The 4th Law of Thermodynamics (LMEP), Autocatakinetics, and the Rise, Development, and Collapse of Socioeconomic Systems

Preprint

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THE 4TH LAW OF THERMODYNAMICS (LMEP), AUTOCATAKINETICS, AND THE RISE, DEVELOPMENT, AND COLLAPSE OF SOCIOECONOMIC SYSTEMS

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ABSTRACT

The foundations of modern science were built on Cartesian metaphysics and its postulates of incommensurability which took all the active, end-directed, and epistemic opportunistic ordering that characterizes the world around us and its evolution out of the physical world, and these postulates and their descendants are still found dominating the mainstream received views in the physical, biological and especially social sciences today. Following Boltzmann's attempt to reduce the 2nd law of thermodynamics to a stochastic collision function, the 2nd law of thermodynamics became known as a "law of disorder" which further amplified these views. Identification and elucidation of the 4th Law of Thermodynamics (the Law of Maximum Entropy Production, LMEP) has provided the basis for dissolving these postulates of incommensurability. The study of autocatakinetics (ACK systems) and the opportunistic ordering following from the 4th Law when coupled with First Law symmetry shows the nomological basis for the particular case of epistemic ordering that characterizes the origin and evolution of living systems, including human cultural systems from autonomous hunter-gatherer groups to the rise of nation states and the explosive globalization going on today. The origin, development (evolution), and collapse (death) of such systems has generic properties independent of type that are particularly relevant in the development of new much needed robust economic and social theories that can better understand and address the explosive growth and instability of current times. The principles, herein are outlined and reviewed.

Keywords: Autocatakinetics, 4th law of thermodynamics, law of maximum entropy production, evolution, cultural evolution, cognition, social theory, economics, natural selection, spontaneous order, self-organization.

1. INTRODUCTION AND BACKGROUND

The foundations of modern science although based on the physics of Newton were built on the metaphysics of Descartes where physics and psychology were defined at their origins by their mutual exclusivity. The former was taken to be comprised of passive, inert ("dead"), reversible (no inherent direction to time), quality-less particles governed by deterministic laws, and defined by extension in space and time, while the latter, "mind" (the "thinking I" or subject, Certesian ego or "self") was defined as active, striving, intentional , perceiving (= "thinking" for Descartes), lawless and immaterial or unbounded in space and time. [1, 2]

The immediate implicate of this was that the physical part which was seen as a giant machine comprised of "dead" reversible particles that like a clock by definition needed an extra-physical "maker" to order it (e.g., God as universal watchmaker, or "mind"). The immediate problem with this scheme (and all descendant dualist versions) is that "mind" (=all extra physical makers) is incoherently (logically) forbidden from interacting with the physical world ("matter") it is relied on to order (the problem of "Cartesian Interactionism"). The reductio leads later to the effective abandonment of ontology (viz. that there is an independent physical world or if there is it cannot be known)[3]. "Mind" ends up perceiving itself (or its own mental states) with perception becoming an act of mental construction or the imagination, an idea that currently pervades psychology and cognitive theory (e.g., see [4]). This idea of individual mental world creation was transposed to the level of intersubjective human social systems ("Closed-Circle Theory") through the work of the Wittgenstein, Khun and others (e.g, see [2]) where it and its inherent anti-realism and relativism has dominated contemporary thought in the social sciences today [2, 5].

Following Descartes, Kant arguing that the teleology or active end-directed striving of living things could could not be accounted for from the dead world of physics promoted a second major dualism (the "Second Postulate of Incommensurability") the incommensurability between biology and physics (living things vs. their environments)[6].

1.1 Evolutionary theory and the problem of end-directed behavior

Later the 2nd postulate of incommensurability, the idea of the "autonomy of biology" from physics became a mainstay of mainstream evolutionary theory (neo-Darwinism). This put an account of the active, end-directedness of living things outside the scope of evolutionary theory with its core explanatory of natural selection [6, 7]. Natural selection as Popper [8] formalized it is defined by a situational logic. *If* certain conditions hold *then* natural selection will follow, and these conditions are heritable variation, finite resources, and the *fecundity principle*, the *sine qua non* of Darwinian theory that captures the active striving of living things; in Darwin's [8] terms to"seize on every unoccupied or less well occupied space in the economy of nature" Natural selection rather than explaining the end-directed behavior of living things, instead thus depends on it outside its theory and thus cannot explain it.

1.2 The doubly compounded problem for human sociocultural systems An account of the active, end-directedness of human social systems, their origins and

evolution is doubly compounded. First because mainstream evolutionary theory defines evolution as a change in gene frequencies and this does not apply to cultural evolution, and second, the current, anti-realist, relativistic stance held by all "closed-circle theories" that dominate the social sciences is anti-evolutionary by its own construct. Because closed circles are incommensurable with respect to each other there is no way to assert that they are part of an evolutionary process as there is no comparative or ordinal measure with respect to time [2]

2. THE 1ST AND 2ND LAWS OF THERMODYNAMICS: PHYSICALIZING PERSISTENCE AND CHANGE

A major challenge to the mechanical world view came with the discovery of the 1st and 2nd laws of thermodynamics. Davies, Mayer, and Joule through a variety of ingenious simple experiments by demonstrating the equivalence of mechanical energy and heat established the 1st Law of Thermodynamics (the conservation of energy) a deep principle that showed the unity of all natural processes (Figure 1). The work of Carnot,

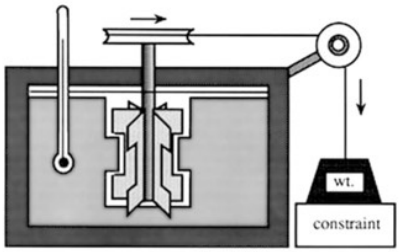

FIGURE 1: In Joule's paddle wheel experiment the potential energy of a weight is converted to the mechanical energy of a turning paddle wheel raising the temperature in a tank of water by an equivalent amount.

however, some years earlier, posed a problem [3]. Carnot [10] had shown it was the "loss of availability" with the "fall of heat", like the fall of water that drives a mill wheel, that provided the motive force that powered the steam engine. Problem was if energy is conserved then there had to be another quantity that is not (is lost). Clausius coined the tern "entropy" (to sound like "energy") to refer to the inverse of Carnot's "availability" or "potential" and the 2nd Law of Thermodynamics in its most general form says that all natural processes proceed so as to maximize the entropy (or minimize the potential or availability), and the "balance equation" of the 2nd Law can thus be given as

$$\Delta S > 0, \text{ or at equilibrium where } \Delta = 0 \qquad (1)$$

This gave scientific meaning to "final cause" bringing end-directedness nomologically into the world from first principles.

Not long after, Boltzmann attempted to save the mechanical world view by reducing the 2nd law to a stochastic collision function. Following Maxwell modeling gas molecules as colliding billiard balls in a box Boltzmann note that with each collision non-equilibrium velocity distributions (molecules moving at the same speed in the same direction) would become more disordered leading to a state of macroscopic uniformity or microscopic disorder, the state of maximum entropy. The 2nd law said Boltzmann was simply the result of the fact that in a world of mechanically colliding particles disordered states are more probable. Molecules, he said [11], "moving at the same speed in the same direction is the most improbable case conceivable...an infinitely improbable configuration of energy." With this the 2nd law became known as the "law of disorder" and the origin and evolution of life and human social systems characterized by the fecundity principle's active opportunistic ordering was now seen as violating or defying the laws of physics (see [7]).

Schroedinger [12], comparing living systems to flames, Bertalanffy [13], (under the rubric of "open systems) and later Prigogine [14] ("dissipative structures") reduced the tension slightly by showing that such systems did not violate the classical version of the 2nd Law as long as they produced enough entropy (minimized potentials fast enough) to compensate for their own internal entropy reduction so the balance equation of the 2nd Law would be satisfied. On this view such ordered systems *can* exist as long as they "paid their entropy debt" Such systems were still seen, however, as struggling against the laws of physics and infinitely improbable according to Boltzmann so the central problem remained [2].

3. THE 4TH LAW OF THERMODYNAMICS: THE LAW OF MAXIMUM ENTROPY PRODUCTION (LMEP)

It is not only the entire evolutionary record that flies in the face of Boltzmann's hypothesis, it is repeatedly and easily falsified by simple physical experiments (Figure 2) where opportunistic ordering is seen to arise not "infinitely improbably" but rather *with a probability of one every time and as soon as it gets the chance* [2, 6] This universality suggests a physical selection principle to account for it. We can see from

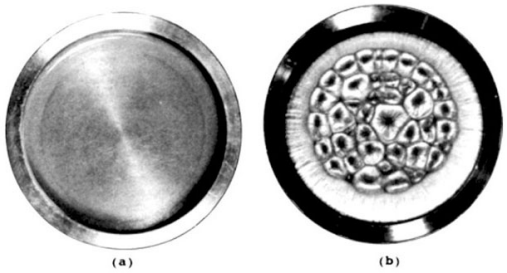

FIGURE 2: Two time slices in the Benard experiment where (a) is the disordered Boltzmann regime and b) spontaneously ordered flow with 100s of millions of molecules moving together [2]

the above that in order to satisfy the balance equation of the 2nd Law that whenever spontaneous ordering occurs *the rate of entropy production must go up* (Figure 3) [15]. This leads us

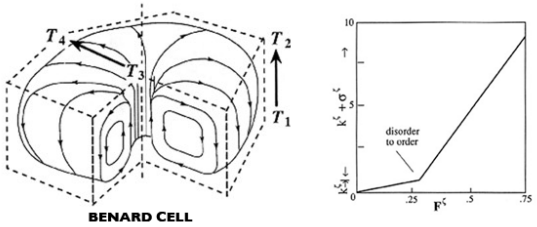

FIGURE 3: Left schematic of ordered flow in Benard experiment and right shows dramatic increase in entropy production that occurs with the emergence of the ordered flow [2].

immediately to ask the question Bertalanffy, Schroedinger, and Prigogine never asked, namely "which paths ot of available paths will a system take (select) to minimize potentials or maximize the entropy out of alternative available paths?" The answer is the Law of Maximum Entropy Production (LMEP) or

the 4th Law of Thermodynamics: (*The world) a system will select the path or assembly of paths out of available paths tha*t *minimizes the potential or maximizes the entropy at the fastest rate available given the constraints* [1, 2, 6] . The 4th Law is valid in all ranges, near and far-from-equilibrium, is readily demonstrated in simple falsifiable experiments, and is intuitively easy to understand (e.g., see "cabin in woods" [6]).[2]

4. AUTOCATAKINETICS (ACK) IDENTITY THROUGH FLOW

The class of systems of relevance is autocatakinetic (ACK) systems[3] (Figure 4). It includes simple physical systems as well as all living systems from single cells to civilizations and the planetary system as a whole. An ACK system is defined as one that: *maintains itself as an entity constituted and empirically traceable to a set of nonlinear (circularly causal) relations through the dissipation or breakdown of environmental potentials (resources) in the continuous coordinated motion of its components* [2, 6, 16]. ACK systems are seeded at their origins ("birth" or "entification") by microscopic fluctuations/ stochasticities. The "selfishness" of ACK systems is both manifested and located in the fact that through the circular relations that define them the are self-amplifying sinks or deviation-amplifying systems Their existence (selection of macro from micro) is predicated on the fact that with the coordinated motion of their components by which their structuring is defined they expand dimensions of space time thereby providing access to otherwise inaccessible or

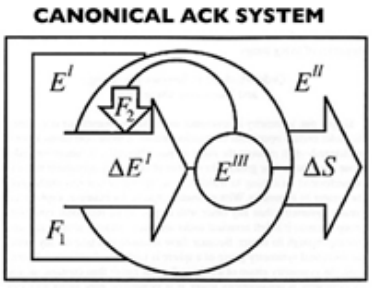

FIGURE 4: The "minimal ontology" of an ACK system where *EI* and *EII* are source and sink and *F1* the thermodynamic force equivalent to the steepness of the gradient, Δ*EI* is flow of energy from sink in, *EIII* is the "on-board" potential which feeds back with an internal force *F2* to amplify, and Δ*S* the entropy production into the sink [2, 6, 16].

unoccupied dissipative dimensions (sinks). The fecundity principle that characterizes planetary evolution and assumed as axiomatic by Darwinian theory but which it is logically forbidden from explaining is seen here from first principles (natural law). Rephrasing Russell [17][4], "every ACK system is a sort of imperialist, seeking to transform as much as possible into itself (and in the case of replicative ACK systems), and its kind."

Further, ACKLMEP solves the generic "origin problem" (otherwise the "problem of the population of one"(see [1], e.g, the origin of life, evolution *of* Earth at the global level as a single system, of human cultural systems/ economies (e.g, see Baker [18]). Orthodox evolutionary theory, dependent on natural selection, cannot explain origins, selection of macro from micro (not between replicators) and must depend on what amounts to miraculous origins stories (an infinitely improbably event that only had to happen once)[1, 6, 7, 19]

5. WHY/WHAT IS LIFE?

If we already understand that the opportunistic drive to fill out the dimension of space-time which captures the fecundity principle is already given by ACKLMEP, then the answer to the first part of this question "why?" we already know; it is to access and fill out otherwise inaccessible or unfilled dimensions of space-time following LMEP [16, 19, 22] . But *what* is it that distinguishes living systems from the nonliving? How would we distinguish a living from non-living system by a) watching it behave from the outside"; or b) looking at it from the inside? What makes the end-directed behavior of the living different? Living things are epistemic systems ("cognitive" or "intelligent" systems). Their end-directed behavior is determined by meaning, or intentional dynamics ("aboutness").

We do not invoke intentionality or intelligence for the end-directed of a river flowing down a slope, or heat flowing down a heat gradient [20]. Their behavior is determined by local potentials; remove the local potential and they "die" (their end-directed behavior stops). They are "slaves" to their local potentials [6]. The distinguishing feature of living systems in contrast is that they are characterized by learning, problem solving, exploration and discovery, constituting their ACKs over times and distances (dimensions of space-time) that are arbitrary with respect of their local potentials using instead their "on board" potentials (*EIII* Figure 4) and "information about" (meaning or semantic content) to seek out and access non-local potentials and access otherwise inaccessible dimensions of space-time. And we now understand, expanding on the work of Gibson [21] who first recognized that invariant properties in ambient energy distributions nomologically carry information about distal future ends to an agent's proximal present, that this is direct result of 1st law symmetry [4].

Living ACK systems are *replicative systems* (cf ."replicating systems"); they are ACK systems with replicating components. The distinguishing primitive of such systems if we look inside is that they carry a set of *rate-independent constraints* (RICs) that provides them the arbitrariness in the component production process needed to create, through trial and error, functions to move arbitrarily relative to local potentials and discover new non-local potentials. Examples of RICs would be base pairs in a DNA string the sequence which is arbitrary with respect to the amount of ATP used to replicate that sequence as opposed to another of equal length, or the words on this page (a higher order instantiation of the same primitive) the energetic difference in writing or reading a different sequence of the same length is inconsequential relative to which one gets used [2, 6, 20, 5].

6. HUMAN SOCIOECONOMIC (HUMAN CULTURAL) SYSTEMS ARE ACK SYSTEMS ON STEROIDS

Human socioeconomic systems or human cultural systems, social systems defined by tool use and language in the search, discovery and use of resources towards their own maintenance development, and growth are all minimally ACK systems. They are like all ACK systems deviation-amplifying systems or self-amplifying sinks that manifest all the generic properties of the class, including instantiation of the fecundity principle as a manifestation of the 4th Law, and their accelerating explosive growth from autonomous hunter-gatherer groups to the rise of chiefdoms, nation states, empires, to the globalization going on today is unmatched heretofore on planet Earth.

All ACK systems (Figure 4 "The Minimal Ontology") by definition are economic systems, and irreducibly so; flow

systems actively engaged in acquiring resources (ΔEI), doing work ($F2$) through the coordinated motion of their components , in the production growth of their own infrastructure, ($\Delta EIII$), "goods" more and less liquid and stored value ($\Delta EIII$) and "services" (pathways of flow ["trade"], and re-investment of stored value back into their own maintenance and growth, all the while having to balance "the books" (the balance equation of the 2nd Law). Just as the advent of living things and their ability to use meaning (information about) or 1st Law symmetry to explore, discover and access non-local potentials opened up vast new dimensions of space-time, so too did the advent of human culture with advanced language and technology signal; an entirely new level of opportunistic access to otherwise inaccessible dissipative dimensions [2, 6,19, 23]. ACKLMEP provides from first principles answers to the deepest questions regarding the origin and nature of life that post-Cartesian theories of evolution cannot, and so also for the social sciences.

In understanding and addressing the origin, growth, and development ("life stages") of human socioeconomic systems the universal generic level-independent properties of ACK systems are important to know and include: i) Threshold dependence, viz. order comes into being (revolution/system overturn) above certain minimal threshold levels of particular forces or potentials (=instabilities); ii) seeding by stochasticities/fluctuations/outliers/deviants from the average (micro nondeterminacy) that meets certain conditions, viz. small changes (fluctuations) lead to big (global) differences (system overturn/revolution =micro to macro changes; iii) path of development (evolution) governed by progressive determinism (from micronondeterminacy to macrodeterminacy), viz, progressive loss of degrees of freedom (accessible microstates), viz., alternative paths or outliers dampened (suppressed = noise, conformity rules); iv) replicative ACK systems (all living systems including human socioeconomic systems) show generic process of senescence ("aging") where flexibility, adaptivity in early stages leads to brittleness, hollowing out of insides, as larger leading parts sequester (pull out) increasing amount of value at the deprivation of the smaller components leading instability, fragility, loss of variation and hence pathways out making them increasingly more vulnerable to collapse, e.g.,individual humans, ecosystem succession an civilizations).

7. CONCLUSION

The ghost of Cartesian metaphysics continues to haunt the social sciences today from the relativistic, postmodern anti-realism that dominates them to equilibrium models in macroeconomic theory. The first leaves us in dangerous place regarding the growth of irrational group think, and both without real hope dealing with the serious and dangerous problems confronting global civilization and instead enable them. Radical income disparity that continues to grow, for example, is just the hollowing out of late stage development that signals fragility, instability and susceptibility to collapse. This is seen in forest ecosystem succession where in late stage succession (think giant redwood tree) almost all the value has been shunted to a very small percentage of the larger leading parts and the majority of the tree hollowed out (effectively dead). Such systems are fragile, vulnerable and unstable to small fluctuations, e.g, a spark bringing on a forrest fire, or viruses that seed pandemic like the case of COVID-19 in the world we are living in a clear example. Current orthodox models by virtue of their decoupling from the natural world have put us in a perilous place. The future will largely be determined by the extent these older models or world view are abandoned or not.

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[1] This paper is a brief summary and companion piece to the Plenary Lecture presented June 23, 2020 to the Thermodynamics 2.0 Conference of the IAISAE https://www.youtube.com/watch?v=500QAKfTDpE&feature=youtu.be

[2] The 4th Law say about spontaneous ordering but it should be clear how the universal ordering principle is derived from it: 1) *If* LMEP, and *if* order produces entropy faster the disorder (the balance equation of the 2nd law), *then* the world can be expected to opportunistically produce as much order as it can whenever it gets the chance [2].

[3] A more rigorous definition of the often used terms "self-organizing" or "spontaneously ordering system to eliminate conflation with misuses of the terms to, e.g, refer to patterns generated by algorithms in computers [19].

[4] "Every living thing," wrote Russell, rewording Darwin, "is a sort of imperialist, seeking to transform as much as possible of its environment into itself and its seed," and what is seen here as a special case of ACKLMP where the components are replicating.,