In: The Cybernetics of Complex Systems: Self-Organization, Evolution, and Social Change, edited by F. Geyer, Salinas, CA: Intersystems Publications, 1991, pp. 41-59.

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END-DIRECTED PHYSICS AND EVOLUTIONARY ORDERING: OBVIATING THE PROBLEM OF THE POPULATION OF ONE

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1. Background and introduction

17th Century mechanisms need makers.

The rise of modern science began in the 17th century with the ascendancy of classical mechanics and the Newtonian world view. The price of the Faustian bargain that permitted Newtonian physics to flourish - an impoverished causal framework and a dualistic ontology - although serving the emotional requirements of the religious ordering of the time (including those doing the physics), has plagued us down to modern times [1]. In particular, with the material world reduced to the deterministic, reversible, analytically continuous mechanical interactions of purposeless elementary particles (efficient cause), spontaneous ordering or discontinuous (creative) change internal to the world is *ruled out a priori*. As Boyle [2] pointed out, such a mechanical world, which he compared to the "ingenious clock of Strasburg Cathedral", like the Strasburg Cathedral clock must have an intelligent creator[1].

The ascendancy of Darwinism as the Theory of Evolution.

Whereas Aristotelian physics, a physics of becoming, was first and foremost the study of ends or *final causes* (the reason for which a thing or process exists or the end it serves) [4], Newtonian physics which explicitly removed all final cause from the scientific discourse was a physics of being; nature, e.g., the stars, sun, the earth, and the life upon it with the exception of those portions cultivated by humans[2], was thought to be immutable [6].

By the middle of the 19th century the empirical facts had punched fatal holes in the theory of immutability. The solar system, in accord with Kant's thesis put forth nearly a century before, was now seen as having *come into being* from an incoherent cosmic gas within the context of the larger universe. This thus denied a single creation event and meant that the Earth and the life upon it had come into being in successive stages, and this was confirmed by the growing geological record. The debate concerning how to deal with the various disparate pieces of the scientific puzzle has been going on ever since. By the middle of the 19th century, it was clear, however, that modern science badly *needed* a theory of evolution.While Mayr [7] has suggested that the ingredients for Darwin's "greatness" were in his "brilliant mind" and "intellectual boldness", Russell [8] has characterized Darwin as an unoriginal thinker who happened to be at the right place at the right time. What is important to note, however, given the abundance and variety of evolutionary ideas that were flourishing at the time (prior, simultaneously, and subsequently), is how narrow evolutionary theory became with the ascendancy of the Darwinian view (and its modern refinements). Like classical mechanics which modeled a very narrow portion of the physical world, so too did Darwinism speak to only a very narrow part of the evolutionary problem.

In fact, as Carneiro [9] has pointed out, although not often advertised by Darwinian theorists, Darwin never even used the word "evolution" in the first five editions of *The Origin of Species*[3]. This was not because the word was not in use. In fact it had been popularized by Herbert Spencer to refer to what he took to be the lawful process of spontaneous ordering (the "transformation of the incoherent into the coherent") as a single process extending from the nonliving right through the "latest results of civilization." The truth is, as Thomas Huxley [10] (perhaps Darwin's most influential 19th century advocate) wrote in 1878, that Darwin never intended to address or put forth a general theory of evolution, and as the word "evolution" became equated with Darwinism, its meaning became increasingly reduced[4]. The dictionary definition of evolution is "a process of change in a certain direction" [11], and while Darwinism has never recognized the directed (or progressive) nature of evolution, Spencer's theory and the other prominent competing theories of the time all saw evolution precisely in this way: they were all finalistic or *end-driven,* although none was ever able to adequately account for their finalism in any other but a supernatural way [6, 12, 13][5].

While the Newtonian world view placated the religious interests of Newton's time by placing the world-maker outside the world, Darwin's theory was particularly attractive because in generalizing Hobbes' law of "bellum omnium contra omnes" and Malthus' theory of population it elevated the favored ideology of his time (capitalist competition) to the status of natural order. Despite (or perhaps *because* of) its deficiency as an evolutionary theory - Darwinism (including its modern forms) avoids the deepest questions of evolution - its hegemony up until the present time has been remarkable.

Darwinism assumes what it should explain.
Darwinism takes evolution to be the result of "natural selection" (so named by Darwin to distinguish it from the breeding of animals and plants by humans) acting on populations of competing replicating or reproducing entities with heritable variation under fixed Malthusian parameters (limited resources). A "struggle for existence inevitably follows," said Darwin [14], from the high rate of reproduction of living organisms resulting in the "survival of the fittest", where fittest thus means reproductive success [7]. Thus, as the full title to his book *On the Origin of Species by Means of Natural Selection, or the Preservation of Favored Races in the Struggle for Existence* reveals, Darwin, as well as the various forms of Darwinism that followed, assumed the "struggle for existence" to begin with.

But by thus assuming the struggle for existence to begin with as a primitive of its theory, Darwinism smuggles in ad hoc that which any evolutionary theory should be in the business to explain [5, 13]. In addition, it is now well-recognized that the Earth system, at its highest level,maintains itself and has evolved as a single global entity [15 - 21], as a planetary self-organizing system that has progressively selected its own internal states so as to become increasingly more highly ordered, that is, so as to move progressively further from equilibrium over geological time [20, 21]. But Darwinism cannot address this global evolution or even recognize the existence of such a global entity (in fact denies it [22]] because there is no population of competing Earth systems on which natural selection can act - *the global Earth system is a population of one.* Natural selection, by definition, cannot account for the progressive tuning or adaptation of any system that is not a member of a competing population of replicating or reproducing entities. The problem has been termed the "closed-biosphere paradox" [23].

2. Final cause and physical law
Clausius and Thomson: The world is not reversible.
Because the problem of the population of one simply cannot, by definition, be dissolved with or reduced to biological explanations (since if it does not require a population of replicating entities the explanation cannot be biological) this puts the physics of the non-living kind directly back on the table; it begs the question of where out of a "dead", purposeless physical world such an end-directed or purposive behavior, the spontaneous selection of order form disorder, can come from [13, 21]. Bacon and Descartes to the contrary[6] [1, 25], we are once again - as was the case for nearly two

millennia before the rise of modern science and the Newtonian world view - unavoidably face to face with the Aristotelian question of *final cause*.

Bunge [26] has defined final cause as the "end to which everything strives and which everything serves", and Aristotle [26] himself defined it as "the end of every motive or generative process". Remarkably, this is precisely the statement of the second law of thermodynamics given by Thomson [27] and Clausius [28] in the middle of the 19th century (around the same time as Darwin's *Origins*) [1]. "The entropy of the world" said Clausius, "*strives* to a maximum" (emphasis added)[7].

The first and second laws of thermodynamics.

The formulation of the first law of thermodynamics (the principle of the conservation of energy) following on the work of Meyer, Joule, Helmholtz and others by the middle of the 19th century can be counted as one of the most significant achievements of modern science. In showing that all forms of energy, e.g., mechanical, chemical, and heat are interconvertible into each other, and that the total amount of energy remains the same (energy is neither created nor destroyed), the underlying unity of all dynamical processes was firmly established.

Although none of them made the observation, the work of Fick, Davies, and Carnot among others, however, showed this unified view to be incomplete in a profound way. For Clausius and Thomson, it was in Carnot's [30] work that they noticed the inconsistency (he showed that the "availability" for producing dynamical change was irreversibly destroyed) that demonstrated either the first law was violated or else in addition to a quantity that was conserved (the energy), there must be another quantity that was not.

Clausius coined the word "entropy" for this quantity (to sound like energy so as to stress the relation between the two)[8]. The second law states that all natural processes (all real-world dynamics) proceed spontaneously (on their own) so as to maximize the entropy. The state of maximum entropy, the time-independent state where all evolution or macroscopic change stops, is known as thermodynamic equilibrium. The discussion so far underscores a fundamental point: the first and second laws of thermodynamics are not ordinary laws of physics. They sit above the ordinary laws of physics as laws about laws expressing symmetry properties that govern the laws of physics themselves. The first law expresses the *persistence* or continuity underlying all physical processes (time-translation symmetry), and the second, which Eddington [31] has called the supreme law of all physical laws, is the fundamental law of *change*. The second law identifies a symmetry which when unfulfilled (when nonequilibrium distributions of energy exist) motivates nature to act until it is.

The active nature of second-law symmetry is easily seen with a sim-

A glass of liquid, e.g., water, at temperature T^I is placed in a box at temperature T^{II} such that $T^I > T^{II}$. The box has been sealed against energy flow to or from the outside (is adiabatically sealed) so that given the first law of thermodynamics (the law of energy conservation) the total quantity of energy contained in the box remains the same. The disequilibrium produces a *field potential* that spontaneously drives a flow of energy in the form of heat $-\Delta Q^I$ from the glass to the box so as to drain the potential until it is minimized (the entropy is maximized) at which time thermodynamic equilibrium $\left(T^I = T^{II}\right)$ is achieved and all flows stop (see text).

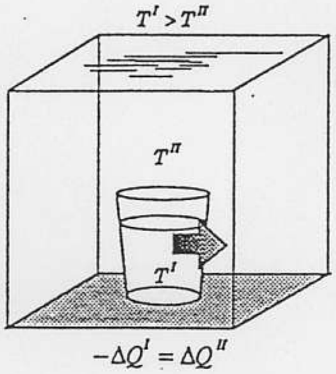


FIGURE 1

ple example. If a glass of warm liquid, e.g., water, is placed in an adiabatically sealed box (one closed to the flow of energy in or out) at a cooler temperature (see Fig. 1), a *field potential* is produced by the difference in temperatures that spontaneously drives a flow of energy as heat from the glass to the box so as to drain the potential. The flow will continue until the potential is minimized (the entropy is maximized) at which point the temperature of the water in the glass and the air in the box are the same and all flows stop. If the starting conditions are reversed (so the air is warmer than the water) the potential is minimized by a flow of heat from the air to the glass. From this what entropy maximization asfinal cause means is easily seen: when the entropy is maximized there is no change, but when it is not, the appropriate dynamics as drains are spontaneously produced until it is[9]. Note that when entropy is maximized, field potentials are minimized. Thus the second law can be equivalently stated as entropy maximization or field potential (or "availability") minimization. Both are expressions of the same symmetry.

Boltzmann's reduction and the "Infinite improbability" of order.

In stark contrast to the aimless reversible Newtonian view, the remarkable insight of the second law thus provided direct evidence for an active and end-directed physics. "Nature prefers certain states," said Planck (32], "and the measure of this preference is Clausius' entropy." The deep implications of the second law, however, were deflected for nearly a century as the result of Boltzmann's attempt to salvage the Newtonian paradigm by reducing the second law to mechanics - to the stochastic collisions of elementary particles (to efficient causes). Until quite recently this reduction was taken to have been successful, and the second law was taken to be a law of disorder.

Maxwell, modeling gas molecules as colliding billiard balls, showed that with each collision nonequilibrium velocity distributions would become increasingly disordered, leading to a final macroscopic state of uniformity and symmetry [13]. Boltzmann recognized this as the state of maximum entropy (where the macroscopic uniformity and microscopic disorder corresponds to the obliteration of all field potentials) and thus claimed entropy maximization, the second law, was simply a result of the fact that disordered states resulting from stochastic collisions were the most probable. Molecules moving "at the same speed and in the same direction" (ordered behavior), said Boltzmann [29], "is the most improbable case conceivable ... an infinitely improbable configuration of energy."

3. The mistake of assuming physics is complete

An "Autonomous Biology" retains miraculous agents.

In challenging the orthodox approach to cognition, which assumes cognitive ordering to be outside the explanatory power of physics, Turvey and Carello [33] have challenged the assumption that goes with it that physical theory is itself complete. This is a perspicacious challenge. To assume that because physics as traditionally conceived cannot address an aspect of the physical world (viz., higher-ordered phenomena), that there is no physics that can do the job only buys into the impoverished material conception that has been with modern science since its beginnings. In fact if physics is taken to be complete there is no way from physics to biology and psychology except by miracle. The fact that Newtonian physics, for example, could not account for the ordering of the world, was Newton's own argument for the existence of a supernatural maker [6]. Boltzmann's interpretation of the second law only made things that much worse.

The widespread belief in the truth and completeness of the Boltzmann conception (still widespread today) is precisely a continuation in modern form of the same dualistic ontology by which order-production has been assumed since the 17th century to reside outside the realm of physical law. Thus the assumption of a "dead" world of physics (the "Newtonian-Boltzmann narrative") is still used to justify claims for a biology (miraculously) "autonomous" from physics [34] and the existence of extra-physical causes in the account of biological ordering[10].

The world so viewed by necessity entails idealist embeddings of active extra-physical agents to account both for the ordering ("programming") of passive or "inanimate" matter into its living or "animate" form and providing it with its "inherent" purposive behavior, e.g., as in Darwin's [14] "all organic beings ... striving" to increase their numbers. The origins of such agents, as has been pointed out above, are simply taken as given. In the case of life, extra-physical agency is miraculously smuggled into the physical world in an "infinitely improbable accident that only had to happen once" [5, 13] with the insertion of a new set of (magic) "elementary" particles in the form of "striving", "active", "selfish" replicators [22, 35][11]. Imputing active, purposive behavior to genes, however, is denied *a priori* by their function [5, 11, 38]: it is specifically their *rate-independence* with respect to the rest of the cellular dynamics that permits them to be used as replicative constraints in biological ordering to begin with [38, 39, 40, 41]. That is, the sequence of the base pairs, like the words on this page, is thermodynamically arbitrary and inert relative to the dynamics with which they are "written" and "read". It is solely by this arbitrariness, ceteris paribus, that replicative ordering can occur. But it is this same thermodynamic inertness that disqualifies genes as active agents: they are utterly passive components meaningless without dynamical systems to "read" them and "write" them [13, 38].

Another mode of smuggling the necessary evolutionary dynamics into the world while rejecting the relevance of physics itself has been to misappropriate common physical terms. Stebbins [42], Mayr [43], and Levins and Lewontin [44] all refer to natural selection as a *force*, e.g., Levins and Lewontin say "natural selection is the only force in evolution ..." They note that Darwin had to separate ontogenetic variation from the "forces of natural selection" (they use the plural here) just as "Newton had to separate the forces acting on bodies from the properties of the bodies."

Forces (most generally defined as the gradient of a potential) acting on bodies (or matter) produce motion or change in the motion of those bodies (or matter) - produce action. Natural selection is a *constraint on motion already produced* (which members out of possible members of a replicating population will exist). The "action" of a constraint only exists as a limitation on the motions of matter and energy motivated by active physical forces in physical fields. Natural selection arises out of the fact of replicative ordering (an action or motion already existing) operating under limited resources. It *cannot explain the replicative ordering of which it is a consequence*, and this is why Darwinian evolutionary theory to avoid an infinite regress must always assume it to begin with.

The statement that natural selection is the "only force in evolution" denies the simple and universal physical facts which were shown in Figure 1: forces producing motion or change in motion arise out of nonequilibrium distribution of conserved quantities or field potentials. In addition, restating for emphasis, neither does the global Earth system replicate nor was replication involved in the progressive evolutionary ordering of which replicating systems were the product. The underlying purposive or directed behavior observed in evolution by which progressively more highly-ordered states come into being *can only reside in physical law*. It turns out that the extent to which order-production is seen to be inimical to physical law is precisely the extent to which the Boltzmann conception of the second law turns out to be error - it is, in fact, *comple-*

tely on its head [13].

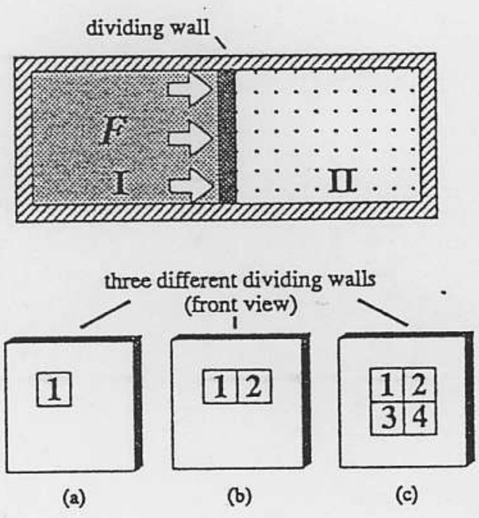
4. Why the world is in the order production business

The selection of macro from micro modes.

Aristotle was right in his insistence that we look for ends to explain the existence or nature of things. The fact that spontaneous ordering - the discontinuous emergence of coherent or coordinated collective motion (macroscopic behavior) from a set of previously disordered, incoherent components (microscopic behavior) - is invariant across transformations of scale suggests the operation of a *selection principle grounded in physical law* (since to repeat, if it does not involve replicating entities it cannot be biological) of which natural selection is a particular consequence. This physical selection principle must operate in the selection of macro (ordered) from micro (disordered) modes, and to understand why it occurs we must understand the ends that are served.

The second thermodynamics: the importance of rates.

Classical thermodynamics says that entropy is maximized at thermodynamic equilibrium but says nothing about the path a system will take to get there. The study of evolution is precisely the study of paths or the particular dynamics selected out of some infinite number of virtual (or otherwise possible) pathways. The Earth system has consisted of a relatively constant



An adiabatically sealed chamber divided with an adiabatically sealed wall into two equal compartments each holding an equal quantity of a monatomic gas is prepared so that $T^{I} > T^{II}$. The disequilibrium produces a field potential with a force F. If the adiabatic seal is stripped off a section of the dividing wall (a), a flux of heat as a drain is spontaneously produced from I to II until the field potential is minimized (entropy maximized). The rate of the entropy production is given by

$$\frac{dS}{dt} = \frac{dQ^{I}}{dt}\left(\frac{1}{T^{I}} - \frac{1}{T^{II}}\right) \qquad (2.1)$$

where dQ^{I}/dt and $\left(1/T^{I} - 1/T^{II}\right)$ are the flux and force respectively (see text).

FIGURE 2

quantity of matter of the same atomic constituents for over 4 billion years; the study of evolution is the study of the redistribution of that matter into patterns of ordered motion over geological time [20, 21]. In particular, we would like to know how selection works at the global level. If we take some of the tools of the classical thermodynamicists such as a monatomic gas in an adiabatically sealed box and install some simple devices that allow the addition, removal and changing of constraints, the principle we seek is immediately revealed [1, 6].

The law of maximum entropy production.
Figure 2 shows an adiabatically sealed chamber divided into two equal compartments with an adiabatic wall so that each holds equal quantities of a monatomic gas. The system is prepared so that the temperature in compartment I is greater than the temperature in compartment II. The disequilibrium between them produces a field potential with force F (the magnitude of which depends on the extent of the difference in temperatures). If the adiabatic seal is stripped off a section of the dividing wall (a), a flux of heat (a drain) is spontaneously produced from I to II until the field potential is minimized (the entropy is maximized) given the constraints. From equation (2.1) it is easy to see that, ceteris paribus, the rate of entropy production is determined by the coefficient of conductivity of the wall.

In (b) a second portion of the seal is stripped away, but the wall underneath is composed of a different material with a different coefficient of conductivity. If the rate of 2 relative to the rate of 1 is sufficient to drain some quantity of field potential before 1 drains it all then that quantity is automatically allocated to it. If 2 drains all the potential before 1 can drain any then all the potential is allocated to it. If more drains are added (c) the behavior is precisely the same: regardless of the particulars, the system as a whole allocates its resources amongst the available dynamics - will *select* the assembly of drains or pathways - so as to minimize the field potential (maximize the entropy) at the fastest possible rate given the constraints. This *law of maximum entropy production* [1, 5, 6, 13, 20, 21, 25, 38, 45] - the law of laws with respect to evolutionary dynamics - provides the missing piece to the understanding of the lawful nature of spontaneous and directed ordering in the natural world (next section).

Order produces entropy faster than disorder.
The flaw in the Boltzmann conception is its reductionism: the world is not reducible to the local (uncorrelated) mechanical interaction of a set of "elementary" particles (efficient cause) - to a stochastic collision function or any other kind of linear, summative behavior. Selection of macro from

micro modes (ordered from disordered flow), by locally reducing the entropy of the fields where it occurs, must necessarily increase the rate of entropy production of the same fields by a precisely corresponding amount; *the greater the amount of order produced and maintained (local entropy reduction), the faster the entropy production (the faster the field potentials are minimized).*

Given the law of maximum entropy production, it is at once easy to see why macro (order) is selected from micro (disorder), why order production is inexorable not improbable [5, 13, 21], and how the problem of the population of one is immediately obviated. Selection is not between competing replicating entities but between ordered and disordered modes.

The generic level-independent relations that define a minimal *autocatakinetic* system between a source E^I and sink E^{II} where dE^I/dt is the flow, F_1 is the field force, E^{III} is the internal potential with internal amplifier (internal force carried in the circular relations of the ordered flow) F_2, and dS/dt is the entropy production.

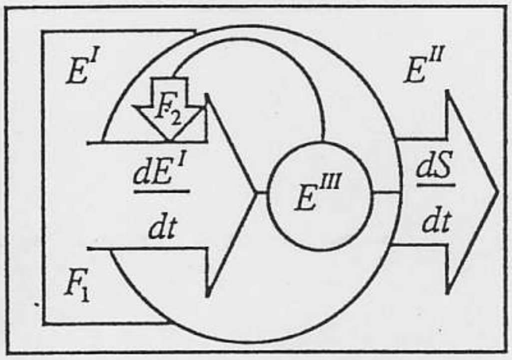


FIGURE 3

Whereas the state of thermodynamic equilibrium may be the state of maximum disorder, the path of choice to equilibrium in a far from equilibrium world is not the linear, summative kinetics of disordered collisions but the *autocatakinetics*[12] of self-organizing states of macroscopic order[13] (Fig. 3). An autocatakinetic system maintains its "self", constituted and empirically traceable by a set of nonlinear ("circularly causal") relations, through the dissipation or breakdown of field potentials in the continuous coordinated or ordered motion of their components [*auto*- "self" + *cata*- "down" + *kinetic*, "of the motion of material bodies and the forces and energy associated therewith" from *kinein*, "to cause to move"].

This description is the minimal and therefore most generalized level-independent description of a spontaneously ordered or self-organizing system, and carries with it a rich repertoire of generic properties that holds regardless of scale or the particular level-dependent material properties of the components (which are additional). Autocatakinetic systems bring qualitatively different behavior discontinuously into the fields from which they emerge. The energy carried in the macroscopic flux that characterizes their ordered states defines an internal potential that acts back as an internal amplifier to further increase the input (the further capturing of field potentials or resources). *Autocatakinetic systems are self-amplifying sinks* [13].

The figure shows the discontinuous increase in field potential minimization that occurs with a transformation from disorder to order in a simple fluid experiment. The intrinsic space-time dimensions increase by orders of magnitude from mean free path distances and relaxation times of 10^{-8} cm and 10^{-15} sec. to centimeters and seconds. k^{ζ} is the rate of heat flow from source to sink in the disordered regime and $k^{\zeta}+\sigma$ is the rate of flow in the ordered regime ($3.1 \times 10^{-4} H$ cal.cm^{-2}s^{-1})[46]. Order occurs spontaneously and inexorably as soon as the field force, F^{ζ}, is at the minimum level that will support it (see [5, 6, 13, and 21] for photos and more details).

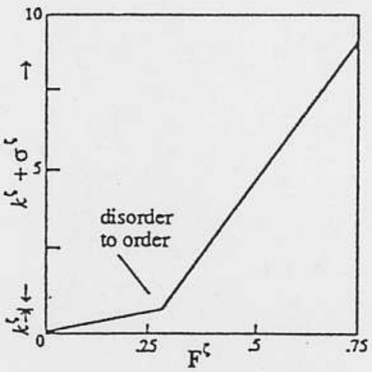


FIGURE 4

Autocatakinetic systems transform resources into themselves through the selection of their own internal microstates so as to extend the intrinsic space-time dimensions and thereby the dissipative dimensions (surfaces) of the fields from which they emerge (see Figure 4). Through this new formal cause (circular causality) or agency [6, 25], viz., autocatakinetics, *new end-states or goal-states spontaneously come into the world as the product of natural law without dualistically embedded "makers"* or any other such truly "infinitely improbable" (miraculous) devices. (The reader is encouraged to read [5, 6, 13, 20, 21] for more details and photos).

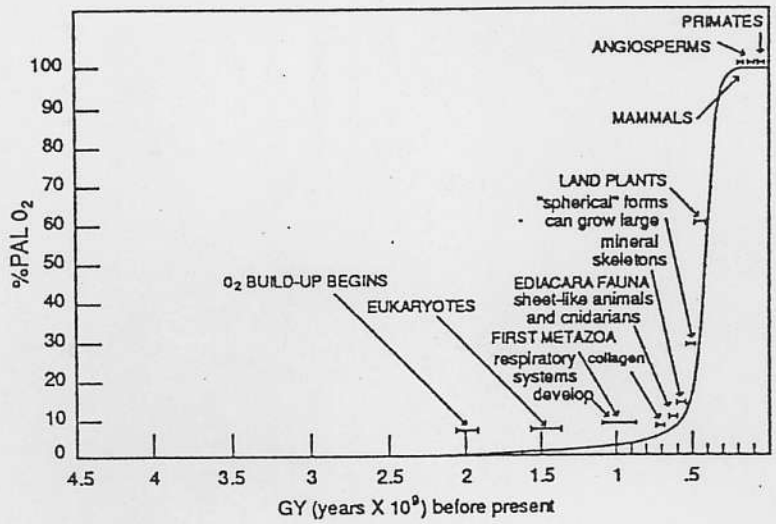
The autocatakinetics of global evolution.

Thus the Earth system itself is an autocatakinetic system embedded in a cosmic field between the solar source and the cold sink of space. Given the geo-cosmic potential and the laws of thermodynamics as now understood, the system can be expected to progressively select its internal micro-states through the production of increasingly higher-ordered states so as to maximize the extension of its dissipative surfaces (its space-time dimensions) [20, 21, 45]. The animal-environment dualism espoused by neo-Darwinism ("living" agents struggling against a "dead" world of physics) is a fiction. The autocatakinetics that define living agents are not isolatable from the persistent global entity, of which they are component productions, and would not exist without its progressive ordering in the past or its ongoing existence as itself a planetary autocatakinetic entity (process) in the present.

The "inherent" property of the living "to seize on every unoccupied or less well occupied place in the economy of nature," which on the orthodox view must be dualistically (miraculously) smuggled into a "dead" world of physics is inherent to the physics itself and needs no smuggling. Given the thermodynamics of the geo-cosmic interface, the Earth system can be expected to opportunistically produce as much order as it can. The replicative ordering of the living (autocatakinetics that entails component replication) is a special case of spontaneous ordering which is selected by physical law because it affords expansion into otherwise inaccessible dimensions of dissipative space (see next section). Natural selection (selection between replicating entities) is a particular kind of selection internal to the process of global self-organization according to physical law.

The need for viewing evolution as a single global process governed by a physical extremum principle was recognized by Vernadsky as early as 1929 [48] when he stated his principle of mass flux maximization (the "first biogeochemical principle"): "the biogenic migration of the chemical elements in the biosphere tends towards a maximum of manifestation," which is "affected not only by means of the mass of atoms in circulation but also the intensity or rate of their circulation." The thermodynamics of entropy production maximization subsumes, fully vindicates Vernadsky's claims, and fulfils his challenge to future researchers to uncover the deeper physical principle from which his law could be derived. Living organisms, he said, cannot be understood except as "function of the biosphere" and "cannot be considered apart from (their) medium...as though the two were independent objects". He noted the necessity of studying "mass respiration" as a measure of the "fundamental property of biogeochemical energy (which is..) the growth of the free energy of the biosphere with the progress of geological time." Put in the more fundamental physical framework outlined here, the increase of biogeochemical energy is equivalent to an internal entropy reduction of the global system and an increase in the rate of entropy production of the geo-cosmic field[14].

The autocatakinetics of entropy production maximization are easily seen in Figure 5 which shows the opportunistic production of increasingly higher-ordered states as a function of increasing atmospheric oxygen. The level of atmospheric oxygen is a measure of the distance of the planetary system from equilibrium (a measure of its internal entropy reduction and thus also its global entropy production). It is likewise a measure of the internal potential of the global system, which is seen to progressively increase over geological time to its present maximum which it reached several hundred million years ago[15]. New states of order taking the system increasingly further from equilibrium are seen to opportunistically (and almost instantaneously in geological time) come into being as soon as conditions permit. Thus the evolutionary production of atmospheric oxygen is not only a measure of the distance of the system from equilibirium, but furnishes conditions by which the system moves even further away from equilibrium.



This rise of atmospheric oxygen (PAL = present atmospheric level) is a measure of global metabolism and the progressive departure of the planetary system from equilibrium over evolutionary time. The spontaneous production of increasingly more highly-ordered states by which the global system has progressively increased not only the dimensions of its dissipative surfaces but the mass-specific intensity of its dissipation is seen to occur opportunistically as minimum levels of oxygen permitting the necessary higher rates of dissipation are reached (see [5, 6, 20, 21] for more details; data from [49, 50]).

FIGURE 5

Higher-order states produce more entropy to maintain their order and require higher levels of oxygen to maintain the extension of their dissipative surfaces. In this way the Earth system as a self-amplifying (autocatakinetic) sink for the geo-cosmic potential, opportunistically selects those states, as Vernadsky [48] noted, that increase not only the quantity of matter in circulation, but the intensity or specific rate of circulation too.

In fact, since increasing the circulation or size (the space-time extension of global autocatakinetics) requires the production of new levels of order [13, 20, 21], and the production of new levels requires increasing the mass specific intensity of respiration (or entropy production), the intensity must necessarily discontinuously increase with increasing dimensions of the system[16]. Figure 5 underscores the the inseparability of evolutionary order from the continuity and self-organization of the global system as a single planetary entity of which it is a self-production.

5. Harnessing kinematic fields with replicative order
Accessing higher-orders of dissipative space.
In the dualistic tradition (animate matter of biology vs. the "dead" matter of physics, organism vs. environment), the living, decoupled from the physical world, is seen as the product of some infinitely improbable accident (whereby the needed properties are miraculously smuggled into the world) somehow struggling against the laws of physics. On the view espoused here, which rejects dualistic accounts as not merely unsubstantiated but miraculous and hence radically unparsimonious (proliferating even more difficult to explain theoretical entities), the living is selected from nonliving as part of a universal (physical) ordering process because it provides access to otherwise inaccessible dimensions of dissipative space. There is nothing improbable about it. The physical world produces order as fast as it can given the constraints, and what is called the living is simply the physics, or a phase of matter, at a particular level of ordering with all the generic level-independent properties that all autocatakinetic systems have, but with emergent level-dependent properties particular to its own level. The living is the physics that entails at its own ecological level.

In fact, the attraction of living states of matter as pathways of choice in the terrestrial production of dissipative dynamics is quite easy to see. Tornadoes, dust devils, Bénard cells[17] as well as various nonliving chemical systems, are all examples of the spontaneous ordering of autocatakinetics - macro is selected from micro through the time-dependent (evolutionary) specification of some much smaller set of accessible microstates (order) from some much larger initially accessible microstates (disorder) [13]. But while increasing the dissipative dimensions of the fields from which they emerge by orders of magnitude, the access to dissipative space of the autocatakinetic nonliving is nonetheless limited; they are slaves to local potentials, e.g., remove the local potential and the ordered state "dies".

This is not the case with even the simplest living systems such as bacteria. When their local potentials are removed (they run out of food), their activity often increases; the autocatakinetics of the living are coordinated with respect to macroscopic invariants in kinematic fields [51, 52], what the ecological psychologist J.J. Gibson (who radically rejected animal-environment dualism) has called "information about" higher-order resources (or field potentials), that permit the living to act arbitrarily with respect to local gradients and access higher dimensions of dissipative space [1, 6, 38][18]. As the result of the replicative ordering that characterizes the living and the interplay of macrodeterminacy and microstochasticity, end-directed behavior is hooked to kinematic invariants in ambient energy distributions, e.g., the ambient optical array, thus affording the hunting down of potentials discontinuously situated in space and time in the production of higher-order dissipative dynamics[12].

Dynamics is induced by field potentials, and the potential with respect to terrestrial evolution is the disequilibrium at the geo-cosmic interface. Terrestrial evolution can be seen as a self-organizing planetary process by which the global system as a whole, progressively and opportunistically orders its own microstates so as to maximize the extension of its dissipative surfaces and reduce the geo-cosmic potential at the fastest possible rate given the constraints [20, 21]. This gives a physical account and globalizes Haldane's argument that evolution is the "struggle to increase surface to volume ratios" [21]. Just as the selection of the living (replicative order) from the nonliving provided access to otherwise inaccessible dimensions of dissipative space, so the use of linguistic constraints in the process of cultural ordering produced a qualitatively new kind of replicative ordering ("second-order kinematics" - flows *about* flows [6] or information about information) which provided access to new and otherwise inaccessible dimensions of dissipative space.

6. Conclusion

The law of maximum entropy production provides the selection principle that accounts for the autocatakinetics of evolutionary ordering and obviates the problem of the population of one. *Autocatakinetic systems are generically self-tuning, adaptive and end-directed.* They transform field potentials into their own self-production as self-organizing, self-amplifying sinks under a law of entropy production maximization. Given this new understanding of thermodynamics, and the geo-cosmic potential that impinges on the geo-cosmic interface, it is at once easy to see why the world is in the order-production business. Spontaneously differentiating, self-tuning macroscopic states of order are no longer seen as inimical to science or outside the laws of physics. They are instead seen to be the natural product of the symmetry properties of the laws of physics themselves. This is not a reductionist account. Instead level-independent laws act on level-dependent substrates, where the order produced at a particular level depends on the observables at that level which are themselves emergent. The world produces order that act backs to produce more order. This new view of physics, an ecological physics, dissolves old dualistic ontologies and the evolutionary "paradoxes" inherited with them.

ACKNOWLEDGEMENT
The author would like to thank CESPA for its support during the spring of 1990 and its stimulating environment where ecological physics is taken as a given, and to Paul Manciewicz for organizing the "Emergence of Regulation in Biological and Abiotic Systems" symposium at the 8th International Congress of Cybernetics and Systems, June 11-15, 1990, New York where this paper was first presented.

NOTES

1. See also Weber's [3] discussion this volume.
2. The privileged anthropocentric position (a hallmark of all dualistic theories) in this should not go unnoticed. See [5] for further discussion of culture theory and anthropocentricity.
3. And as Gilson [10] has pointed out, the word is not found in any of the thirty-six chapters or summaries of *The Descent of Man* either.
4. First it was reduced from a universal process of spontaneous ordering of which organic evolution was a part to organic evolution, and then specifically to the result of natural selection (the consequence of competition between replicators or reproducers in a Malthusian population).
5. Spencer's "law of evolution" took spontaneous evolutionary ordering to be a lawful universal process, but he was never able to provide an acceptable physical account of where such a law could come from.
6. It was Bacon who, attacking the Aristotelian causal framework, argued that "inquiry into final causes is sterile, and, like a virgin consecrated to God, produces nothing" [24].
7. As part of the systematic removal or dilution of end-directed language from common texts this is usually translated as "tends" but no reputable German scholar would translate it ("strebt ... zu") that way. Boltzmann [29] called entropy maximization the "goal" of all natural processes, and Planck (see text) also used intentional language. I have argued elsewhere [1] that this language was deliberate, and reflected their understanding of the second law, and that rather than inappropriately intentionalizing physics lays the groundwork, if properly understood, for physicalizing (and thus demystifying) intentionality.
8. Entropy is used throughout this paper in the physical thermodynamic observer-independent sense as the quantity that increases according to the second law (the inverse of generalized field potentials), e.g., a glass of warm water will equilibrate with a cooler room, whether an observer watches it or not, as a matter of universal law (see text). This should not be confused with the many other kinds of observer-dependent "entropies" later introduced, e.g., information entropies, which despite their various merits (or lack thereof) have no *a priori* connection with physical law.
9. Notice that a popular notion of "energy consumption" or a not uncommon definition of energy as "the capacity of a system to do work" (produce macroscopic change) erroneously conflates energy and entropy. Energy cannot be consumed (a violation of the first law), only entropy produced. Since the energy of a system is the same at equilibrium (has no internal field potentials) as when it is not (has potentials), it cannot be *the* measure of a system's ability to produce change; this is only measured by the extent to which the entropy is maximized [6]. *The world is driven by entropy production, not energy consumption.*

10. Thus Mayr's [34] statement that "there is no pathway from the laws of physics to man" can be taken as a statement about the absolute limitations of physical theory and to justify seeking extra-physical causes (which he does), or it can be taken to be a statement about the necessity to expand physical theory to seek the relevant laws that can do the job as Turvey and Carello advocate in cognitive theory [33].
11. See Fleischaker's [36] challenge to the notion of "living molecules", and Webster and Goodman's [37] attack on genetic reductionism as a transformation of the concept of the immortal "Idea"
12. I here re-introduce the term "autocatakinetics" into the literature in its updated and more precisely defined form. It was first coined by Ostwald at the turn of the century and also noted by Lotka [47].
13. The most direct path to equilibrium under such circumstances is not a straight line but a circle [11].
14. Lotka advanced an extremum principle of maximum energy flux that he said governed evolution, but because he explicitly dissociated his principle from the second law and instead derived it from the expansive tendency of living things he starts with the same assumptions of Darwin (see [6, 13]) for further discussion as well as an extremum of Prigogine which was for a time mistakenly applied to spontaneous ordering and whose vestigial remains are still unfortunately occasionally encountered in the literature).
15. And on which substrate new and increasingly more powerful amplifiers have been progressively emerged at an accelerating rate ever since (see [5]).
16. The relation between surface/volume ratios, spontaneous fission (horizontal proliferation of dissipative surfaces), and the production of new levels (vertical proliferation of dissipative surfaces) of order has been discussed in detail elsewhere [5, 6, 13, 20, 21]. Suffice it to say here that it is easy to show that as the result of simple dimensionless ratios the proliferation of order beyond certain scales must include not only spontaneous fission but level-building behavior (why, for example, evolution must go in stages). Physical law, noted in the text, requires the specific entropy production of a newly ordered state to be greater than the disordered substrated (the previous level) from which it emerges.
17. The reader should see [13, 21) for photos and more detailed discussion of the generic properties of spontaneous ordering as observed in this simple physical system.
18. It is precisely the arbitrariness of the internal rate-independent constraints (see text above) that affords the arbitrariness with respect to local gradients in the external kinematic coupling [6, 38].

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