. We will call such systems *stochastically-singular.*

The work of Prigogine[42] has established that open thermodynamic systems may not tend to equilibrium, but may adopt non-equilibrium steady states characterized by a minimum rate of entropy production, or give rise to spontaneous production of dissipative structures through non-linear feedback effects. Both the origin of life and biological evolution are open thermodynamic systems, which are in a non-equilibrium state of minimum entropy production in the sense of Prigogine. Such a system may remain stochastically-singular because quantum fluctuations contribute to the dissipative structures produced. The Zhabotinskii autocatalytic reactions provide a graphic example of such potentialities. Despite the obvious stability introduced by large gene pools, the description of the entire evolutionary process may be most correctly described as an unstable chaotic system in which structures such as speciation represent only temporary islands of stability.

(a) The origin of the universe. Since the universe at its singularity or initial fluctuation is dominated by the quantum nature of its own parameters, the universe may be most correctly described through the evolution of a hidden-variable theory into the dual-time description through symmetry-breaking. The form of the universe may thus be equally a product of the hidden-variable dynamics. Since the symmetric-time model does not allow complete transactional resolution of the state until the completion of the universe, the origin evolution and culmination of the universe may be described in the same transaction set.

(b) The origin of life.

The prebiotic environment is a unique 'negentropic' interface, in which the free energy of stellar radiation generates a flux of moderate energy incident photons which, along with their secondary effects of electrical discharge, weathering cycles of alternate dehydration etc. provide a multi-dimensional free energy input into the molecular *mileau.* This is in a very real sense the culmination of the interactive effects of cosmological symmetry-breaking of the fundamental forces. The subsequent energetic interaction of these forces through both baryogenesis and supernova nucleogenesis is a necessary quantum substrate for the higher-order complexity of atomic and molecular structures as well as providing an energetically matched free energy input. Furthermore, molecular interactions themselves form the ultimate structural hierarchy of fermionic wave forms. The non-linearity of charge interaction in electronic orbitals provides for residual higher-order effects including weak-bonding associations which culminate in tertiray structures of proteins and RNA's and inter-molecular structures such as membranes.

To date the origin of life has resisted a definitive theoretical treatment. It is a particularly interesting problem from a quantum-mechanical point of view because it provides some of the richest examples of growth in quantum-mechanical complexity in which a relatively small number of simpler quantum structures give rise to increasingly complex structures whose properties cannot be fully predicted from the simpler initial conditions. For example, the multiple-bonded $H_2C{=}O$, and $HC{\equiv}N$ in aqueous solution gives rise to 4 to 7 carbon sugars including ribose, and heterocyclic purines and pyrimidines respectively, through opening of the double bonds to form polymers[43,44,45]. However, in addition to the heterocyclic nucleic acid bases, they are capable of producing several of the amino acids, polypeptides, porphyrins, and many other types of biomolecule (fig 15). Although several of these are stable product structures (such as the ring polymers ribose, $(H_2CO)^5$ and adenine, $(HCN)^5$), many of the less common products may be metastable or unstable products of the reaction. These conditions differ markedly from the current biochemical *regime* in which structurally-stable metabolic pathways are maintained through enzyme catalysis.

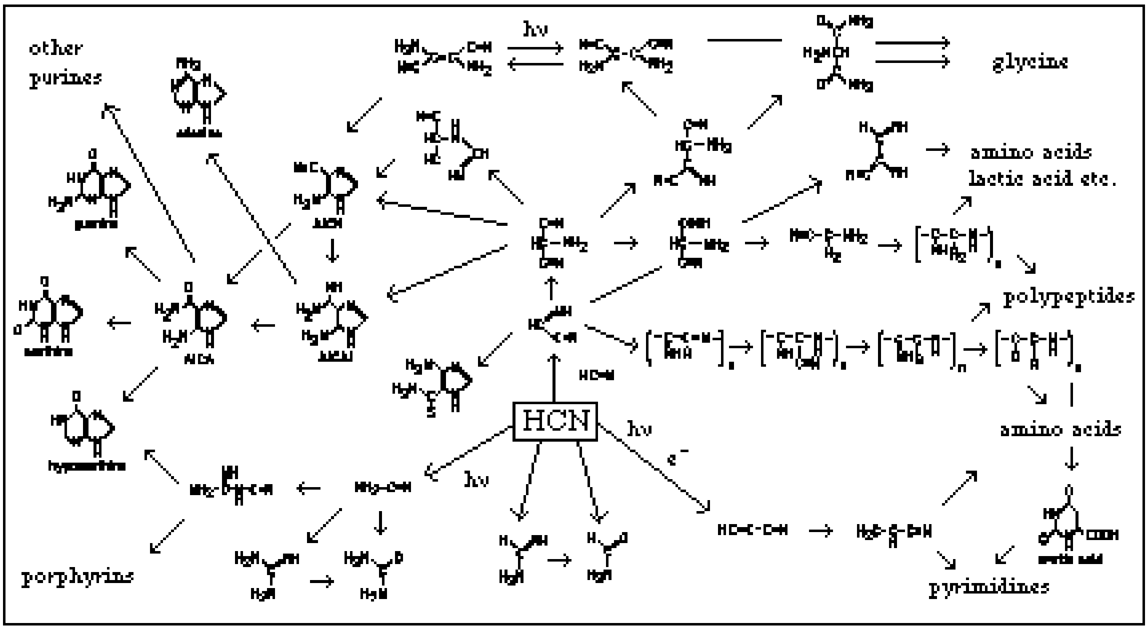


Fig 15: Immediate products of the polymerization of HCN.

At least four significant factors complicate the potential behavior of the polymerization:
(1) The lower energy configuration of key stable products such as adenine leads to their formation based on free energy considerations.
(2) Specific molecular associations involving products of increasing complexity such as polypeptides lead directly to the possibility that certain products may precipitate autocatalytic pathways which alter the structural-stability of the polymerization to favor new types of product. Polypeptides provide a rich variety of possibilities for autocatalysis through non-random association factors during polymerization.
(3) Stochastic behavior, in the form of accidental kinetic association between initial molecular species which subsequently promotes chain reaction, permits individual quantum fluctuations to form an organizing centre for subsequent structural evolution. This effect closely resembles biological evolution of nucleic acids.
(4) The reaction may also be analysed as a structurally-unstable dynamical system in terms of chaotic dynamics. The difficulty of developing laboratory simulations of primitive nucleic acid replication[46,47] has left the development of a clear structural model of the origin of life unresolved, since no other molecular species, such as the more stable & varied polypeptides, have been proved capable of informational replication. This suggests that some aspects of the origin may be structurally unstable and hence unavailable to a deterministic description. Research into quantum analogues of classical chaotic dynamical systems [48,49,50] has so far given structurally stable solutions for $h \neq 0$, raising the issue of which systems form models of the chaotic limit as $h \to 0$. The above polymerizing systems give a rich source of non-trivial models because they deal with the interface between the quantum and macroscopic domains under boundary conditions which force unstable solutions, involving unbounded variations in quantum form.

The above factors combine to leave open the involvement of supercausalities in the probability evolution of the origin of life. The diagram of fig 13(c) shows that in a transactional-transcausal description, retrospective resolution of the absorber confirming waves would cause reaction intermediate collapse dynamics to be a function of the ultimate products, upsetting a temporal-deterministic description of the process. Laboratory tests of the involvement of chaotic bifurcations in such polymerizations would be a first step in the investigation and analysis of their principles.

A direct role for symmetry-breaking in the form of biological evolution is supported by several optimal properties of molecules such as proteins and water. The scheme of fig 16(a) views the selection of the bioelements in terms of the interference interaction of several key quantum interaction types:
(1) The interaction of H with the core covalent elements C, N, O is the principal symmetry-splitting.
(2) Secondary splitting between the properties of O, N, & C results in bifurcation of the medium into polar and hydrophobic phases. The optimal nature of water as a hydride is illustrated in boiling points (b). Water provides several secondary bifurcations such as acid-base, anion-cation, and hydrogen-bonding structures. Many properties of proteins and nucleic acids are derived from water bonding structures.
(3) Secondary involvement of P, S as covalent modifiers.
(4) Ionic bifurcation is generated in three stages, anion-cation, monovalent-divalent, and series (Ca, K - Mg, Na).
(5) Diverse involvement of transition element series add d-orbital effects, forming a catalytic group.
(6) Breaking of dl-symmetry to form chiral systems.

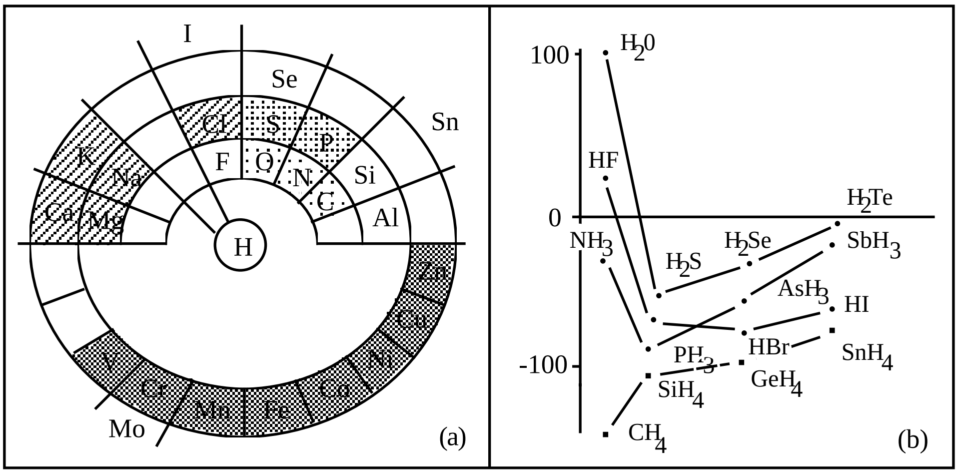


Fig 16: (a) Symmetry-breaking model of selection of bioelements. (b) Boiling points of hydrides.

<u>(c) Biological Evolution</u>.
Reference has already been made to Darwinian evolution as a dual theory in which probabilities and deterministic algorithms have a complementary role. Because the probabilities are a product of quantum fluctuations associated with random kinetic phenomena, the extension of quantum mechanics to a supercausal framework permits evolution to be influenced by sub-quantum effects, as a system which does not fully converge to stochastic equilibrium.

Mutational variation does not conform to a simple random model, because of site-dependent variations in mutability of a genome. In bacterial and viral genomes the point mutational frequency is not random, but is concentrated in hot spots related to local nucleic acid sequencing. Speciation may also be an unstable discontinuous phenomenon in evolutionary time and not be well modelled by microevolutionary change.

Some of the most significant steps in evolution are changes in the regulation of existing genes, associated for example with the embryonic development of the eye and brain. There is increasing evidence that such evolution may be a partly inbuilt process through the interaction of cellular and nomadic gene elements associated with viruses and other transposable sequences, which can be transmitted down the germ-line as part of the chromosomal genome. Such processing involves the transcription of a repeated element and insertion into new chromosomal sites, as well as excision and transposition events. For example, insertion and excision of transposable elements involve inverted or direct repeat sequences which permit the local folding out of hairpin loops and the exchange of a nomadic element by crossing over at the repeated section[43] The splicing out of non-coding introns in eucaryote RNA can take place without enzymes, emphasising that structured quantum exchanges are a property of nucleic acids themselves. Nucleic acid is believed to open kinetically in quantum soliton waves. Coherent, low intensity photon emission has also been reported[51]. Nucleic acid processing, including structured mutational effects thus involves interesting quantum-mechanical properties and cellular processes which are not simply of a random entropic nature alone. It thus remains an open question whether such processes converge to stochastic equilibrium.

Mechanisms in which specific classes of quantum structure, such as transposons, are involved in programmed quantum-transformation of the genome, lead to deep questions concerning the causality of such processes. For example, the long reproduction period of primates such as man can be offset against the maximum number of deleterious mutations per generation if somatic transposons can be mapped in a structured way back into the germ-line, as is possible with endogenous retroviruses[52]. This provides for a transactional transcausal description similar to that of polymerizing systems.

<u>(d) Biosystems</u>.
Biological systems contain many examples of quantum-mechanical phenomena which could form a structural basis for supercausal interaction. The central medium of chemical exchange is the electron. Although the state vector of a quantum-mechanical system comprises a linear combination of eigenfunctions, the electrostatic charge of the electron causes orbital interaction to have non-linear energetics. This results in global interactive effects based on the rich variety of weak bonds (H-bonds, ionic, hydrophobic, and van der Waals interactions) in biosystems which permit cooperative effects from the catalytic capacity of enzyme tertiary structure to such super-molecular structures as the electron transport chain, membrane ion transport, and the structured photon traps of the eye and photosynthetic membrane.

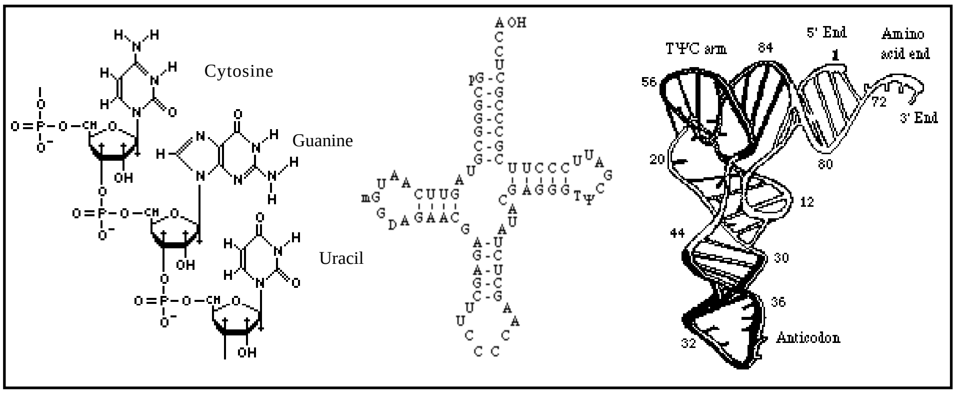


Fig 17: Primary (covalent), secondary (weak-bonded) and tertiary (residual global) structures of tRNA illustrate non-linear effects of charge in quantum states, which permit complex hierarchial organization in biochemical systems. Such structures are also dependent for their stability on the extreme charge asymmetry of the nucleus and orbital electrons.

Proteins are noted as having a low specific heat as a result of their relatively few modes of excitation in addition to the interactions which permit catalytic action[53]. Biomolecules permit many types of electronic activity involving interesting quantum effects. For example in the chain of narrowly spaced energies of the electron transport chain, there are singlet-triplet state conversions[54] as the electron passes from Fe-S proteins through cytochromes and flavoproteins. Many types of biomolecules possess delocalized electrons[55]. For example heterocyclic (N-C) rings in resonance configurations enable $n \rightarrow \pi$ and also $\pi \rightarrow \pi$ transitions. Bioluminescent systems develop excited states which transmit photons[56,57]. Nucleic acids are good absorbers in both the ultra-violet and infra-red. It has been suggested that nucleic acids act as photon traps and that coherent activity of the excited states plays an organizing role in nucleic acid dynamics[58,59].

Ion transport is also the source of significant electronic effects, because the membrane under polarization is piezo-electric and is capable of spontaneous excitation to action potentials. Studies of microcells produced by prebiotic techniques have displayed action potentials on irradiation with light, demonstrating that such effects are fundamental to the quantum architecture of lipid membranes.

(e) The brain.

A cell which is homeostatically tuned to the threshold for neuro-excitation, could become a powerful amplifier for quantum fluctuations in the membrane, whether caused by a single kinetic encounter with a neurotransmitter or other sources. Neurons in interaction form a system which may be even more sensitive than a single cell, through unstable feedback or resonance. The activity of motor nets for example is often coordinated through 'silent' cells which do not have action potentials themselves but modify the action of those that do. The parallel nature of much central nervous circuitry facilitates dynamical phase relationships, resulting in the alpha, beta, and theta rhythms of the electroencephalogram. The orienting reaction in mammals for example is accompanied by a loss of electroencephalographic phase coherence in the hippocampus.

One of the most intriguing aspects of brain function is that it is accompanied by subjective consciousness and the sensation of free-will. Thus in addition to the brain functioning, we are aware that we are present as observers. Sensory deprivation, meditation, hallucinogenic and hypnogogic trance states have the common effect of placing this conscious process in an unstable state in which the brain is operating without external input. Paradoxical sleep is an even more extreme case in which brain activity is similar to waking but the subject instead has the vivid experiences of dreaming. Several commentators have noted apparent violations of causal determinism in dreaming involving pre-perception of subsequent waking experiences[60].

It is interesting to examine possible reasons why the brain has evolved to be conscious. One explanation is that the evolution of behavior has repeatedly faced intrinsically-difficult computational problems resulting from instabilities in an organisms niche associated particularly with self-competition. Such problems involve exponentiating computation for a small increase in efficiency. The brain may then have evolved to complement computational function with a global means to make choices based on unstable resonances, bifurcations etc. involving quantum uncertainty. The advantage of such a 'conscious' brain could be a capacity to anticipate environmental changes through supercausal effects. These could arise through the amplification of quantum instabilities into global processes.

The notion of free-will then becomes a direct expression of the principle of choice, and is consistent with physical processes in the brain because they include quantum uncertainty in their evolution. If the brain is capable of supercausal interaction, paradoxical time reversal may not confine experiences to the past and present, enabling the notion of 'anticipation' to have more than a figurative significance. Dreaming and meditative states may also have deeper implications in a dual universe. In what I would loosely describe the 'sorcerer's explanation' the dreaming aspect of reality *subtends* the physical so that the waking experience of the physical world is just one manifestation of a wider *dreaming totality*, rather than vice versa. One interesting aspect of dreaming may be that time is symmetric between future and past experiences giving rise to powerful instances of causality-violating phenomena.

This model of quantum brain function permits a lighthearted experiment, which in a sense reverses the cat paradox scheme, and has a long history in human culture. Fig 12 shows a meditating observer creating an unstable toss of a coin. According to the model, the triggering of the decision when and how to toss arises from a quantum fluctuation which becomes amplified by a structurally unstable global brain state. The resulting physical toss is also structurally unstable, with one of two outcomes. The experiment reverses the Cat paradox scheme, because it is now the conscious observer which forms the detection apparatus.

The Chinese oracle, *I Ching* uses the principles of probability to determine a state of transformation predicting the form of an occurrence being contemplated by the observer. This occurrence may be in the present or future. By defining a system of 64x 64 transformations of a system of 64 states, a conscious association is generated for the observer between each outcome and its hexagram. Three coins are tossed six times over. Each toss can have one of four states as shown in F. Including both forward (- - -> ---) and reverse transformations, we have 4^6 states. The definition of the hexagrams may be arbitrary, but introduce a conscious association in the throwing process. According to the *I Ching*, consciousness, living systems and probability share the same cosmic principles of duality, which are accessed by the oracle.

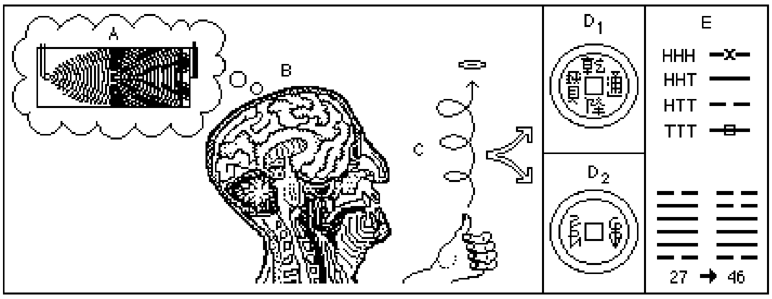


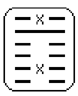
Fig 16: Reversed Cat paradox experiment. A quantum wave-particle reduction, A triggers a structurally unstable brain state B. This in turn triggers a structurally unstable physical process C, giving rise to two possible outcomes, D_1 and D_2. The system may be refined by using sequential reductions to generate an interpretation E.

11: POSTSCRIPT : THE DUAL-UNIVERSE.

This brings us to the final point of discussing dual models of the universe based on the physical and the experiential. Our world view is based on two dual perspectives, the objective physical world and the continuum of experience. When we describe our physical existence as biological or molecular systems, consciousness fails to exist as a valid phenomenon because it has no physical parameters. Yet we are entirely dependent on the subjective experience of our existence both in dreams and waking life from our earliest memories to the present and future. This 'world' of experience is in a sense more fundamental , because without it, it is not clear there would be a palpable physical universe to be experienced. By comparison, the physical world view has a mythical and illusory quality, because many of its central constructs are remote from subjective experience. The physical world then begins to look more like an aspect of consciousness.

This description coincides neatly with the complementary roles of symmetric and directed time. Consciousness, as a manifestation of symmetric-time appears dual to our experiences of the physical world which, in turn, manifest the time-directed aspects of symmetry-breaking and retarded particle interaction. Memory is similarly time-directed, as a result of retarded interaction. In this respect, consciousness may provide a potent link with the inner workings of symmetric-time and the foundation and totality of the quantum universe.

Although such ideas are relatively alien to molecular biologists, they have a strong history in modern physics with the role of consciousness in the observable universe running through the work of Margenau, Wigner, Wheeler, Costa de Beauregard and others[61,62,63,64]. In addition to their conceptual interest, supercausalities may add new perspective on the role of consciousness and the principle of choice in the evolution of the physical universe.



Holding Together (particle) → Dispersion (wave)

REFERENCES

1. Messiah A. *Quantum Mechanics* North-Holland, (Amsterdam1965).
2. Davies, P.C.W. *The Physics of Time Asymmetry,* (Surrey Univ. Press, 1974).
3. Barrow J.D., Tipler F.J. *The Anthropic Cosmological Principle* (Clarendon Press, Oxford, 1986).
4. Carr B., Rees M. Nature **278**, 605, (1979).
5. Feynman R.P. *Quantum Electrodynamics* (W.A. Benjamin, N.Y. 1961).
6. Feynman R.P. Phys. Rev. **80/3**, 440, (1950).
7. Pegg D.T. Phys. Lett. **108B/6**, 386, (1982).
8. Cramer J.G. Rev. Mod. Phys. **58**, 647, (1986).
9. Cramer J.G. Found. Phys. **13**, 887, (1983).
10. Quigg C. *Introd. to Theories of the Strong, Weak & Electromagnetic Interactions,* Fermi Nat. Acc. Lab.
11. Weinberg S. Phys. Rev. Lett. **48/9**, 1303, (1982).
12. Green M.B. Nature **314**, 409, (1985).
13. Goldman T., Hughes R.J., Nieto M.M. Sci. Am. **258/3** (Mar 1988).
14. Guth A., Steinhardt P. The Inflationary Universe, Sci Am, May 1984 , 90.
15. Guth A. , Phys. Rev. **D23**, 347, (1981).
16. Hawking S.W. Phys. Rev. **D32**, 2489, (1985).
17. Page D.N. Phys. Rev. **D32**, 2496, (1985).
18. Garden R.W., *Modern Logic & Quantum Mechanics* (Adam Hilger, Bristol, 1984).
19. d'Espagnat B. (ed.), Proc. Int. Sch. Phys. "Enrico Fermi" **IL**, 171, 211, 271, 346, 412, (1971).
20. de Broglie L., *Non-Linear Wave Mechanics*, (Elsevier, Amsterdam, 1960).
21. Bohm D., Dewdeny C., Hiley B. Nature **315**, 294, (1985).
22. Bohm D., Hiley B. Found. Phys. **11/7,8**, 529, (1981); **12/10**, 1001, (1982); **14/3**, 255, (1984).
23. Bohm D., Hiley B., Kaloyerou P.N. Phys. Letts. **144/6**, 323,349, (1987).
24. Harari H., Sci. Am. **248/4**, 48, (1983).
25. Bohm D., Bub J. Rev. Mod. Phys. **38/3**, 453, (1966).
26. Longtin L., Mattuck R.D. Found. Phys. **14/8**, 685, (1984).
27. Bell J.S. Rev. Mod. Phys. **38/3**, 447, (1966).
28. Clauser J.F., Shimony A., Rep. Prog. Phys. **41**, 1881, (1978).
29. Bell J.S. Found. Phys. **12/10**, 989, (1982).
30. Drummond P.D. Phys. Rev. Lett. **50/19**, 1407, (1983).
31. Aspect A., Dalibard J., Roger G. Phys. Rev. Lett. **49**, 1804, (1982).
32. Aspect A., Grangier P., Roger G. Phys. Rev. Lett. **47**, 460, (1981).
33. Aspect A., Grangier P., Roger G. Phys. Rev. Lett. **49**, 91, (1982).
34. Mackintosh A.R., JensenJ. Eur. J. Phys. **4**, 235, (1983).
35. Herbert N. Found. Phys. **12**, 1171, (1982).
36. Feinberg G. Phys. Rev. **159/5**, 1089, (1967).
37. Girard R., Marchildon L. Found. Phys. **14/6**, 535, (1984).
38. Maccarone G., Recami E. Found. Phys. **14/5**, 367, (1984).
39. Pirani F.A.E. Phys. Rev. D **1/12**, 3224, (1970).
40. Bohm D *Wholeness & the Implicate Order* (Routledge Kegan Paul, London, 1980).
41. Buhl D. Orig. Life **5**, 29, (1974).
42. Glansdorff P., Prigogine I., *Thermodynamic Theory of Structure Stability & Fluctuations*(London, Wiley 1971).
43. King C., Origins of Life, **12**, 405, (1982).
44. Lowe C., Rees M., Markham R. Nature **199**, 219, (1963).
45. Mizutani H., Mikuni H., Takahasi M., Noda H. Origins of Life **6**, 513, (1975).
46. Inoue T., Orgel L. Science **219**, 859, (1983).
47. Ninio J., Orgel L. J. Mol. Evol. **12**, 91, (1979).
48. Casati G. Chirikov B., Guarneri G., Shepelyanski D. Phys. Rev. Lett., **56/23**, 2437, (1986).
49. Giesel T., Radons G., Rubner J. Phys. Rev. Letts. **57/23**, 2883, (1986).
50. Schuster P. *Deterministic Chaos* , (Springer-Verlag 1986).
52. King C.,Jour. Theor. Biol. **114**, 447, (1985).
53. Cochran A., Found. Phys. **1**, 235, (1971).
54. McGlynn S., Smith F., Cilento G. Photochem. Photobiol. **3**, 269, (1964).
55. Pullman B., & Pullman A. Nature **198**, 1224, (1963).
56. Hastings J. , J. Mol. Evol. **19**, 309, (1983).
57. McCapra F. Endeavour **39**, 139, (1973).
58. Nagl W., Popp F. Cytobios **37**, 45, (1983).
59. Popp F., Nagl W. Cytobios **37**, 71, (1983).
60. Dunne J.W. *An Experiment with time*, (Faber, 1962).
61. Costa de Beauregard O. Found. Phys. **15**, 871, (1985).
62. d'Espagnat B., *Conceptual Foundations of Quantum Mechanics,* (W.A. Benjamin, Reading, Mass., 1976).
63. Stap H.B. Found. Phys. **15/1**, 35, (1985).
64. Wigner E.P. Found. Phys. **1**, 35, (1970).

Minkowski metric $x^2 + y^2 + z^2 + (it)^2 = 1$ time=imaginary space

The probability interpretation $P = \varphi * \overline{\varphi}$ is simply an expression that the probability is induced by the offer-confirmation wave interaction.

Note that collapse of the wave function is not determined by a simple non-linear optimization of the combined confirmation strengths or we would have the strongest dominating and would not get a wave model at all, only the highest peak - i.e. a purely particle theory - strongest wins.

This means that the dynamics is one where all can bid and the strongest just has a higher probability. This could possibly occur if they all perturb the emmitter dynamic to produce an ergodic transition.

We need a model which is both ergodic and takes place locally over the time scale of emission - e.g. the half-life of the excited state.

Notice that the excited state, e.g. an atom is making continual virtual transitions. In these transitions, the emitted photon must be reabsorbed locally by uncertainty, but just as in the case of a real particle, the wave of the virtual exchange can extend into space, but must be followed by an energy reversal within the uncertainty window. Such "zero integral" waves have the same status as any real wave has e.g. after collapse of the wave function. Although these merely become part of the uncertainty fluctuation background, they continue to inform other regions of space-time with exactly the φ of a real particle's wave.

Hypothesis: This sea of waves from virtual transitions of the real, [but contingent] absorbers inform the emitter that they can be reabsorbed and thus influence the emission process. By stimulating virtual transitions in the emitter each absorber contributes to a chaotic transition background which results in $P = \varphi * \overline{\varphi}$.

How do these not get smothered by the rest of the virtual transitions in the uncertainty window?

Hypothesis: For a given class of interaction, those probability universes having potential to interact gain a probability of becoming by the interaction.

Consciousness and free will thus have the role of promoting those choices which lead to future states in which there is greater capacity to exchange. In particular, in the case of a weak brain quantum, those futures in which the quantum can be reabsorbed by the emitting brain constitute futures in which the brain survives. Premonitions thus lead to greater probability of surving a chance disaster.