Energy transformation and flow: A theory of evolution

Abstract

Spontaneous emission by an atomic oscillator is defined in terms of energy transformation and flow. The description is expanded to include dissipative systems by introducing energy equipartition as a property of the flow. The Feigenbaum constant is derived quantum mechanically. A law of flow equivalent to the laws of thermodynamics is formulated for bounded systems and is then applied to living organisms. The common genetic structure of cells is seen as fulfilling the structural requirement of equipartition while the tendency of the organism towards an equilibrium state, or homeostasis, describes the equipartitioned flow. Since energy flow increases by superposition evolution may be interpreted as an extended series of spontaneous energy transformations from external to internal modes. Finally evolutionary theory is used heuristically to define a universal law of energy flow and to introduce time as a quantum mechanical variable. Two experimental tests are proposed.

Résumé

Les phénomènes d'émission spontanée issus d'un oscillateur atomique sont définis en termes de transformation et de flux d'énergie. En posant l'équipartition de l'énergie comme une des propriétés du flux, cette approche est généralisable à l'étude des systèmes dissipatifs. Une théorie des flux dans les systèmes clos faisant écho aux grands principes de la thermodynamique est proposée, qui permet d'étudier les organismes vivants. Dans ce modèle, on considère que la structure génétique commune à toutes les cellules satisfait aux conditions structurelles de l'équipartition et la tendance des organismes à évoluer vers un état d'équilibre, ou homéostasie, est assimilée à un flux équiréparti. Dans la mesure où un flux croît par phénomène de superposition, le principe d'évolution peut être considéré comme une série ininterrompue de transformations spontanées d'énergie, passant du mode externe au mode interne. Enfin, la théorie de l'évolution est utilisée à des fins heuristiques pour définir une loi naturelle des flux d'énergie et poser le temps comme une variable de mécanique quantique. Plusieurs tests expérimentaux sont proposés.

Key words: Thermodynamics, spontaneous emission, evolution, homeostasis, genetics, Cambrian explosion

1.0 Introduction

1.1 Energy flow

We use the term "energy" to describe phenomena as diverse as a hurricane and the creativity of an artist, but because we cannot analyze energy into its parts it is impossible to say precisely what it is. Although energy may seem to be well understood when used in the physical sciences within the context of well-known nuclear, chemical, or electromagnetic interactions; if we attempt to define energy independently, as in the case of an electron's field, we cannot say where the energy actually resides. Also the electron has a self-energy that yields an extremely accurate value for the magnetic moment when calculated using Feynman's path integral method[1]. However, because the self-energy leads to infinities that have yet to be satisfactorily resolved the precision of the calculations does not translate into a good understanding of energy itself.

A quantum mechanical description of energy is with respect to point electrons undergoing specific transitions. Energy is expressed as a characteristic of the transition and cannot be compared with other transitions because it is unique. However, if energy is treated as a dynamic variable by combining it with time to create a flow, the flows will be seen to have much in common with each other whereas the material structures that support flows can for practical purposes be ignored. Transformations of energy flow will also be compared since they evolve in similar ways whether energy refers to radiation or an ability to do work. Once the program is complete it will be seen that the physical variables composing energy flow, energy and time, define coordinates complementary to those of position and momentum and are so closely intertwined that neither one can be properly understood without the other. Perhaps therein also lies the key to understanding self-energy[2]. We begin by considering the simplest and most fundamental of all energy transformations.

2.0 Spontaneous emission

A recent paper described spontaneous emission as the interaction of a radiation field, consisting of n wave trains, with the bound electron of a single atomic oscillator[3]. It differs from both the quantum and semiclassical theories because it conceives of spontaneous emission as a continuous classical excitation followed by a discrete quantum mechanical decay. During excitation independently oscillating wave train fields superimpose randomly as they resonate with a bound electron. If a sufficient field intensity is realized the electron will be raised to a higher energy state along a continuous trajectory. A photon is then released and the electron returns to the ground state. Thus *spontaneous emission is described as a transformation of field from continuous to discrete forms, or equivalently as a localization of field energy*. Because forces are conservative the flow of field energy to the electron during excitation is continuous, occurs reversibly, and is exact. In contrast quantization happens abruptly, is irreversible, and is subject to the uncertainty principle. Since the excitation energy and photon energy are equal, energy transformation occurs without loss.

Coordinates of position and momentum (q,p) describe emission as a statistical event; however, energy-time coordinates (E,t) may be used to describe it as a field process in terms of a flow of energy from n wave trains to the point electron of an oscillator. In the process work is performed on the electron by increasing its potential energy relative to the nucleus.

As the electron subsequently decays its potential energy decreases and a photon is released. The transformation of energy is described by field variables of exact value so it is subject to the conservation laws. The photon is emitted in the direction required for momentum to be conserved while the quantization process is governed by the uncertainty principle.

$$\Delta E \cdot \Delta t \geq \hbar \qquad 1)$$

In the statistical view the uncertainty relation interprets ΔE as a spread in frequency that determines the spectral line width. However, because fields give an exact description of emission we may interpret ΔE as the energy of the photon and Δt as its period.

3.0 Thermodynamics of complex systems

3.1 Classical energy flow

In classical thermodynamics energy flow is described by kinetic theory in terms of particles with reversible trajectories and deterministic equations of motion. The mass of gas molecules plays a significant role in these models and due to the second law an increasing entropy suggests the eventual "heat death of the universe". On the other hand, in the field interpretation of increasing energy described previously the mass of the electron provides an insignificant contribution to energy flow since energy is conducted primarily by bonds. The flow of energy establishes a direction in time for both models, but the two are distinct because the atomic oscillator reverses the trend to disorder by transforming energy from a diffuse to a localized form. We shall account for the differences between these two models by using the canonical coordinates energy and time (E,t) rather than position and momentum (q,p).

In kinetic theory the energy flow of a gas is transmitted by the elastic collision of spherically symmetric point particles so that only translational degrees of freedom are allowable. Flow is governed by the first and second laws of thermodynamics together with the principle of equipartition. These laws were derived using large temperature differences and high flows so that ideal gases and elastic collisions serve as good approximations. In contrast heat is applied to complex systems by much smaller temperature differences and conducted by molecules of asymmetric structure with rotational and vibrational degrees of freedom. Inelastic collisions dampen molecular motions thereby leading to irreversible particle trajectories and uniform particle speeds. Although kinetic theory can include these forms of energy as a summation of parts, structural divisions are erased by equipartition which demands the unrestricted flow of energy. In order to avoid inaccuracies inherent to a particle interpretation (q_i,p_i) we shall use coordinates of energy and time (E,t) to describe the flow. *As energy flows through a system it distributes itself uniformly over all available energy states beginning with the lowest.* The "law of equipartitioned flow" cannot be expressed mathematically in any useful way because energy is both diffuse and indeterminate. Nevertheless it is superior to kinetic theory for describing energy flow in complex systems because it includes the second law of thermodynamics, equipartition, and ergodicity in a single statement. And because equipartition does not distinguish between discrete and continuous states it combines classical thermodynamics and quantum mechanics into one model.

3.2 Quantum mechanical transformations

During far-from-equilibrium processes energy dissipates to the environment thereby increasing the entropy of a complex system. However, these processes also generate "dissipative structures" such as turbulence, implying negative entropy. Such paradoxical behavior may be explained if we compare it with the description of spontaneous emission from 2.0 in which reversible increases of energy are due to field superposition, while irreversible energy discharge is due to structural change brought about by quantization. Thus a gradual increase of entropy followed by the sudden appearance of dissipative structures may be due to the time evolution of an emission process. The transformation causes new structures to be created to support increasing flow. It is governed by an uncertainty relation similar to 1).

$$\dot{E} \cdot \tau = \mathfrak{H} \qquad 2)$$

In the above transformation equation $\dot{E}$ is the equipartitioned flow, τ is the periodicity of the flow, and $\mathfrak{H}$ is a universal constant relating flow and periodicity similar to the way Planck's constant relates energy and oscillatory period in 1).

Let us apply 2) and the equipartitioned flow law to a quantity of liquid helium confined in a box. In the language of quantum mechanics helium atoms are bosons so the wave function is symmetric with respect to the exchange of identical particles. While the canonical coordinates (q_i,p_i) of kinetic theory are clearly inadequate to interpret the behavior of the system, energy-time coordinates (E,t) may be used. This is because heat energy disperses over molecular bonds for exactly the same reason that it disperses over the translational energies of gas molecules. Energy occupies the lowest permissible states, and the most stable, first; the way a liquid fills a container. If a temperature difference of a mere .001°C is now applied to the upper and lower sides of the box cylindrical rolls of fluid are created by thermal currents[4]. The rolls conduct a continuous flow of energy from high temperature to low. As the heat is increased a wobble appears and soon the period doubles, or "bifurcates" as a second oscillation is added. The flows superpose continuously so they do not interfere with each other; however, the appearance of the new output frequency occurs discontinuously. The pattern of bifurcations for increasing energy flow (i.e. temperature difference) is precisely determined by the Feigenbaum constant[5].

Whereas quantizations described by 1) refer to field, in 2) they refer to energy flow. We cannot verify 2) by substituting values for energy flow and periodicity, but we can make use of the fact that dissipative systems approach bifurcation asymptotically to compare dissipation rates. To analyze energy flow quantum mechanically we must first decretize it by dividing the total flow by the flow associated with a single period, or $\Sigma\dot{E} / \dot{E}_\tau$,, where $\dot{E}_\tau = \dot{E}/\tau$. Now let Q represent the decretized flow and let three successive bifurcations n, (n-1), and (n-2) be given by Q_n, Q_{n-1}, and Q_{n-2} [6]. Then the differences between the bifurcations are invariants of the flow and the rate at which the period of the system doubles may be obtained as follows:

$$F_n\left(\dot{E}\right) = \frac{Q_{n-1} - Q_{n-2}}{Q_n - Q_{n-1}} \qquad 3)$$

This gives the quantum mechanical interpretation of Feigenbaum's universal constant. As expected the quantization of a rate is also a rate, the rate of the system's degeneration into chaos. Quantization occurs because of the relationship of energy flow to periodicity given by 2) and serves the same purpose for complex systems as energy-time uncertainty does for atomic systems. Thus the combined action of equipartition and superposition can cause quantization to take on many forms.

3.3 Energy flow in life systems

If energy flows naturally disperse, and due to quantization they localize; then it is natural to ask whether energy transformations occur in other bounded systems. Life forms are open systems that conduct bounded flows of energy and they are in dynamic equilibrium with the environment. Thus we may ignore obvious structural differences with non-living matter expressed in position-momentum coordinates and analyze them using energy-time coordinates. It then becomes apparent that characteristics of energy transformation and flow are readily observed and are seen perhaps most clearly of all in humans. Indeed there is already a widespread realization among researchers that energy plays an important role in every aspect of human existence. In cell biology athletic performance has been shown to relate to mitochondrial density[7]; physiological studies show that skin conductance is in direct correspondence with the rate of energy transformation in physical activity[8]; in psychology activity level is related to several personality traits[9]; and in behavior "every response of the organism is fundamentally concerned with energy transformation and release"[10].

We may greatly simplify an analysis of life forms by consolidating their innumerable properties into a single observable: energy flow. Although difficult to measure, due to energy conservation no other physical variable is as precisely defined. Thus we shall view the life form from the microscopic level to the macroscopic level as layer upon layer of energy flow, each deriving its existence from still wider systems of material structure so that the final superposition state determines a life form's interaction with the environment. The internal organs are assumed not to have independent influence on energy flow and may therefore be ignored. Stimuli from the environment cause the organism to respond by means of energy discharge. This causes a displacement from equilibrium and the imbalance is then restored by homeostasis. In other words, organisms act as transducers of energy. They absorb energy that is dispersed throughout the environment and then localize it by applying it towards a specific function, task, or purpose as directed behavior. The organism exhibits the same gross characteristics of energy flow that an atomic oscillator does, but with an extremely slow characteristic time.

The characteristics of energy transformation for an atomic oscillator are also present within life forms. The behavior of neurons follows closely the general properties of spontaneous emission: an increasing flow of energy through the cell builds to a climax and is followed by a sudden discharge obeying 2). This flow pattern suggests that neurons attain a higher flow rate than other cells and in fact this is known to be true. During communication along nerve fibers each neuron signals the next forming a continuous chain. However, the maximum speed of the signal is a mere 120 m/sec and compares unfavorably to the much greater speed and efficiency of an electrical signal. Although it may appear initially that this manner of nerve cell communication places organisms at a disadvantage because it is relatively slow; it could well mean that the cell is the organism's fundamental unit of energy production and flow, and that this precludes the possibility of an unbounded process such as electrical signaling. In other words, it is hypothesized that energy equipartition requires all cells to have the same capacity to produce energy. Because energy equipartition is a universal law of nature it is more fundamental than the structures that support it, the genes. We may conclude therefore that genes are structural characteristics that allow equipartition to occur. This new interpretation requires that we conceive of genes not as templates or patterns, but as conduits that enable the flow of energy to different areas of the organism at precisely determined times. *The genome enables an equipartitioned flow, while homeostasis maintains and restores it.*

4.0 Evolution

4.1 Theory

The similar patterns of energy flow in atoms and organisms suggests that further comparisons can be made. For example, due to the sun we experience a constant flow of energy which fluctuates both diurnally and seasonally. Matter absorbs energy when flow is high and then releases it when it is low. Although we might expect these processes to be reversible so that the time duration for warming and cooling is the same, no one has ever performed an experiment to test this possibility. Let us instead make the prediction that energy returns more slowly to the environment than when it is absorbed and that the returning energy flow can cause spontaneous energy discharges, or quantizations, that result in structural change. It is hypothesized that the ever increasing internal energy of life forms is what we refer to as evolution. In other words, one way to describe evolution is as a *transformation of energy from external to internal modes*.

If life evolved as a result of the spontaneous conversion of external solar energy flow to the internal energy flow of organisms then energy flow should play a prominent role in evolutionary progress. Thus it is predicted that the energy of life forms will increase gradually from generation to generation. When the internal energy level/vitality has reached a certain level the life form's structure will no longer be able to support it. An irreversible discharge of energy then occurs in germ cells at the microscopic level causing changes in genetic content. Small changes of the genome will cause large changes in growth patterns and the sudden appearance of new structural characteristics in what is referred to in evolutionary theory as a “saltation”. The newly organized internal processes now act as the existing framework for energy flow and are a basis for further increases of the flow. Thus energy transformation provides a burst of localized energy that is capable of reorganizing internal structure. However, a precise chain of events in terms of material particles and their motions cannot be specified during quantization processes because the *particle motions during transition are indeterminate*. Because a transition will not repeat itself exactly even if initial conditions are identical quantization can also account for biological diversity. To see if this gives an accurate description of evolution we must compare its predictions with the fossil record.

4.2 Early evolutionary progress

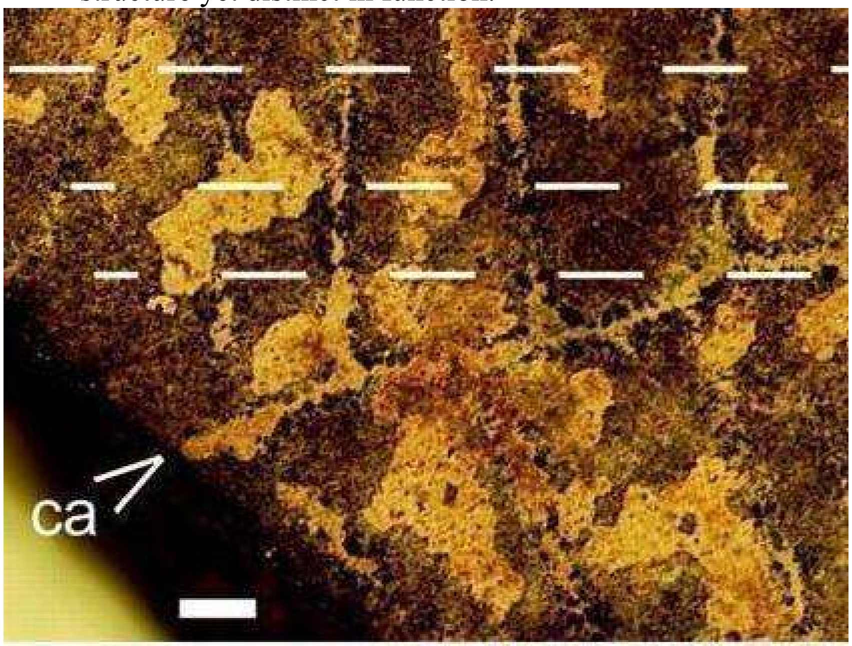
The opposing influences of equipartition, which disperses energy flow; and transformation, which localizes it, determine how life forms are configured. Because these processes are spontaneous the initial appearance of life occurred in a great number of different times and places rather than at a single location, which is consistent with the fossil record. They caused complex systems to assemble at first into non-replicating centers of flow. When flows exceeded structural limitations, bifurcations (cell division) occurred that are analogous to the period doubling of chaos theory. *In both cases bifurcation results in a doubling of energy flow*. Thus life and the fundamental property characterizing it, reproduction, can be explained naturally as a result of the innate potentials of matter.

Current evolutionary theory cannot explain either the expansion in biological

Figure 1. Trilobite, a common organism from the Cambrian Age showing its bilateral symmetry.

Figure 2. Rangeomorph frondlet showing a fractal growth pattern. Typical diameters are 1 to 5 mm at first order, .3 to .5 mm at second order, and less than .15 mm at third order.

diversity or the greatly increased complexity of life forms that resulted during the Cambrian Age given the relatively short time period over which the changes occurred. Nor can it explain why this burst of creativity has never been repeated. However, it appears that the phyla have all acquired the same new characteristic, axial or bilateral symmetry (Figure 1). These dramatic changes in structure may be explained very simply by interpreting them as manifestations of the equipartition of energy. It is hypothesized that external symmetry reflects an internal energy gradient. If energy flow is initiated internally as in the case of photosynthesis, spherical symmetry may result; however, as flows increase in more advanced organisms an external energy source such as the sun will require axial or bilateral symmetry to reflect the higher flow. The Cambrian fauna are radically different from previous life forms because flow is global. In other words, organisms increased their internal energies *without dramatically increasing in size* by superimposing flows. Energy flows superimpose linearly to yield two levels of equipartition: cellular and organismic. Therefore the Cambrian explosion marks the point in evolutionary history that cells became subordinated as parts of a greater whole, rather than as independent building blocks. The fact that eleven or more phyla appeared at the same time is an indication that energy transformation, i.e. evolutionary progress, occurred at nearly the same rate throughout the biosphere. The homeotic genes enable organismic equipartition since they are identical in structure yet distinct in function.



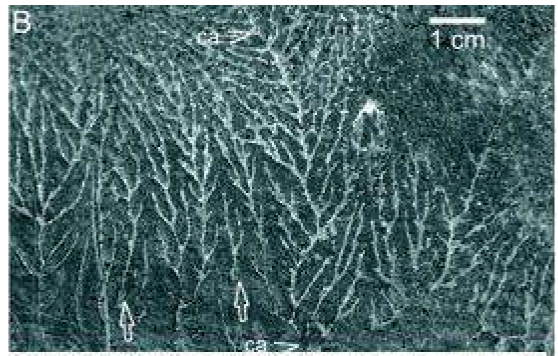


Figure 4.Recumbent life forms showing asymmetric growth by linear segmentation. Arrows indicate organisms that stopped growing due to overcrowding.

Figure 3. Fossilized organism showing the more primitive symmetry of a central axis instead of a stem. Scale bar - 1mm.

Another group of multicelled organisms, the Ediacarans, preceded the Cambrian Age by 40 million years. A large number of them were rangeomorphs, neither plants nor animals, with a frond-like appearance. Tiny "frondlets" (Figure 2) with fractal-like growth patterns acted as building-blocks to form structures up to a meter or more in size[11]. Careful examination of these organisms reveals that growth was asymmetric in one or more respects. Also it is well known that fractal patterns are generated mechanistically by repetitive mathematical operations. If these factors are taken together the evidence suggests that energy flow within these organisms was not global, but linear; such that homeostasis did not regulate flow. Thus homeotic genes were either absent or of greatly simplified form. Since germ cells lacked the ability to generate specialized tissues nearly all processes; nutrient absorption, growth, and regulation; were conducted where growth occurred, at the peripherals of the organism. This lack of specialization caused extremely slow growth rates characterized by modular or quilted construction (Figure 3); and linearly segmented, recumbent growth patterns (Figure 4)[12]. In every case asymmetry indicates primitive forms of growth without homeostatic regulation. Whereas the energy flow of the Ediacarans was linear that of Cambrian fauna was superposed thereby permitting higher flows of energy within the same volume and allowing increased rates of growth that soon (i.e. in an evolutionary time frame) crowded out Precambrian organisms. Their entire morphology has disappeared because homeostasis is a far more complex process and thus requires more involved physical pathways.

4.3 Punctuated equilibrium

Periods of structural stability in organisms, or "stasis", are common in the fossil record. They are followed by abrupt changes, or saltations, that are often accompanied by increased diversity; but with little or no evidence of transitional specimens. This is referred to as "punctuated equilibrium". The irregular behavior of evolution will be recognized as having the characteristics of spontaneous emission; a slow reversible increase of energy followed by an abrupt structural change due to energy transformation. This explains the regularity of saltations and extinctions, which are documented to have occurred 36,380 times in separate marine genera during the last 500 million years[13]. It also explains the opportunistic nature of evolution (as opposed to the causal origin favored by Darwinian theory), sometimes favoring primitive organisms yet eliminating others that appear to be more advanced. Only the integrated flow, the sum of the internal energy flows of all organisms, is assured of increase during evolution.

Predictions may be made concerning the relationship between stasis and saltation in the fossil record. This is because, due to energy conservation the energy absorbed during stasis is equal to the energy discharge of quantization. From the uncertainty relation governing structural change 1) the product of energy discharge ΔE and saltation time Δt must be equal to a constant. If stasis is long, then ΔE will be large and the time period of transition Δt must be correspondingly short. Therefore transitional life forms for the Cambrian explosion are necessarily missing and it is predicted that intermediate fossils will not be found. On the other hand, if Δt is long such that transitional specimens are well-represented in the fossil record, then ΔE must be small. This is the case for the transitional species between reptiles and birds, Archaeopteryx. A long series of fossils have been found documenting this transition during the Jurassic and Cretaceous periods, a span of 140 million years[14]. It indicates that the internal energy, or vitality of birds changed very slowly during their transition. We would expect this, however, since developing a capability for flight involves dramatic changes in structure that have little to do with internal energy flow.

4.4 Integrated energy flow

Life systems defy traditional scientific methods that attempt to analyze them using coordinates of position and momentum (q,p). This is because the behavior of organisms is governed by laws of energy flow formulated in coordinates of energy and time (E,t). Plants absorb solar energy to create a form of stored chemical energy which may be converted to other forms many times by insects and animals, and could perhaps terminate as the activity of human behavior. The path that energy takes during its return to the environment often covers long distances and takes months or even years to complete. In fact the integrated energy flow seems to have no well-defined purpose other than prolonging and increasing its own existence. For example, the existence of various beak strengths in Galapagos finches allows different seed types to enter the food chain[15]. This acts solely to increase the integrated flow.

There is no doubt that structure and evolution go hand in hand; however, only by analyzing the integrated flow are we able to correctly interpret the significance of their relationship. This more comprehensive interpretation of evolution can be used to explain the relevance of theories that attempt to explain evolutionary progress in terms of structure[16]. For example, the structural differences that allow flight permit dramatic increases in the integrated energy flow even though there is little difference of flow between them and the flightless organisms they replace. Thus integrated flow is the true measure of evolutionary progress and the energy-time uncertainty relation is the law that governs it. Genetic variation and natural selection are observables that reflect the presence of a simpler force operating at a deeper level.

The slowing of energy dissipation by material structure and resultant increase of the integrated flow by life forms does not refer to specific types of matter. Thus if it is assumed that all energy flow is subject to this rule we may use it heuristically to define a universal law of nature. It may then be hypothesized that galaxies are dissipative structures that were formed by an as yet unknown field superposition process and that the universe avoids “heat death” due to increases of the integrated flow.

5.0 Conclusion

Though they progress at very different rates, spontaneous emission and life processes demonstrate many similarities and this is also evident during evolutionary progress. Long periods of constant energy flow during stasis are then followed by abrupt reorganizations of structure, or saltations. If saltation indicates a change in structure to a higher energy state then it is comparable to electron excitation and further comparisons with quantum mechanics are possible. Whereas in classical theory variables refer to the same state, in quantum mechanics they are determined by pairs of states. The time duration of stasis is an observable determined by a pair of states so time may be classified as a quantum mechanical variable in this case. The stasis-saltation transitions form a spectrum of states that can be traced back from life forms to complex systems and finally to their origin in elementary matter. A smooth progression of quantization exists for all energy levels and at all levels of material complexity thereby demonstrating the universality of quantum processes.

Darwin used top-down logic to trace the fossil record back to its origins. He then formed an hypothesis that uses bottom-up logic to explain how natural selection shapes future generations. Because this constitutes circular logic both arguments are possible and result in exchanges such as: "Which life forms survive? The fittest. Which are the fittest? The ones that survive." On the other hand, logic used here to describe life processes is exclusively bottom-up since it begins at the level of the atom. It allows fitness to be unequivocally defined in terms of a single variable, energy. Thus it is hypothesized that expressions of excess energy in play and cultural activity are more significant than intelligence as measurements of fitness.

Several hypotheses may be tested experimentally by using energy-time coordinates. The most challenging aspect of each one will be to develop a method for measuring the energy flow of a complex system.

1. At the molecular level complex systems release energy more slowly than they absorb it.
2. Energy transformations such as occur in stasis-saltation, dissipative structures, neuronal discharge, etc. obey either or both of 1) and 2).
3. Excess energy as manifested by play and cultural activity will correlate positively with birth rate. Play is also a characteristic of many mammals and may therefore be used as a measure of fitness or to compare the evolutionary progress of a species, i.e. time required to evolve.

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