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The Fourth Law of Thermodynamics (LMEP) and How It Makes the World

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Review

The Fourth Law of Thermodynamics (LMEP) and How It Makes the World

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Abstract: Founders of quantum theory have pointed out the irreducibility of living systems to quantum mechanics. Quantum mechanics is never violated they rightfully argue but works under a set of active macroscopic constraints that selectively order the behavior of the micro components and these constraints are not reducible to the reversible, causally closed formalism of quantum mechanics. The whole of biological evolution is characterized by the production of increasingly more highly-ordered levels of such macroscopic constraints and biological evolutionary theory has no account for this either. It is assumed outside its theoretical first principles. In fact this generative macroscopic ordering, the production of increasingly more highly differentiated levels of order—more things, more kinds of things, cannot be explained *within* biological theory because it is generic to the universe itself. Irreducible to quantum mechanics this begs the question of fundamentality in physics. Fundamental laws in a universe defined by active macroscopic ordering, level-building, and differentiation must be able to causally cross levels, and more importantly explain why there is any level-building at all to begin with. The laws of thermodynamics are fundamental laws in this sense, and 4th Law path selection explains the generative universal ordering and differentiation ("complexification").

Keywords: 4th law of thermodynamics; evolutionary theory; complexification; cognitive theory; fundamental physics; information; self-organization; spontaneous order; time-translation symmetry; universal evolution

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1. Introduction

The present paper which is at core about the 4th Law of Thermodynamics path selection, proceeds by layering across multiple levels. This is not simply because the subject itself is multi-leveled so that it requires 'cross-sectionality' to address it, or because empirically it is a multi-leveled world in which we find ourselves, but also because it is central to the substantive contribution of this paper which is to show *causally* and universally why there are any levels or level-building at all to begin with and how they come into the world. The paper includes a running discussion of metaphysics. This is because our view of what the world *is* (ontology) and what we claim to know about it and how we know it (epistemology) effectively determines the kind of questions we ask and the answers we allow or deny and this is also central to the substantive contribution of this paper. If your ontology is that the world is flat, you are going to have a theoretical problem with people sailing around it, and if you are intent on insisting on your ontology you may be forced to deny that they do.

2. The Measurement Problem, Irreversiblity and The Universality of Theories

Some three decades ago physicist David Mermin [1] wrote a well-quoted paper regarding the deep problems with quantuum mechanical theory, not for its success as a highly (or one might concede spectacularly and revolutionarily) successful tool or formalism (an epistemic instrument) allowing us to calculate quantuum states for certain well-constrained and defined very small systems,

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but as a complete or universal theory that tells us something definitive about reality (ontology). As the reader might guess, Mermin was talking about the "measurement problem". Reviewing in simplest, most abbreviated terms, the problem is that prior to measurement, the quantum side of the "Heisenberg cut", the observables under investigation, the precise positions and momenta of a particle, on quantum theory do not exist at all, nor in fact, do any particles. The only existants (the only ontology assumed) in the formalism prior to measurement are probability waves with no precise position or individuation at all. It is only with the act of measurement we get the "collapse of the wave function" (the other side of the Heisenberg cut) and actual particles which now behave in a classical way. That the problem has far from having gone away is evidenced by the fact that just recently it was the focal issue of a featured lecture by theoretical physicist Sean Carroll before the American Institute of Physics (AIP)[2] where Carroll re-iterated and expanded on Mermin's concerns. Specificlly, for emphasis, it is that from the common interpretaton of quantum mechanics, the "Copenhagen Interpretation"[1] the "classical world" (which from the usual view of physics is construed as the world we live in and know), prior to being measured does not exist. It only exists after it has been measured (or is sometimes more generally put "observed")[3] that it is effectively brought into being.

There is not the slightest intention here to develop the particular case of quantum measurement in any even remotely exhaustive or detailed way[2], but there are some very straight-forward substantive theoretical points of fundamental import that fall out of it, both ontological and epistemological (in fact where they collapse to one and the same), that are central to the subject of this paper. Namely, questions about causality, what is and is not rightly considered "fundamental" in physics, and more particularly about the nature of the active, end-directed, agential and generative nature of the world, and how it develops, or evolves in the universe. What concerned Mermin, and I also believe the main concern for Carroll too, is the extreme instrumentalist turn recent science[3] seems to be increasingly taking that ends up sidelining many of these deepest questions. What both were/are concerned about regarding the measurement problem is not only how it has been dealt with by the larger contemporary physics community since the inception of quantum mechanics in the first half of the last century but also how it is taught in universities to up-and-coming physicists today. "(T)o sum up the Copenhagen interpretation," Mermin wrote [1] [p. 89], it is to "shut up and calculate!". "But I won't shut up", he said, I "think there are still important things [perhaps very, very important things] to know (about the world)…including how certain powerful but flawed verbal and mental tools we [often take] for granted continue to infect our thinking…they are so sedately practical, they deprive us of the stimulus for exploring some very important questions."

Carroll, nearly three and a half decades after Mermin was reiterating this same concern and the fact that the measurement problem is still being pushed under the rug today noting that if current university students studying quantum mechanics raise the measurement problem, or the cascade of problems with quantum theory following from it, they are told "don't ask those questions!" just learn the equations or, as Mermin previously said "shut up and calculate"[3]. This kind of bracketing out problems from scientific inquiry to protect a paradigm or immunize the core assumptions of a theory from challenge is a textbook case of the irrational component in science that Khun, Lakatos and many other philosophers of science have pointed out in the history of science. To examine how seriously this bracketing has been done in this particular case of quantum mechanics in contemporary physics in 2016 Sujeevan and Nielsen [5] conducted a study in which a survey was sent to better than 1,200

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[1] There are actually a number of versions of the Copenhagen interpretation, but for our purpsoses they all converge on the same general idea.

[2] There is a huge amount of literature out there in the discourse on the philosophy of science, and also in the popular literature (some of which gets pretty woolly), but Carroll is not a bad place to start.

[3] "Instrumentalism is the view that the value of scientific concepts and theories is determined not by whether they are literally true or correspond to reality…(but that they) should be thought of primarily as tools for solving practical problems rather than as meaningful descriptions of the natural world."[4]

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physicists at 8 major universities on the fundamental theoretical ground of quantum theory. The results of the study the authors wrote "revealed that..only a minority of physicists were familiar with the foundational concepts of quantum mechanics…raising the question of what is required of a physical theory?" [4] [p.1][4]. Namely, "is it enough" they wrote, "that its formalism [for a very limited and constrained range] is able to make predictions, or does it need to give an explicable description of what is being described by the formalism" which clearly the quantum mechanics formalism does not do.

The study showed clearly that there is good reason for Mermin's and Carroll's concern. It showed that under the current dominant paradigm, or core assumptions of quantum theory, that in practice the deeper metaphysical questions (viz., ontology [what reality *is*] and epistemology [what can be known about it, or how it is that we can know something]) are pushed so far outside the discourse that to a very large percentage of today's professionals they effectively *do not exist at all*. The history and philosophy of science has shown repeatedly, however, that it is just the anomalies (or by deconstruction, what is left out or avoided) in a theory that with their solving point the way to the discovery of more expansive, deeper, and explanatory theories. In fact, there is very deep issue here with the Heisenberg cut that is fundamentally deeper and transcends the particular case of quantum mechanics that has been haunting scientific inquiry in various forms from its ancient beginnings. Doing a little fast and dirty reverse-engineering, forensics, or deconstruction with the quantum measurement problem readily shines a light on the issue. The central problem for quantum theory, the one that forces it, like it or not, into an extreme instrumentalist stance, and then as a consequence, although rarely acknowledged, *give up any claims to being a universal theory* is that to collapse the wave function, that is for the quantum formalism to work, it requires a classical measuring device that is not described *within* quantum mechanical theory. The theory depends on it to work, but the existence (ontology) of the device sits outside its explanatory framework. For a theory t*o qualify as a fundamental or universal theory it would have to encompass and account for both sides* of the Heisenberg cut and this is just what quantum mechanics does not, and cannot do.

Formally, that is looking at its metaphysical structure or shape rather than the particulars, the cornerstone of the problem identified here goes way back to ancient times. In particular, it is a species of the more general problem we have called elsewhere the "Problem of Parmenides" (e.g., [6], see also Hodges and Fowler [7]). The pre-Socratic Parmenides, the reader may recall, postulated a true reality of perfect symmetry (a homogeneous sphere) claiming that the manifest world of change we live in and experience is only an illusion. All the later Eleatic arguments or "paradoxes" regarding change follow from this. The "Problem of Parmenides" was that his ontology (what he claimed true reality was) had no place in it for him as a postulator, or the epistemic act of his postulating (illusory or not). As soon as he had a thought, made an observation opened his mouth to pontificate about it, or engaged in any kind of epistemic act at all he would have irreversibly broken the symmetry of his hypothesized changeless time-symmetric reality, thus violating and falsifying his claim and in fact his own being. Any and all epistemic acts, claims, thoughts, or expressions of a theory even as illusions are all *irreducibly irreversibly temporal*. In other words, they are all *processual*, and processes do not and cannot exist in a Parmenides' static world of unchanging perfect symmetry. They automatically break Parmenidean symmetry and can only thus exist outside or in a different world than the one he postulates. His ontology (or first principles), had no place in it for his epistemologizing, or more strongly, as we have said, his being. That is the "Problem of Parmenides".

The formal equivalence to the Problem of Parmenides and the measurement problem in quantum mechanics is straightforward. In both instances the epistemic part (the assertions of Parmenides and the act of measurement respectively) of each of the two systems is unaccounted for, or more definitively not even tolerated if not simply forbidden by the first principles being advanced

[4] Among other things, the survey showed that regarding the various, extremely different, interpretations of quantum theory (e.g, Copenhagen, De Broglie-Bohm, "many worlds" or "many minds" etc.) less than half could agree on any one of them although the Copenhagen interpretation had the greatest number at 39%, and a similar number said they just did not know enough about the issue to offer an opinion.

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or covered by the theory. Neither theory of course, independently, can clearly thus stand as a universal or fundamental theory. The extreme instrumentalist account of the current received view of quantum mechanics ("don't ask those questions, shut up and calculate") avoids the issue by effectively stating up front it will not address it (e.g.see Bohr for the issue in the early days of quantum mechanics [8]). Regardless, however, for those understandably committed to not shutting up and instead asking what are actually the fundamentally problematic questions, the "Heisenberg cut" can be seen as a later version, although a compounded one, of the "Parmenidian cut" and the Problem of Parmenides. In fact, formally the problem was effectively built into the foundations of the modern scientific worldview well before quantum mechanics as the "Cartesian cut" with what became the hegemony of Cartesian metaphysics in the early days of the 17th century scientific revolution.

Drilling down a little more deeply, however, now takes us back to the measurement problem to highlight the actual fundamental theoretical aporia at its heart that is often pushed under the metaphysical rug even by those who like Mermin, Carroll, and others who have otherwise served to shine a light on the measurement problem in general. In particular, the measurement problem is almost entirely given as arising from the fact that to get quantum mechanics to work there needs to be a classical measuring device outside the theory to collapse the wave function. While this is certainly correct, couched in this way it tends to obscure the deeper part of the problem. Namely, because it is not the measuring device *per se* that collapses the wave function. It is the *act* of measurement that collapses the wave function, and the *act of measurement is irreducibly time-asymmetric (irreversible*).

More broadly, as in the case of the epistemic act of Parmenides of which the measurement problem is a special case, the act of measurement is *not a thing but a process*, and the fatal problem here is that *both* quantum mechanics and classical mechanics are completely time-symmetric (reversible). A physics reduced to time-symmetric equations and efficient cause whether quantum mechanical, classical mechanical or otherwise, will never be able to account for how a measuring device, the act of measurement (or epistemic act of *any* kind) got there, or how it could work. In regard to such theories, which are *causally closed* in this way, it is an anomaly by definition right out of the box. In different terms, for the act of measurement[5] (or any epistemic act) to become an existant in such a theoretically impoverished physical world will always require that it be assumed or brought in extra-physically (= magically, or supernaturally) from outside that world or universe. Generically, then such ontologies instantiate the generic Parmenidean cut from day one. This may be good instrumentalism, but to confuse it with ontology is to make what Whitehead termed "the fallacy of misplaced concreteness"[9]. In any case, it is an ackowledgement (although it is not often openly acknowledged or even recognized) that such a theory *ab initio* cannot and can never be or qualify as a universal or fundamental theory.

3. The 1st Law of Thermodynamics, Perpetual Motion, and the Denial of Dualist Interactionism

The nature of this impoverished ontology or paradigmatic view, that necessarily leads to the consequence of extra-physical conjuring should not be surprising once it is understood how deeply, as we have discussed elsewhere in more detail, it is built into the Cartesian metaphysics at the foundations of modern science [e.g, [10,11]]. While it was Newtonian physics that was dominant in the 17th century and thereafter, it was Descartes' metaphysics that set the ground for the reductionistic "dead" (static, reversible) mechanical worldview that became entrenched in modern science across the disciplines ever since. It was here that physics ("matter") and psychology ("mind" or the active epistemic, creative, end-directed part of the world) were very literally *defined by their mutual exclusivity* at their modern origins (the "Cartesian cut") [11–13]. "Matter", or the physical world (*res extensa*), was said to consist of inert, immutable or eternal, reversible, quality-less particles (not coincidentally little Parmenidean spheres) completely defined by extension in space and time, reversible deterministic laws, and reduced to efficient cause, while "mind" (*res cogitans*), the active,

[5] Or even a statically conceived measuring device, since in that case it would have to be *actively* and intentionally time-asymmetrically (irreversibly) constructed.

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striving, epistemic end-directed part of the world was taken to be unbounded in space and time (not extensionally defined) and immune from physical law.

This disjunctive removal of all the active, creative, end-directed behavior, and particularly in this case the epistemic part of the world from the physical world was a compromise of necessity made with the religious dogma of the time that enabled science to flourish in harmony with the church[6]. It kept the "watchmaker", master designer, or world orderer intact *outside* the Newtonian machine as the Church would have it be. A reversible, reductive, "dead" physical world of this kind then itself became "proof" for the existence of God, as Boyle's (and his younger protege Newton's) remark that it was precisely because the universe was like the well-ordered clock of Strasburg-Cathedral that it must have an intelligent creator made clear [12,13]. Humans were seen as somehow dualistically situated with "mind" outside the physical world or nature, and body within it dualistically interacting with the "clock" towards divine ends. It was a world where at that time the stars, the sun, the earth, and even life upon it with the exception of the portions worked by man (sic) were thought to be essentially eternal. What characterized the mechanical world view was a belief in the *immutability of nature*.

Leibniz, recognizing the formal, and fatal, problem with the requisite "dualist interactionism" this necessitated was an early critic of Cartesian dualism [11,14,15]. Presciently grasping what would later be identified as the 1st Law of Thermodynamics[7] Leibniz recognized that for one thing to interact causally with another there had to be something conserved over the interaction. That is, *persistence through change*, and for "mind" as an unextended lawless thing, by definition, there is no such conservation. For mind (or any extra-physical agent or agency) to causally act upon the physical world, that is to *exert some force* upon it, it must meet it at some particular place in space and time. But for Cartesian mind to do so would require it becoming extensively defined and thus on pain of contradiction becoming that which it is not. Dualism, in every one of its surrogate forms or guises, is defeated on this point alone. Expressed in different terms, again following directly from the later discovered 1st Law of Thermodynamics, the possibility of dualist interactionism is readily denied (falsified) full stop with the *impossibility of perpetual motion*[8] of the first kind (perpetual motion achieved through violation of the 1st Law). More generally, starting to bring together the discussion here so far, in each case where we find a "dualist cut", whether Parmenidian, Cartesian, Heisenbergian, or Kantian, who following Descartes added a biology vs. physics cut (the "autonomy of life" and the "teleomechanics' [see below and [11,12]] that follows from it), we see the irrational and hopeless attempt to float an ontology divided into two formally incommensurable parts. In all such cases the explanatory ground for all the the active, agential, creative, and epistemic part of the manifest unniverse must be magically (extra-physically) smuggled in or simply assumed dualisticall *ad hoc* from outside the theory.

4. The 1st and 2nd Laws of Thermodynamics as Universal Entailments and the Question of Fundamentality in Physics

With the point attributed to Leibniz above, and his prescience regarding the 1st Law of Thermodynamics, and at the same time the irreducibility of time-asymmetry or irreversibility in the act of measurement (and any epistemic act of any kind) we can see how the laws of thermodynamics

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[6] The "marriage of the Pope and Galileo" [12]

[7] Like Carnot nearly 200 years later, he had the conserved quantity wrong, but understood the idea that there had to be one and what the implications of this were

[8] Kostic [16] has done a great job addressing the catastrophic unstable consequences of such an event in regard to the 2nd Law and the same applies to a violation of the 1st ("getting energy from nowhere"). In simplest terms, such a creation or discovery, in this case violating the 1st Law or conservation of energy, would puncture the very fabric of space-time and in one form or another implode or explode the universe, if such a concept ("universe") would even have any intelligibility at that point.

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begin to enter unavoidably into the conversation. This is hardly an accident, and it is simply just because of their universality or fundamentality. They unavoidably come into the conversation, because, as we have already shown, they are *entailed* by the very (f)act of conversation itself, or epistemic act of *any* kind. This draws attention to the fact that the laws of thermodynamics, developed more fully throughout this paper, are very special laws of physics that sit above the ordinary laws of physics, because without them, for example the *time-translation symmetry* of the 1st Law (the conservation of energy or strictly after Einstein [16] mass-energy conservation), there could be no other laws at all, no act of measurement, no measurable quantities, or, in fact, remarkably and profoundly no projectible predicates of any kind whatsoever. Restating for emphasis, in a way that coincides with the way Leibniz was able to recognize it, there is *universal entailment* relation with all of the processual "things" just mentioned and the time-translation symmetry of the 1st Law (they could not happen without the 1st Law being true).

Yet, while the profound significance of the 1st Law is hard to over emphasize, taken alone, the world might be not be far off from the static changeless ontology claimed by Parmenides. To paraphrase Parmenides' theoretical Pre-Socratic rival, Heraclites, reality is, from the origin of the universe as we know it through its entire evolution right up until present times, including all the processual things we have already focussed on within it, *a world of flow* [11]. While entailing the 1st Law, as Leibniz essentially pointed out, the act of measurement, and any epistemic act, (even imagining illusory non-existent things like flying pigs or unicorns, Parmenides static ontology, or the reversible deterministic physics of Newton, or quantum mechanics) as already discussed in the first section above, is an *irreducibly irreversible* (time-assymetric) process, and this points to an unavoidable second irreducible entailment, one that is both dependent on the first, but at the same time governs what does and does not happen in regard to it, and in fact tells us why anything should happen at all. And this is the 2nd Law of Thermodynamics.

It is with the 2nd Law that irreversibllity or time-asymmetry and end-directedness entailed by the act of measurement nomologically comes into the world (it could not happen without the 2nd Law being true). To put the universality or fundamentality more strongly, there is a universal entailment relation not just with the the act of measurement, but with every thing that happens and has happened in the known universe from its very beginning through the evolution of life on Earth to the present, and this is the 2nd Law. And the same is true for the 1st Law. In fact, the two are mutually entailing. That is just how fundamental they are. For those who are unwilling to accept the ontic necessity of this, or who as ontic mechanical reductionists want to keep thinking that this itself is an illusion then we would ask they start with the task of constructing a perpetual motion machine[9].

4.1. Fundamental Physics as Bottom-Level Ontic Reductionism = More Parmenidean-Cartesian Incommensurable First Principles

The universality of the 1st and 2nd Laws compells us to focus more fully on the question of *fundamentality* in physics, what should qualify for it what should not. Unfortunately, the most widely held view of fundamentality, in various forms (explicitly recognized or not) goes hand in hand with the kind of ontic mechanical reductionism in direct descent from the Parmenidean-Cartesian lineage we have already been outlining. Currently, albeit in various slightly nuanced versions, it is generally concomitant with the idea that "fundamental physics refers to physics at or below the atomic scale" [e.g. [17]]. More broadly, it is the belief that there is some "deepest" and on this basis most fundamental level of reality comprised of some smallest, indivisible "elementary" or fundamental "particles" wherein all the causal efficacy of the world resides. This "bottom-up" view (micro-mechanical "ontic reductionism") holds that once we understand the forces and laws governing the interactions of these particles at this level then this would explain everything else all the way up, and give us a "theory of everything". It is assumed that the laws governing the *causally closed* efficient causal relations between these fundamental particles at this fundamental level are then also the

[9] Again, see Kostic [16] for a great discussion of the cataclysmic consquences that would follow if such a thing were ever actually done.

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fundamental laws of physics, meaning universal, since on this view all causality for the manifest world is located at this bottom level. Macro causality, which would dramatically break this causal closure goes completely unrecognized and in fact is largely if not completely denied from this point of view. The two senses of "fundamental" here are thus one of a fundamental level of particles ("things") and the two, that of fundamental laws. From the view of micro-mechanical ontic reductionism these go together.

By giving ontic supremacy or exclusivity to this postulated bottom level, that is, what is taken to be "truly real", seeing the place of this metaphysical point of view as a direct descendent of the Parmenidean-Cartesian bifurcated metaphysical paradigmatic lineage is impossible to avoid. Although expressed in many different ways, the view that everything above this "fundamental" level of physics is less real, nothing but an epiphenomenon, or more straightforwardly simply an illusion that in any case has no causal power of existence at all, goes hand in glove with this doctrine. Starting with these paradigmatic assumptions about fundamentality philosophers of science have spent decades, and decades arguing with each other filling journal pages with what are essentially sounds from a Cartesian echo chamber where the problems they are ostensibly working on in fact are simply artifacts of the incommensurable first principle assumptions they begin with. For example, Merrick [18], [p. 47] in a paper entitled "No statues", argues the "nothing but" point of view common to this discourse. "Your visual experience" he says, "…is caused by *atoms arranged statuewise* and not the statue". There is nothing real from this point of view except arrangements of atoms. The manifest world may seem as obvious to you (as it does to me) as the nose on your face (as mine does to me), but from this point of view be assured there are no noses, just atoms arranged nosewise, and, in fact, no you or me, just attoms arranged youwise and mewise.

So clearly there are some fairly deep problems here. The *reductios* from this view compound readily. For one thing there is the issue here of why Merrick and others in this philosophical discourse wanting to support this reductionist bottom-up metaphysic regularly pick "atoms" as the their fundamental level of reality when it is surely true that in any case these cannot be *the* elemental or fundamental unit or level of ontology (usually "matter") they would want to plant their flag on. By current theoretical doctrine atoms are surely not the (as yet imaginary and still undiscovered) bottom or fundamental level since they are made of electrons, protons, and neutrons, and these, in turn, as it now goes, are made of quarks and gluons? Further, it is generally held that in large part due to the failure to unify gravity and quantum mechanics there are still vastly smaller elemental units, the subject of string theory, not yet identified that might perform this unification[10].

4.2. It Is a Time-Asymmetric Process All the Way (Up and) Down

Regardless of how this particular detail plays out, what can be agreed on, however, is that at present *no fundamental level* of physics (in/of the universe) at this point has been identified. However, if Merrick or others want to start with atoms in the non-sculpture sculptures they want to start with they must concede they are already dealing with macroscopic entities that were not even in existence during the early life of the universe, and thus *cannot be called fundamental* in this sense at all. They were *processually* produced as component productions interior to larger pre-existing macroscopic time-asymmetric *process structures*, (more technically, "autocatakinetic systems" [ACK systems]) discussed more fully below) in this particular case stars. Continuing now to try and put this in Merrick's terms we need to say of course there are no stars just atoms arranged starwise, but since the atoms that comprise a star, and its exudes, in the later stage of its "life" cycle did not exist in the earlier part it becomes impossible to do this also. If there is something that is fundamental here, it is the *causal process* that produced the atoms, that therefore ontologically precedes them and that in this case is clearly more fundamental.

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[10] String theory at best is controversial and the number of increasing critics suggesting it is essentially a failed approach to fix something that cannot be fixed and that the unification of physics needs come from a completely different direction with set of different starting assumptions.

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This now segues well into what is actually the central and deeper problem with Merrick's defense of ontological and causal reductionism. It is that his claim that there are no statues just "atoms arranged statuewise" begs the crucial question of where it is that all this arranging (hereafter "arranging" = "ordering") comes from? Statues are highly ordered systems. Static order to be sure, but highly ordered, nevertheless. What is more, and even worse for Merrick, is that having picked a cultural artifact for his exemplar (oftentimes done by those under the trance of this metaphysics), he has picked a highly *intentionally* ordered system as his example. Sculptures are intentionally macroscopically ordered by sculptors who are themselves highly ordered[11]. Merrick does not answer where any of this ordering or arranging and intentionality comes from. He depends upon it. It is just assumed or given *ad hoc* from outside his reduction. And we need take this one step further and that is directly to the epistemic act performed by Merrick himself in his postulating, arguing and writing down of his thoughts.

From the moment he does so, has a thought, touches his keypad, opens his mouth on this subject, as we have already seen above, he (writing as a first person singular "self") is engaged in an irreducibly irreversible (time-asymmetric) process over a conserved quantity of higher macroscopically ordered ordering that takes him even one step further removed from the "nothing but" ontology he wants to claim. His own act literally sits outside the fundamental ontology of his theory. Minimally, as we have shown above, there are universal entailments in such an act, specifically *persistence*, the time-translation symmetry of the !st Law, and the force driven *change,* irreversibility or time-asymmetry, of the 2nd Law. With the reflexivity (self-reference) involved in such an act, we must importantly add the 4th Law of Thermodynamics too (discussed more fully below), but the bottom line is that his ontic reduction leaves out the fundamental part here, and that is the *process and the causal universal laws that drive or bring it into being and produce it* in the first place.

If Merrick's problem sounds a lot like the Problem of Parmenides—the Parmenidean, Cartesian, Kantian, or Heisenburg cut, or the core aporia of the generalized measurement problem—it should, because underneath, that is metaphysically, it is completely formally *identical or isomorphic*. If fundamental physics, or fundamentality, is conceived and causally closed, or reduced in the way he wants there is no way to get to the manifest multi-leveled time-asymmetric macro universe that we experience all around us, and more particularly its epistemic dimension which Merrick invokes as his example[12] (see also [7]). The view that everything above some imagined single fundamental level is an illusion, or epiphenomenon goes hand in hand with this kind of fundamentality only highlights its deficiencies, but beyond that it unavoidably recapitulates the Problem of Parmenides whose ontological claims, his claim about what true reality was, had no place in it for him or his postulating. Bohr, writing on the irreducibility of life to quantum mechanics, wrote the following:

"…quantum mechanics is concerned with the statistical behavior of a given number of atoms under well-defined external conditions, while we are unable to define the state of a living being in terms of atomic measures; in fact owing to the metabolism of the organism, it is not even possible to ascertain what atoms actually belong to the individual" [19].

His solution to the life/physics, or mind/physics, unfortunately was also his dualistic principle of complementarity, the principle he had first invoked as his version of solving or getting around the measurement problem in quantum mechanics. He got the irreducibility of course quite clearly. His solution however, essentially leading back to two irreducible parts to the world, falls, on the argument first made by Leibniz regarding the time-translation symmetry of the 1st Law.

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[11] The reader will be spared from the continued *reductio* at this point, viz., not really scuptors but atoms arranged sculptorlike etc., since presumably the point has already been made.

[12] Its implicate decoupling of perception, or in effect the epistemic part of the world from physics if it has not been sufficiently hammered here, it should not go unrecognized fits lock step with the Cartesian metaphysical tradition flowing again from Parmenides to Descartes and all the other dualist "cuts" we have been writing about here. An impovershed ontology leads to an impoverished epistemology.

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4.3. The Fundamental "Thing" Is Process and the Laws That Account for It Are Therefore the Fundamental Laws

Beginning with a claim by Crumpa [20], and then developed by French [21], and Shaffer [22] in that order, they have articulated a direction for addressing the question of what the requirement for fundamentality might more accurately be or more legitimately mean in a way that makes important points consistent with what is being developed here. It sits well with rejecting the idea of some yet to be found irreducible fundamental level of particles—a fundamental, or bottom-level of reality where, denying macro causality, all causal power reversibly resides, and to which everything above this level can be effectively dismissed as somehow less real or a "mental" illusion (specifically including time-asymmetry itself). Crumpa's assertion of what fundamentality is, as as highlighted by French "requires that any cadidate for fundamentality must be 'cross-sectional'", that is it must be able to *relationally or causally cross levels*. This immediately gives ontic equality to every level (all levels are equally real) vs. the causally closed bottom-up view which as Shaffer [22] has written gives true reality or ontic necessity residing only fundamentally at a bottom level as the "actually" or primarily real and the rest of the world becomes causally impotent "if real at all".

Expanding on this view which immediately opens the study of the world that to one that admits levels and kinds of causality, levels of macrocausality actually consistent with what we scientifically observe, or experience in the manifest world that are clearly well-beyond efficient cause. It allows us to include in our observations and theorizing an ontology, and consequently an epistemology that does not paradigmatically bracket out the universalities that characterize the processual world we see and measure. In fact it leads to a bracketing in the other direction, that is facing full stop the impossibility of bottom-up, reversible, ontic reductionism. Not as, it has in many cases been, the source of extremely *instrumentally useful models, but as ontology.* As Bohr, (above) among many other pioneers in science have well recognized, for example, while in general everything going on inside a living system can be seen as obeying the principles of quantum mechanics, the system itself is not in the least reducible to them. Quantum mechanics can be said to hold, re-quoting Bohr, operating under a set of very "well-defined" constraints but these constraints are *not* given by quantum mechanics. It is these *macroscopic constraints* that effectively order, that is, *selectively determine the behavior of the micro components*. To qualify for fundamental in Crumpa's expanded terms a fundamental law must be able to causally cross these levels, and this would include the creation of the constraints and where they universally come from. All of this is something well-beyond the reach of quantum mechanics (or causally closed hypothesized bottom level) which cannot account for the creation of the constraints, or the causal ordering they instantiate.

Clearly when we are talking about living systems we are already talking about levels of order (dynamic constraints) built on other nested levels of order over evolutionary time. This level building as we have continued to emphasize is thus *irreducibly processual*, that is progressive, and irreversible (time-assymetric). And if we look back over the history of the universe, it is this process from the beginning, not of particular "things" *per se*, but of "thing making", the number and kind of which has been progressively and dramatically increasing over time, that is clearly fundamental. A fundamental physics thus must not only *causally or relationally cross levels*, it must explain *why there are levels at all* and explicitly account for the progressive, opportunistic and generative level-building *process* that universally causally characterizes and explains it. Thermodynamics, in particular the expanded understanding of its laws we now have in our hands today *is* fundamental physics in this deeper sense of fundamentality.

In complete opposition to the bottom-up ontic reductionist's claim of fundamentality, for which there is no evidence and which is in incommensurable causal conflict (e.g the Parmidean cut and all its heirs) with the manifest, experienced or studied (measured) world we see around us, the laws of thermodynamics are entirely level-independent, applying to all levels and all scales while not reducible to any one of them. In addition, the study of thermodynamics is the study of mass-energy flow, and when we look at our evolving universe we see at all levels, and with all "things" that it is exactly that. Rather than comprised of fixed or static things, all of it from top to bottom as far as we can see is processually characterized by *identity through flow* [3,23,24]. That is things brought into

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being, not fixed in number but increasing in kind, number and size, and developing into increasingly more highly ordered states. *All* in the end are flow structures, component productions of earlier flow structures, whose identity is neither static nor permanent but in all cases brought into being through end-directed, that is dissipative (entropy producing) energy flow, and this properly understood is the subject of thermodynamics.

Summarizing the view advanced here, the fundamental view of the the world, reality or ontology is, to underscore, first and foremost not static, not comprised of static eternal things, but *evolutionary*, and generative. *It is the process itself that is fundamental and the governing laws of this process are the fundamental laws*. Understanding this evolutionary process and the causal laws that govern it and has and is producing it, that is explaining it theoretically, has got to be the fundamental task of fundamental physics. This is quite different than the standard paradigmatic view that people are generally taught more or less explicitly today both regarding notions of fundamentality or of evolution. Currently, and still most widely, the term "evolution" is most generally taken to be a subject for biologists and not for physicists. The view here is different. It is that evolutionary theory *is* the fundamental job of physicists or theoretical physics. This by no means should be taken as a dismissal say of particle physics on the one hand or theoretical or evolutionary biology on the other. Far from it. It provides contextualization and grounding for both of them. It is taken as a way to actually further ground theoretical biology and theoretical psychology (cognitive science, mind-in nature, intentionality, perception, action, intelligence and so on) and account for things they cannot when theoretically separated from the physical world. The same can, in fact, be said for virtually every other discipline across the board that has been theoretically hampered by being forced into the other side of the Parmenidian-Cartesian-Kantian cut or divide and the irrationality, and empirically untenable position of teleomechanics (discussed more below), or a "dead" world of reversible physics on one side and some form of "magic" or extra-physical agential maker on the other.

Such cuts, summarizing briefly, are all in the end, as Leibnitz was one of the first to point out, imaginary impossibilities, impossible by virtue of the time-translation symmetry of the 1st Law and the time-asymmetry of 2nd Law. Stated more strongly, the 1st and 2nd Laws are *universal entailments* in all things processual, including the epistemic act (in whatever form, illusory or not), of which the act of measurement is a special case, cross-level, all the way through. Both laws are developed further through the next section of this paper which further lays down the theoretical ground for a fundamental theory of generative evolutionary ordering, with particular focus on the 4th Law of Thermodynamics and the way it, in concert with the other fundamental laws of thermodynamics, "makes the world".

5. Fundamental Physics Is the Physics of Evolution

On its surface it would seem hard to disagree with Dobzhansky's now well-quoted phrase that "[n]othing in biology makes sense except in the light of evolution" [25], but actually it contains a strong negative heuristic that brackets out the possibility of a full-blown universal theory of evolution (one that might actually explain biological evolution which current evolutionary theory does not) and the fundamental physics that would be needed to do it. What Dobzahansky does not say here because in contemporary discourse it is simply taken for granted is that what he means by the term "evolution" is *biological* evolution, or the evolution of life following from Darwinian theory, or natural selection. What this does then, largely transparently (invisible in any case to those schooled or indoctrinated under the Darwinian paradigm), is to continue the dominant post-Newtonian-Cartesian paradigm of radically separating biology from physics, —or the "autonomy of biology" from physics, maintained and argued by leading evolutionary theorists up to the present day [e.g, [26,27]]. It was Kant [28] arguing correctly that it was impossible for the active end-directedness or *telos* of living things to be accounted for by the mechanical, purposeless-particle worldview of Descartes and Newton but then, however, rather than questioning the physics, instead argued for the autonomy of life from it (the "Kantian cut"). The "dead" world of physics on the one hand and the *telos* of living things, viewed as vitalistic natural purposes (where "natural" means something that simply exists extra-physically *sui generis* in living things) on the other.

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This Kantian "teleomechanical" view, the belief in the incommensurability between life and its evolution from physics, became further deeply embedded into modern science, and theoretical biology with the "Darwinian Revolution" during the first half of the 19th century. Then, during the second half of the 19th century, with Boltzmann's apparent (but as shown below failed) reduction of the 2nd Law of Thermodynamics to a "law of disorder", the idea that the active and progressive ordering that characterizes the origin and evolution of life came to be seen as not only something outside the world of physics, but now as though it had the laws of physics working against it. This idea, the idea of effectively two incommensurable "rivers", the river of physics *flowing down* to disorder and the river of life, cognition and human cultural systems *flowing up* to increasingly more highly ordered, and differentiated or complexified states still sits at the core of contemporary science and the theory of evolution today [11,29].

As a theoretical first principle, the Kantian cut, the "autonomy of biology", or life vs. physics of course formally recapitulates all the fatal ontic problems associated with all such cuts. The central one being that the invocation of any extra-physical agency or *telos* immediatelly (as discussed above) comes crashing down *ab initio* by virtue of the universal entailments of the 1st and 2nd Laws. Both empirically, and theoretically it brackets out, as we will continue to develop here, the *fundamental universality of evolution* itself. So here, while agreeing with Dobzhansky's general idea that, nothing makes sense except in the light or context of evolution, we depart definitively with him that this is *biological* evolution. Instead, we re-write his statement to put this in the context of *universal* evolution:

Nothing (literally "no thing") in the world makes sense except in the light of the fundamental process of universal evolution and the fundamental physics (that is thermodynamics) that explains it.

The rest of this section works explicitly on both parts of this. First, what the fundamental nature, or ontology of this evolution is, and second what the universal physical laws it entails are (that explain it or are necessary for it to happen). The most fundamental thing we *can* say about the world as we have said is that it *is* evolutionary, that *it is an evolution*, and from the point of view asserted here this *is* ontic fundamentality. "Reality" put in different terms, is not a "thing" ordinarily construed but a *process*, and the "things" or components it produces in its evolution, are themselves, every one of them as far as we can see from the smallest to largest scale processual—characterized by *identity through flow* [11,13,30]. The whole of it is a process-producing process of processes. Below we look further at what this evolution is and then how it is explained theoretically with focus on the 4th Law of Thermodynamics as the featured player. We begin by looking in review at the current state of the generally received view of evolutionary theory, that is, Darwinian evolution by natural selection, and its deficiencies.

5.1. The 'Darwinian Revolution", the Problem with Darwinism as the Theory of Evolution, and the Processual Ontology of the Manifest World

It was Herbert Spencer, not Charles Darwin who first popularized the term "evolution" in a series of best-selling books during the middle of the 19th century that conceived of evolution as a universal process of progressive ordering accounted for by fundamental universal law. "Evolution" wrote Spencer [31] [p. 215], "is the transformation of the homogenous into the heterogeneous, the indefinite into the definite, or the transformation of the incoherent into the coherent [less ordered into more ordered]". This "law of evolution" as he called it is the same "whether it be in the development of the Earth, in the development of life upon its surface, in the development of society…from the earliest traceable cosmical changes down to the latest results of civilization" [31], [p. 10, see also [32]]. In short, Spencer's theoretical grasp, with not but the tiniest fraction of what we know today (his cosmology only went as far back as a rudimentary nebular hypothesis regarding the formation of our solar system) is remarkable. His contributions to evolutionary theory, where evolution referred to a universal process with biological evolution as a processual part rather than something *de novo* and autonomously separated from it, were effectively pushed to the side with the "Darwinian Revolution" and Spencer despite the high regard with which he was held in his time and through at least the first quarter of the 21st century (see e.g, Einstein's "Herbert Spencer Lecture"[33]) being marginalized as a minor player [29].

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5.1.1. The Reduction of Term "Evolution" from Universal to Biological

Scientific revolutions are defined by replacing one theoretical core with another, and what happened with the Darwinian Revolution was the replacing of the theory of evolution as universal ordering with a theory reduced to biological evolution as an autonomous *de novo* extra-physical process following from natural selection. In most straightforward terms this revolution, or change in core or background assumptions, hinged entirely on the redefinition of the term evolution and with it the scope of the evolutionary discourse [29] was profoundly diminished. It chiseled the Cartesian-Kantian cut, or Kantian teleomechanics right into the center of the evolutionary discourse along with all the generic system-theoretic aporia we have been discussing in the earlier part of this paper associated with it—an impoverished physics on one side of the cut and an impoverished theoretical biology on the other. When Darwinian theory became *the* theory of evolution the terms "evolution" and "Darwinism" effectively came to be taken as synonymous [34–38]. The central problems with this, all the consequences of taking evolution (now meaning reduced to the evolution of life) out of its universal and thus its universal physical context are highlighted below, but in the end, as we shall see, they all are parts of the same problem.

5.1.2. The 'Struggle for Existence' (the "Fecundity Principle") and Natural Selection as the Explanation of Evolution

Currently, while there are many brands of Darwinism (disagreements within the paradigm but that do not challenge its core assumptions), but what unifies them all under the single term "Darwinism" is the core concept of natural selection, the central principle according to which Darwinian theory both defines and is said to *explain evolution*. The "almost universally adopted definition of evolution" today, according to Mayr [39], [p. 12] "is a change in gene frequencies" following from natural selection. Evolution is thus defined as that which follows from natural selection and natural selection, as Popper [40] has pointed out, is lawfully entailed by, or follows from, a situational logic. Namely ***If*** certain conditions hold, ***then*** natural selection will ***necessarily*** follow. These conditions are: heritable variation, Malthusian closure (finite access to resources), and the *fecundity principle*, a biological extremum that captures, in Darwin's [41], [p. 266] words the active "striving [of every living thing] to seize on every unoccupied or less well occupied space in the economy of nature". Because "every organic being" is "striving its utmost to increase, there is the strongest possible power tending to make each site support as much life as possible", and given finite accessibility to resources (Malthusian closure), a "struggle for existence" necessarily follows leading to the selection of the fittest variants or the "survival of the fittest". Nature strives in Schweber's [42][, p. 38] words, paraphrasing Darwin, in effect to "maximize the amount of life per unit area".

5.1.3. Darwinism Must Assume Teleomechancially What an Evolutionary Theory Should Otherwise Explain

The deep deficiencies of Darwinian theory as a theory of evolution are readily seen. It assumes the most fundamental things that an evolutionary theory should otherwise explain. In particular, by assuming the fecundity principle, or the active striving of living things to fill out the economy of nature, that is, the *sine qua non*, or very *nature of life itself* in advance as given outside its theory Darwinian theory assumes what any robust theory of evolution must necessarily explain. This would not have been surprising to Darwin, who contrary to the narrative myth of the "Darwinian Revolution" which reduced the meaning of the universal term evolution introduced by Spencer to the one given today and projected back onto Darwin, he never imagined his theory of natural selection was a general theory of evolution at all [29]. It was the mechanism that explained adaptation in living things. This is clearly evidenced in the words of Darwin's most enthusiastic and influential19th century supporter Thomas Huxley ("Darwin's bulldog") who in his entry in the *Encyclopedia Britannica* at the time wrote that Mr. Darwin has made "numerous and important contributions to the problems of biological evolution…[whereas] on the other hand Mr. Spencer…has dealt with the whole problem of evolution" [43], [p. 212]. In fact, Darwin never even used the word

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"evolution" until the 6th edition of the *The Origin*, and the word is not found in the twenty-one chapters of the *Descent of Man* nor in any of the summaries of these chapters or the summaries of the fifteen chapters of the *The Origin* either [24,35].

For Darwin, the active striving of living things or the fecundity principle, that separated life from the dead world of physics was always assumed as something outside his theory. For him, the active striving or *telos* of life was simply "breathed into" otherwise dead matter by the Creator [41]. The dualistic Cartesian-Kantian lineage, or Kantian teleomechanics, with the two sides of the Kantian cut (*telos*, extra-physical or vitalistic ordering on one side and "dead" reversible matter following Newtonian laws and consistent Cartesian metaphysics on the other) is easy to see, and this is a fatal problem for Darwinian theory right out of the box if indeed it would want to be considered as a real theory of evolution. Given how it is defined, it always needs the very nature of living things, their active agential ordering, or the fecundity principle, imported "magically" (or extra-physically) *ad hoc* like so much *vitalism* from outside the physical world. In the first two thirds of the 20th century an attempt was made to give this a more respectable scientific cloaking (appearing somehow less theological or vitalistic) by imagining that life, or its special vital property, got inserted into dead matter probabilistically with a special *infinitely improbable* "origin event" that given enough time "only had to happen once". This argument relied on the assumption that there were as many as 4GY years before life arose on Earth (not much before the Cambrian)[13].

Discoveries in Paleobiology and biogeochemistry during the end of the last century, however, showed that life emerged on Earth not after many billions of years but, consistent with the fecundity principle, opportunistically virtually as soon after the planet's formation and meteoric bombardment had stopped sufficiently so that the Earth had cooled enough to keep the oceans from evaporating [13,37,44–46]. This destroyed the "given enough time" argument while at the same time, by implication, suggesting (for those not permanently blinded by the underlying Cartesian-Kantian metaphysics) that the *opportunistic ordering* so characteristic of the fecundity principle was to be explained by universal rather than magical biological principles (viz. the opportunism characterizing the fecundity principle could not be a special property of life since if it was causally operative in bringing life into being)[13]. Evolutionary theorists, of course, have allowed themselves to largely ignore this issue by the fact that they have bracketed it out of their work as evolutionary theorists (as with Darwin) which they take to start with life already up and running (e.g., [47]).

5.1.3. Magic Particle Reductionism and the Myth of the Selfish Replicator

In the later quarter of the 20th century, the teleomechanics of Darwinian theory gained prominence in the "magic particle" reductionism of "selfish gene theory" especially developed and promoted by Dawkins [47], and brought into cognitive theory (or theory of "mind") supposedly grounding the computationalist theory of mind with the "selfish algorithm" theory of Dennett [48,49]. Here to somehow explain all the opportunistic active agential ("selfish") striving of living things it is taken to be extra-physically inserted *ad hoc* into an otherwise presumed dead world of physics with little bits of "program" carried in "selfish genes" (or "selfish macros" for Dennett) as though they autonomously possessed this agential vitalistic property. Following discoveries in molecular biology (e.g, the discovery of DNA etc.) the focus of neo-Darwinism had become genes rather than organisms (as it was for Darwin's generation) as the target of natural selection. Then, to give support to the Kantian notion of the autonomy of biology Mayr from physics coined the term "teleonomic" defined as end-directedness or *telos* coming from a program [50]. On this view the *telos* of living things was then "explained" as being programmed into the otherwise dead world of physics by DNA. Especially Dawkins and then Dennett with "selfish replicator" or "magic particle" theory took this teleomechanical idealist reductionism to a further extremized conclusion, virtually

[13] Although even then, without carefully tweaking the initial conditions even this would not allow enough time even if increased by many, many orders of magnitude.

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decoupling genes or "macros" as "immortal" immaterial selfish replicators from physical reality altogether like so many immaterial Platonic forms[14].

This idealist ontological reductionism, or "myth of the selfish replicator" as Levins and Lewontin [51] have felicitously stated it takes "abstractions that have been transformed by fetishism and reification into realities with an independent ontological status" and then put them at the center of its theory. What further underscores the *reductio* of this attempt to smuggle all the active end-directed intentional dynamics of living things into the world with "selfish replicators" is that, as discussed in more detail below in this section, the *entire function of DNA strings depends on the relative inertness of their sequences*. They are by any common measure the most *inactive* components of the entire cell there are [e.g, [10,11,13,51]]. A large proportion of current origin of life theories today, which have hardly developed theoretically at all in the last thirty years still spend the largest part of their time looking for ways to discover the origin of the first "replicator" built on the idea that once you found one of these idealist agential "natural purposes" to use Kant's [28] term, all the active striving or opportunistic ordering of life and evolution would be explained as a result of their *de novo* extra-physical properties.

The problem of course, as above, is that no such vitalistically endowed replicator exists. DNA strands or genes, do not replicate themselves, they are *replicated* [13,14,23]. They are components of *replicative* systems (a particular kind of *autocatakinetic* system). Allowing that DNA sequences function as kind of algorithmic code, as with any such system the code must be written and read by a larger end-directed thermodynamic system (the replicative system of which it is a component). The *thermodynamic entailments* of such a system, following the thread from the previous section are the same entailments we have noted for the *act* of measurement, a higher-ordered evolutionary instantiation of the same general set of properties. The replicative "reading" and "writing" here are part of a reflexive (that is *circularly causal*) *irreversible act* and the unavoidably same necessary entailments of thermodynamic law. It is in these entailments, that is in thermodynamic law, and particularly the 4th Law, as we will continue to develop, and *not* in the essentially inert sequences of code (or some other Kantian vitalistic autonomous "purpose") that one finds the source of the *telos* or fecundity principle and active ordering that characterize the world.

5.1.4. Darwinism Has No Theory for the Progressive Opportunistic Evolutionary Ordering That Characterizes the Universe

Summarizing this section so far the punchline is that the most general and central problem for Darwinism as the theory for evolution, that is both as a definition for and an explanation of it, is that it actually has no theory for the opportunistic ordering that is the most fundamental property of life and the evolving world. How deeply this reduces the conception of evolution, that is the ontology of evolution, what the shape of it is, and what "things" it consists of is further illustrated with Figure 1 and two important points to take away from it here. If the study of evolution on/of Earth makes anything clear, it is that over its 4.6 billion year (GY) history, what we see from the origin and emergence of life to the globalization of human culture in the Anthropocene today is the *time-asymmetric or progressive* (meaning going in a direction) *and accelerating (self-amplifying) opportunistic production of increasingly more highly-ordered and differentiated states ("complexification")*[12,13,23,53].

The general pattern of this is easily seen in Figure 1 which in concordance with the fecundity principle (here seen operating globally) shows the opportunistic production of increasingly more highly ordered and differentiated states as a function of increasing levels of planetary atmospheric O2 over evolutionary time. The circularly causal, self-amplifying (autocatakinetic) relation between the increase in O2, a progressive departure of the whole planetary system from chemical equilibrium, and the production of increasingly more highly ordered differentiated states driven by this is vividly

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[14] "immortal" and non-physical because it is not DNA strings or codons that are selfishly striving for replication but the information, message or code that is carried by such strings, the material part only being a "vehicle".

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seen [13,54]. This picture, to underscore here is in complete contradiction to the ontic reductionist's commitment to some reversible causally closed fundamental level of "things" as discussed above . Well-evidenced here in Figure 1 to the contrary is the progressive (and in geological time scales explosive) creation through discontinuous symmetry-breaking events of increasing numbers of new, more highly ordered and differentiated kinds of things (or generalized "species" of things), as well as a proliferation] of the numbers of things within each kind that typically become the micro-components for the next level of macroscopic ordering.

While Figure 1 shows only a very bare-bones highlight of just some of these events, the generative progressive processual pattern of a) creation/production in number of new higher-ordered kinds of things, and b) at the same time the increase in the numbers of those things within each population or class of things and which then typically become the micro-components for the next level of things is unavoidable when looking at the evolutionary record. For example, from abiotic chemistry in the Hadean to the biochemistry of the single-celled prokaryotic world of the Archean through the origin of the eukarotic cells, multicellularity, increases in kinds and numbers cells, numbers and kinds of macromolecules, and the truly astronomical numbers, for example in the oft-cited number of neurons in the human brain estimated at 100 billion neurons with possibly 1,000 trillion synaptic connections [55]. The ordering and differentiation of Earth, for example, with the number of minerals following the dissipative accretion of planetary formation estimated at a mere 60 at that time to more than 4,300 today [56] and currently undergoing a dramatic symmetry-breaking upward spike with the current implementation of robotic chemistry and AI).

5.1.4.1. Darwinism Has No Observables Within Its Theory That Allow It to Recognize the Progressive (Time-Asymmetric) Nature of Evolution

Even setting aside momentarily the broader problem identified in this section regarding Darwinism's failure to have a theoretical account of the opportunistic ordering that is the hallmark of evolution on/of Earth for the moment and looking at the progressive nature of evolution itself, from the standpoint of *any* observable, some of which we have just given, Darwinian theory can neither explain nor address it. And as conequence has forced leading Darwinians to even deny it [57]. The reason? Simply put, formally as a theory it has no observables within its ontology that can be used to measure the direction of evolution at all. Because "fitness" is relativized to members of a breeding population there are no grounds to compare one group to another [13,19,58]. One zebra that runs faster than another zebra, better avoids predators and thus produces more offspring can be said to be more fit than a slower zebra, but a zebra cannot be compared on the same basis to a mouse or bacterium. By Darwinian criteria mice can only be judged more or less fit than other mice, and bacteria only with respect to other bacteria and this makes fitness an incommensurable observable with respect to the direction of evolution writ large.

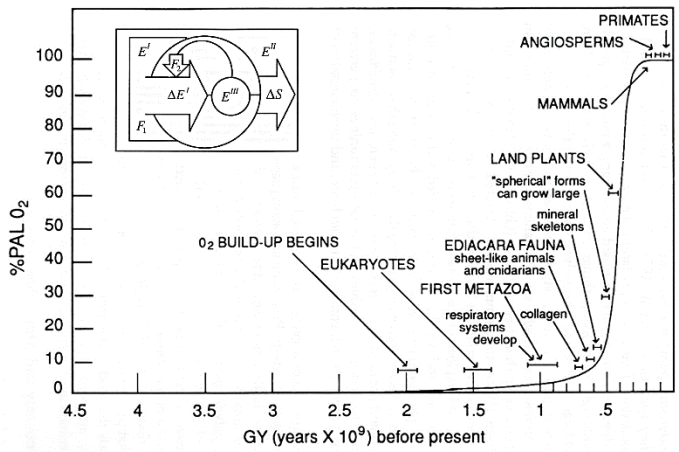

Figure 1. The progressive opportunistic planetary production of increasingly more highly-ordered states increasingly further from equilibrium shown here as a function of increasing atmospheric O_2

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levels from an early larely anoxic Earth to present atmospheric levels (PAL) today. Among other things, it provides direct simple *prima face* evidence for the fact that the Earth at its highest and most fundamental level has evolved as a single coherent planetary processual entity on which the existence of all other more usually construed forms of life depend as effectively internal component productions or differentiations. Such systems are members of the class of *autocatakinetic* (ACK) systems (inset) discussed more fully in the text (and Figure 4). The planetary-life-driven shift in the redox state of the Earth and the build up of atmospheric O_2 is a measure of an increasing departure from chemical equilbrium and the build-up of an internal potential, $\boldsymbol{E}^{III}$ with an increasing force $\boldsymbol{F}_1$ respectively in the inset, that works back as an amplifying forcing function to drive more highly ordered states into being [13,59].

5.1.5. Evolution of (vs. On) Earth and the Generic Problem of the Population of One

The second important theoretical and specifically ontological point shown by Figure 1 and our discussion in this section so far is what has been referred to as the "Problem of the Population of One" [24,53,59]. The latter term originates from the discourse explicitly regarding the evolution "on vs. of" Earth. By the early 1980's, if not before, studies in paleobiology and biogeochemistry had led to the widespread recognition that at its highest level life has evolved, and continues evolving as a single planetary entity [11,13,60,61]. The present oxygen-rich atmosphere put in place and maintained by life at the planetary level over evolutionary time as shown in Figure 1 is perhaps the simplest and most obvious *prima facie* evidence for this, although it has been going on from the time of planetary accretion, infall, and outgassing in the Hadean onward. This is an extremely significant and consequential fact. Because the production, evolution, differentiation and persistence of all higher-ordered life has depended, and continues to depend on the *prior existence and processual persistence of evolution at the planetary level*, this single planetary system ("entity") may be fairly judged to be the *fundamental unit of terrestrial evolution*. What is more, it makes all living systems, the more usually designated units of evolution (e.g, "organisms" and/or "genes") to be dependent on as evolutionary *component productions* and differentiations of and within this larger system. Such a system, as discussed more fully below is a paradigmatic example of an *autocatakinetic* ("ACK") system.

For Darwinian theory, however, this poses a major aporia because on the received view the planetary system as a whole cannot evolve, and thus cannot be a unit of evolution [62]. Darwinian theory, which defines evolution as the consequence of natural selection acting on a competitive replicating or reproducing population of many, cannot address or even recognize planetary evolution, and in fact denies it because there is no replicating or reproducing population of competing Earth systems on which natural selection can act (e.g., Dawkins [62]). The Earth evolves as a *population of one* [59], and natural selection simply cannot explain it or even acknowledge it. This however, is just another unavoidable example of the underlying problem with Darwinian theory which is the problem of spontaneous ordering, the evolutionary transformation from micro disordered (or less ordered) components to ordered macroscopic ones that is seen to be the hallmark of evolution from and including the origin of life (an in kind micro to macro transformation) to present human techno-cultural systems and globalization [11,23,30].

5.1.6. The Evolutiion of Cultural (Human Techno-Social Systems) Is Outside the Reach of Darwinian Theory

This takes us quickly to a final point that needs be mentioned in this section dealing with the shape and constitution (the ontology) of evolution and evolutionary theory and the insurmountable problems for Darwinism, given its own impoverished first principles to deal with it. As touched on in the previous paragraph, this is the problem of the evolution of human cultural (techno-social) systems from largely autonomous hunter-gatherer groups through chiefdoms, the rise of nation-states, to the present explosive globalization going in the present Anthropocene era. Since none of this can be measured, or accounted for as a consequence of changing gene frequencies (it is way, way too fast for that) this also puts it outside the reach of Darwinian evolutionary theory which as a consequence also willingly brackets out.

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"Cultural evolution," writes Dawkins "is not really evolution at all if we are being fussy…about our words" [63], [p.216]. Cultural evolution, however, the latest manifestation of the universal pattern of evolution we have been talking about cannot be defined away. Although it is inexplicable by natural selection as defined by Darwinian theory, it is entirely generic to an evolutionary theory that first acknowledges and then can account for the opportunistic generative ontology that characterizes the evolution of the self-evidencing world. With anthropogenic mass having just past the point of *currently exceeding all other biomass on Earth combined* and currently doubling every 20 years [64] this is something that any robust theory of evolution cannot define away. Understood as happening at an accelerating self-amplifying rate over the past 10,000 years, this is not even a blink in evolutionary time, it is rather understood as an explosion.

5.2. The 4th Law of Thermodynamics and How It 'Makes the World'

This section begins expanding on the fundamentality of the 1st and 2nd Laws of Thermodynamics as universal ontological and epistemological entailments with a some brief historical highlights from their classical origins where we look to revive components of their significance often lost or watered down in their more recent characterizations. This is followed with a short review of Boltzmann's (failed) attempt to reduce the 2nd Law to a stochastic collision function, and the calamitous misconstrual of the 2nd Law as a "law of disorder" that followed. And finally growing out of this context the 4th Law of Thermodynamics and the universal ordering imperative derived from it that provides the universal basis for the generative opportunistic evolutionary ordering and differentiation (complexification) that *is* the known universe is discussed and explicated.

5.2.1. Simple Classical Demonstrations of the Ontic Fundamentality of the 1st Law of Thermodynamics

The received view in the first half of the 19th century, notably at complete odds with ordinary everyday experience, was that heat (then "the caloric") was a conserved substance. The error of this idea was challenged when Davies, rubbing ice cubes together to produce heat from friction to melt them, Rumford producing heat wtih the boring of cannon barrels (and the duller the boring bit the more), and Mayer brought the temperature of a jar of water up by shaking it. Mayer's paper on this, effectively what they all showed, namely the equivalence of mechanical energy and heat (that heat could be produced by performing mechanical work) was firmly rejected by the academy. It was Joule who, after many rejections himself, was finally able to convince at least key players in the establishment with his now famous paddle wheel experiment [65] (Figure 2), and this put down a solid foundation for what became the 1st Law of Thermodynamics, or the law of energy conservation.

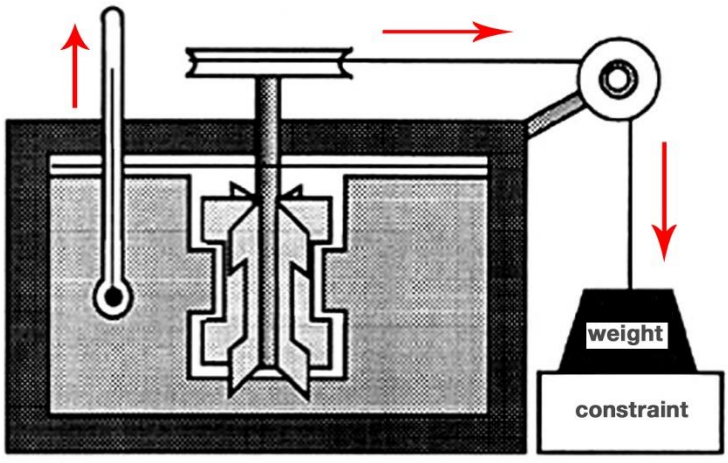

Figure 2. Joule's paddle wheel experiment demonstrating the 1st Law of Thermodynamics, or the conservation of energy, by virtue of the equivalence of mechanical energy (in newtons) and heat (in

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joules). In the experiment, an elevated weight held in place by a constraint is attached to a paddle wheel submerged in water in an adiabatically sealed container. When the constraint is removed the weight falls, turning the paddle wheel and elevatiing the temperature in the water by friction. The experiment, rightfully is considered a landmark in the recognition of the 1st law. What was not recognized or noted by Joule or widely elsewhere but has deep theoretical import is that the experiment is also a demonstration of the 2nd Law of Thermodynamics too (not yet at the time of Joule formally discovered). In fact, as discussed in the text, it *depends* on it to work. Any experiment, by necessity, is an *act of measurement* and every measurement is by necessity an irreversible act. It is the re-equilibration of the system or 2nd Law forcing that drives the experiment. To do the experiment again the system needs to be set up again out of equilibrium. The deeper take-away from the experiment is that any act of measurment *entails* both the 1st and 2nd Laws of Thermodynamics, and this in turn has deep implications for questions about fundmentality in physics or science in general built as they are at some level on acts of measurements [23].

Other experiments on the equivalence of heat and other forms of energy (e.g., chemical, electrical) confirmed what the 1st Law says which is that all real world processes consist of transformations of one form of energy into another (e.g, mechanical, chemical, electrical or heat) and that the total quantity of energy is always conserved. The law, as we have noted, was completed in the 20th century with Einstein's [16] demonstration that mass (matter) is also a form of energy ($E = mc^2$), making the law the universal conservation of mass-energy. The deep and universal symmetry that sits behind the 1st Law gives ample reason for its designation as the "1st Law" because without such a symmetry, namely universal *time-translation symmetry* there could be no other laws all. Although as we have seen, it is demonstrated and quantified in very simple falsifiable experiments *a posteriori*, understood deeply enough, it is simply put, no less than an *a priori* universal entailment, or *first principle* on which the existence of the entire manifest world and our perception of it depends. It is the symmetry out of and through which the processually constituted existence of the entire manifest universe has and continues to evolve into being—fully inclusive as an ontic entailment *without exception* of all the processual things like acts of measurement, the ability to take measurements, or observations (cognitive acts), or epistemic acts of any kind, and agents like us who do it and recursively explicate it. Without time-translation symmetry, non of these things, as we discussed above in more detail would be possible. It is truly fundamental in this sense. Reference the Clausius [66] statement here expressing the law:

"The energy of the universe is constant"

Falsifiable test of first and last resort: Produce a perpetual motion machine of the first kind (violating the conservation of mass-energy).

5.2.2. The Universal Entailment of the 2nd Law of Thermodynamics Necessarily (Although Unintentionally) Demonstrated by Joule's Classic Experiment

Looking now again at Figure 2 in a different way allows us to make some additional insights to further build out and illustrate some of the main points we have introduced earlier. In particular, Joule's experiment, a demonstration or empirical proof (a falsifiable quantitive demonstration) of the1st Law, in this case the equivalence of mechanical energy and heat, is an *act of measurement* with a simple but ingenious *measuring device* (joules/Kelvins). What is notable here, but was not noted by Joule is that the experiment also demonstrates (or "proves" if you will) in the same sense as the 1st or *depends on*, that is fully *entails the 2nd Law* too. Significantly, although in the air, the 2nd Law had not been identified at this time but regardless it is shown here unavoidably and straightforwardly (although, again, not noticed) with Joule's demonstration of the 1st Law which, again, it entirely depends on. This allows us to highlight and illustrate the *act* of measurement discussed in the first section of this paper, and fact that it is unavoidably an irreversible, that is entropy producing process, following from the out-of-equilibrium initial conditions in this case set up by Joule, but *driven* by 2nd Law forcing.

Further, to give this unavoidable physical meaning, the change in entropy that (per the Carnot-Clausius inequality or "balance equation" of the 2nd Law) must always be

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$$\Delta S \geq 0 \quad (1)$$

where $\Delta S = 0$ corresponds to the final equilibrium state of the system when the weight has stopped falling and the paddle wheel has consequently ceased to turn, can be quantified straightforwardly measured with the same degree of accuracy as Joules' measure of the energy by the classical thermodynamic method

$$\Delta S = \Delta Q/T \text{ (J/K)} \quad (2)$$

It may be worth noting, but not with the significance of the fundamental entailment we have shown here for the 2nd Law, that Joule's thermometer (or any generalized measuring device) at the same time depends on the The Zeroth law, the transitivity of equilbrium states (viz. if A is in thermal equilibrium with B and B is in thermal equilibrium with C then C will be in thermal equilibrium with A). This law which with a proper understanding of the 2nd Law can in fact be derived from it and is therefore not at all a law or fundamental law in the way the 1st and 2nd Laws are. Likewise the 3rd Law which importantly, but simply provides that the quantity of entropy can be expressed on an absolutle scale where the entropy of perfectly crystalline substances is zero at zero Kelvins (-273.15C, -459.67F). Of course, again, having a scale for conducting uniform measurements only has meaning if an act of measurement can otherwise occur and this entails the 1st and 2nd Laws.

5.2.3. Recovering the Classical Active (Forceful) End-Directed Nature of the Second Law from Historical Dilution

The time-translation symmetry or conservation expressed by the 1st Law gives us a starting place for building an evolutionary, that is fundamental, processual physics—the ontic fundamentality, out of and through which the manifest world has evolved or come into being. As noted above, this symmetry, the conservation of energy (mass-energy) gives us the time-translation symmetry entailed, that is nomologically necessitated, by such an evolution. Left to this symmetry alone, however, there is no reason or cause for anything to happen at all. There is no reason to not be left with a Parmenidian static reality. The 2nd Law of Thermodynamics, entailed as we have shown in the act of measurement, however, provides the reason. The 1st Law gives is the ontological *what* that this processualism minimally consists of, but the 2nd Law tells us *why* there is any processualism at all. The laws are universally mutually entailed in and *every* process there is. If the 1st Law is "persistence" then the 2nd Law is "change" for It is with the 2nd Law that active, that is causal, universal end-directed behavior comes into the world [11,12].

The causally active (forceful) end-directed behavior of the 2nd Law and the deep and fundamental universal nature of it has been obfuscated in many theoretical rephrasings since it was first recognized by the early classical thermodynamicists in the 19th century (see [16[). Most prominent among these is Boltzmann's attempt to save the static causally closed mechanical world view by attempting to reduce the 2nd Law to to a stochastic collision function (next section below) and then it is fair to say Shannon's unfortunate use of the term "entropy' for a completely non-physical quantity in "information theory" (a practice which has only increased in recent years) would be next. Beyond this, thermodynamics is often taught, for reasons (often hidden) under the impress of the hegemony of first classical and then statistical mechanics, in a way that hides the active, and most essential part of what the law is. For example, it is entirely ordinary for physics texts to give the 2nd Law in either of the two following ways, the first due to Clausius [67] and the second due to Planck [68]

Heat can never pass from a colder to a warmer body without some other changes, connected therein occurring at the same time

It is impossible to construct an engine which will work in a complete cycle, and produce no effect except the raising of a weight and the cooling of a heat reservoir

Both of these pioneers in physics did write these things but clearly there is nothing in these statements about the active, forceful or end-directed nature of the 2nd Law. They are both statements about *what cannot happen not about things that do*. Both are particular versions of the impossibility of perpetual motion (of the 2nd kind) and that is it. They are not, in fact, statements of the 2nd Law.

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5.2.3.1. What Did Clausius and Planck Really Say?

Contrary to the fact that both of these statements are represented as statements of the 2nd Law by Clausius and Planck, neither of them presented them as such, and both of them clearly said so. By 1775, the Royal Academy of Sciences in Paris had already made a statement that they "would no longer accept or deal with proposals concerning perpetual motion" [69]. It was generally agreed that it was impossible. What both Clausius and then Planck (who cited Clausius regarding it) did was to take the prohibition of perpetual motion stated this way (as perpetual motion of the 2nd kind) as an *axiom* in order, in Planck's words to "deduce (a statement of) the 2nd Law from it" [68], or In different terms, as a test of falsifiability. A good part of Planck's 1903 opus *Treatise on Thermodynamics* is then spent on one experimental test after another to try and falsify it (which of course he could not do). At the end he deduced what he calls "the most general statement of the 2nd Law of Thermodynamics" which he gives as:

Every physical or chemical process in nature takes place in such a way as to increase the sum of the entropies of all the bodies taking place in the process

The universal ("every physical or chemcal process in nature") and the active, end-directed ("in such a way as to") nature of the law is clearly seen here. Clausius's effectively similar concluding statement of the 2nd Law (coupled in his paper with his universal statement of the first law above) is;

The entropy of the universe strives to a maximum

It should be noted that in most current texts as a consequence of the hegemony of Boltzman's probabilistic definition of the 2nd Law one finds the misleading revisionist substitution of Clausius' word "strives" with the word "tends", but in the original Clausiuis the word is "strives" (the German word "strebt")[66]. In his Seventh Memoir [70] as elsewhere he reinforces this clearly again

heat accordingly incessantly strives to pass from warmer to colder bodies

5.2.3.1. Carnot, Disequilibrium, Re-Equilibration and the Motive Power of the 2nd Law

Finally, to underscore the impelling force or active end-directed nature of the 2nd Law as clearly understood and expressed in the theoretical work of the early pioneers of classical thermodynamics, one can hardly leave out Carnot considered by many to be the modern founder of thermodynamics and the one who actually discovered the 2nd Law. Although he had the conservation wrong (the equivalence of mechanical energy and heat had not yet been established) and it took Clausius, who coined the term "entropy" to articulate the 2nd Law correctly, Carnot [71] clearly grasped the fundamental substance of it. Most substantively for our discussion here is that it was his search for the physical basis for the *motive power*, or *impelling force* that powered the steam engine that got him there. And it was the 2nd Law, put simply, that was the answer to his question. These things like the general idea of how to build a steam engine, at least in general do of course seem so obvious in hindsight that to the instrumentalist not worth wondering about. The way to build and operate a steam engine, very roughly, is to first heat some water with a wood fire or coal to produce steam under pressure. Then provide a pathway for the steam to flow under pressure through some pipes where it moves some pistons, and the heat is dispelled at a lower temperature. To the instrumentalist that is basically how a steam engine works, and that is all you really need to know. For Carnot, however, this only begged the question.

He understood that the motive power cannot come from the conservation *per se* (for him erroneously "the caloric" but for us "energy") because, simply put it is conserved, but what he observed rather was that *it came from the distribution of it*. The potential for motive power, he recognized, always depends on the *disequilibrium of the conservation*, and it was in the *spontaneous re-equilibration of this distribution* that he found the motive force. Further, comparing the "fall of heat" to the fall of water that drives a water wheel in a mill, he noted that the magnitude of the force was determined by the "height of the fall" (or temperature difference in the case of heat), or the extent of the disequilibrium between the source and the sink. Again, although it was Clausius who really put

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it together correctly and named and created the term "entropy"[15], it is fair to say that what Carnot had discovered was the 2nd Law, and the fundamental forceful, active, end-directed nature of it. Not of course simply the motive force that drives the steam engine, but what *universally drives all processes* in the manifest world —the symmetry-seeking behavior of the 2nd Law and the "striving" towards an end state of maximum entropy of Clausius.

It has utility to note that in framing his statement of what would be the 2nd Law as Carnot does, not in terms of entropy *per se* (a term not yet coined), but in terms of the *forced minimization of a potential*, or the *re-equilibration of (in the case of the steam engine an intentional) disequlibrium in the conservation*, what he has done here really is flip the sign of the entropy. Or perhaps it might be more accurate to say it was Clausius who later flipped the sign for reasons it has never seemed quite clear. Maxwell [29,72] himself and Tait (as Maxwell tells it) both urged Clausius to change the sign but to no avail. They certainly felt, and it is hard not to agree, that it would have been easier for people to understand the concept if Clausius had done so (as a measure of a quantity that decreases with the reduction of potential rather than increases), but, in any case any (correct) statement of the 2nd Law can also be stated as the minimization of the potential (disequilibrium) of the conservation or equivalently as the maximization of the entropy.

5.2.3. Boltzmann and the 2nd Law as a Law of Disorder

The forceful active end-driven (time-asymmetric) nature of the 2nd Law presented a direct threat to the "dead" reversible ontic reductionism of the mechanical world view. Boltzmann tried to meet this challenge by reducing the 2nd Law to a mechanical stochastic collision function. The 2nd Law on this view became *nothing but* the probabilistic consequence of randomly colliding classical (reversible) mechanical particles. Boltzmann took his lead from Maxwell who had used probability calculus to develop a kinetic theory of gases with a "colliding billiard ball" model (the molecules in an ideal gas taken as perfectly elastic spheres acting on each other only during impact).

Observing Maxwell's results, Boltzmann noted that with each collision any non-equilibrium velocity distribution (groups of molecules moving at the same speed and in the same direction) would become increasingly disordered (moving less and less at the same speed or in the same direction) leading to a final state of macroscopic uniformity and microscopic disorder, corresponding to the state of maximum thermodynamic equilibrium. From this, he argued, the 2nd Law could be reduced to the fact that in a world of mechanically colliding reversible particles disordered states are simply way more probable. Due to the fact that there are so many more possible disordered states than ordered ones, he argued, the system (or universe) will almost always be found either in a state of maximum disorder, the macrostate with the greatest number of accessible microstates, such as a gas in a box at equilibrium, or else moving towards it making transitions from disorder to order "infinitely improbable" [73].

Molecules, Boltzmann wrote

moving at the same speed and in the same direction is the most improbable case conceivable…an infinitely improbable configuration of energy….

This view, or Boltzmann's attempted reduction of the 2nd Law to a stochastic collision function, as we will show momentariiy, is readily falsified but despite this fact the view of the 2nd Law as a *"law of disorder"* became unfortunately fully entrenched across the disciplines from physics to biology, social and cognitive theory and evolutionary theory writ large or small. It puts, as we have shown, what is purported to be physics at complete odds with the entire self-evidencing nature of universal evolution from its beginning which is characterized by the generative progressive evolutionary production of increasingly more highly ordered, and differentiated states. From Boltzmann's perspective universal evolution becomes the origin and development of one more infinitely improbable state after another.

If there was a previous paradigmatic belief in the dualistic Cartesian (*res extensia/res cognito* or mind/matter) or Kantian cuts (life/physics) before this then Boltzmann's apparent reduction of the

[15] Solving what we have called elsewhere "the problem with Carnot", e.g.,[11]

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2nd Law to a "law of disorder" was taken to fully support it now. In evolutionary theory we see statements from leading Darwinian theorists convinced by this view as a matter of fact. Ronald Fisher [74] one of the paramount figures of neo-Darwinism establishment wrote "[e]ntropy changes lead to progressive disorganization…while evolutionary changes lead to progressively higher organization," while Levins and Lewontin [75] unequivocally assert "organic evolution to be the negation of physical evolution". After stating "entropy…is simply disorder" and that according to the 2nd Law "things run down", Dennett [76], in support of his magic (extra-physical) "selfish-algorithm"/computationalist theory of mind (cognition), defines living things as things that "defy" the 2nd Law of thermodynamics. Then, very currently, Friston [77], promoting his own non-physical syntactical or information-theoretical account of cognition ("mind") describes living systems a systems that "somehow manage to violate" the 2nd Law.

To be clear moving on, no argument is advanced here about the clear heuristic utility of statistical methods in physics or anywhere else, but Boltzmann's universal claim to have reduced the 2nd Law to a stochastic collision function and the infinite improbability of spontaneous ordering erroneously and fundamentally conflates a limited heuristic model with ontology. It makes the profound mistake of claiming to reduce the latter to the former, a very deeply misleading mistake that in this case is not simply wrong, *but actually upside down*. Beyond being effectively falsified by the entire universal evolutionary record which shows progressive opportunistic ordering to increasingly more highly macroscopically ordered and differentiated states as fundamental and generic, it is easily falsified any and every day by repeatable simple physical experiments.

Figure 3 shows two time frames from the now classic Benard cell experiment done in our lab some years ago where a viscous liquid (silicone oil) is held between a uniform heat source below and the cooler air above (sink)[12]. As first well-shown by Carnot (above) the disequilibrium, in this case the temperature difference between the source and the sink creates a *potential* with a force ***F*** the magnitude of which is determined by the steepness of the gradient between them (the extent of disquilibrium or Carnot's terms "the height of the fall"). When ***F*** is below a critical threshold (a) the system is in the disordered or "Boltzmann regime", appears macroscopically smooth and homogenous and the flow of heat from source to sink is by the disordered stochastic micro-collisions between its molecular components. As soon as ***F*** is increased above a critical threshold level (b), however, macroscopic order ("macro") is selected from microscopic disorder ("micro") breaking the spatio-temporal symmetry of the disordered regime as hundreds of milliions of molecules begin moving collectively together. This immediately falsifies Boltzmann's claim that the production of order from disorder (molecules "moving at the same speed in the same direction") is infinitely improbable, but rather occurs opportunistically and spontaneously with a *probability of one* (deterministically) each and every time, and as soon as, ***F*** reaches the critical threshold [12,13]. This opportunistic ordering that underlies the entire evolution of the universe as we know it follows directly as we unpack further below from the 4th Law.

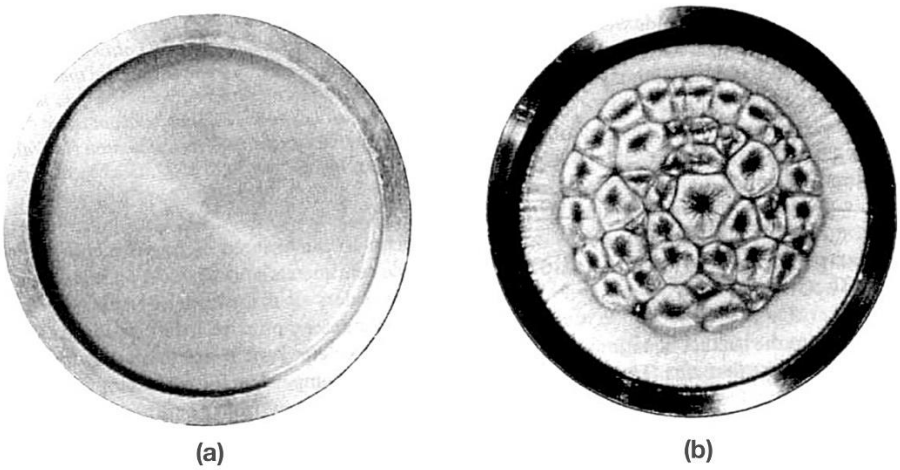

Figure 3. Two time frames from the Benard cell experiment where a viscous liquid is held out of equilibrium between a uniform heat source below (source) and cooler air above (sink). The

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temperature difference between them creates a potential with a force ***F*** with the steepness of the gradient determining its magnitude. When ***F*** is below a critical level (a) the flow of heat is due to the disordered collisions of the component molecules and the macrostate appears symmetric and homogenous (the disordered or "Boltzmann regime"). As soon as ***F*** is increased above the critical threshold (b) macroscopic order is opportunistically selected from microscopic disorder ("macro from micro") as hundreds of millions of molecules begin moving collectiely together. With selection of macro from micro the intrinsic spaciotemporal dimensions of the system (universe or subvolume within it) defined by the correlations between components are dramatically increased. In the disordered regime the actual measurable dimensions are mean free path distances and relaxation times (the average distances and times between collisions) of the order of 10^{-8} centimeters and 10^{-15} seconds whereas in the ordered regime the correlation times increase to centimeters and seconds. To give a rough idea of how dramatic this transformation is if the molecular or micro mode were scaled to the size of a human being, then the macro mode would be many times greater than the circumferance of the Earth persisting over time scales greater than the 4.5 years of Earth's evolution [12,13].

5.2.6. The 4th Law of Thermodynamics and the Universal Basis for Evolutionary Ordering

In developing a fundamental theory of universal evolution we have with the time-translation symmetry or conservation identified by the 1st Law of Thermodynamics the "what" out of and through which everything that subsequently processually comes into being is constituted. With the mass-energy displacements of the conservation driven by the forceful symmetry-seeking (time-asymmetric) behavior of the 2nd Law we are given the "why" anything happens at all and the processual nature of it. As much as these deep and powerful laws give us, however, this still leaves the opportunistic ordering that is the hallmark not just of the nature and evolution of life but of the entire visible universe from its early relatively homogeneous origin to the progressively increasing more highly-ordered, differentiating complexifying world that we find ourselves in today a *mystery*. We have discussed at some length the variety of ways this property, or the lack of its explanation or imagined negation of it by physics has been used to support a dualistic metaphysics with a list of magical (extra-physical) "makers", agents, or agency to account for it. We have also shown how any and why all of these accounts or theories, by their own definitions, *must necessarily fail* as a consequence of (but not limited to) the *ontic constraints or entailments of the 1st and 2nd Laws of Thermodynamics* (the impossibility of perpetual motion of the first and second kind).

5.2.6.1. Looking for the Universality That Solves the Mystery

Herein, however, is the generally construed problem. Empirically we start with the self-evidencing fact (meaning unavoidable by observation) of a visible universe characterized by the progressive generative production of increasingly more highly ordered and differentiated states. However, even understanding that Boltzmann's attempt to reduce the 2nd Law to a stochastic collision function (atoms or molecules "moving at the same speed and in the same direction…is infinitely improbable") is falsified, the most widespread view of the 2nd Law following from general classical assumptions (including Carnot's idea about re-establishment of equilibrium) still seems problematic. It mandates energy distributions spreading out from more concentrated to less concentrated distributions, from systems with fewer degrees of freedom, or a lesser number of accessible microstates for a given macrostate, to distributions with a greater number of accessible microstates. This is directly opposite to what we see with the autocatakinesis of spontaneous ordering which arises opportunistically at symmetry breaking events initializing new levels of order characterized by the progressive and radical reduction in accessible microstates—to states further, and further away from equilibrium and of higher energy concentrations. Clearly, given that this is an unavoidable *fundamenta*l universal proccess, there must be a fundamental universal account of it. We still need an account of what this irreducible universality is. Solving this mystery was what launched our work some three and a half decades ago.

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5.2.6.2. The Autocatakinesis of Level-Building as the Causal (Force-Driven) Production of Processual Constraints

Like the 1st and 2nd Laws of Thermodynamics the universality we are looking for here is clearly entirely level-independent. In fact, most significantly, this irreduciblity (to some single particular level) is just because what we are looking for is in fact the *causal basis for why there are any levels at all*, or *why there is any level-building at all in the first place*. The production of spontaneous ordering, the process of *autocatakinesis*, each and every time it occurs *is* the production of a new macroscopic level, a *macroscopically causal (force-driven)* level that comes into being and exists by causally selecting, channelling, controlling as a set of *processual constraints*, the degrees of freedom or accessible microstates of its components. It is these *constitutive relations* that literally define the state or entity as an entity distinct or differentiated from its surrounds and as a higher state of order. The production/origin and development or evolution of all such systems thus shows structural, and behavioral isomorphisms with a generic minimal ontology symmetric over transformations of scale that identifies them as members of the broad level-independent class of systems called "autocatakinetic" (ACK) systems[16]. An ACK system is:

a system that maintains its "self" as an entity constituted and empirically traceable to a set of nonlinear (circularly causal) relations (constitutive relations)

through the breakdown of environmental potentials (non-equilbrium mass-energy distributions) in the continuous coordinated motion of its components [13,30]

Figure 4 shows a schematic of the minimal ontology of a canonical ACK system that defines the class. The of scope of the class is fully universal ranging from clusters of galaxies, galaxies, stars and their evolution, all living systems from single cells to ecosystems to the planetary scale (e.g, the 'population of one" we have already discussed), to meso and smaller scale abiotic systems such as tornadoes and dust devils and experimental ones such as the BC we have already pointed to regarding Boltzmann's claim about the supposed infinite improbability of order. In most general terms, the entire evolving universe is made up of, and the coming into being of, increasingly nested levels of such systems and their differentiated exudes.

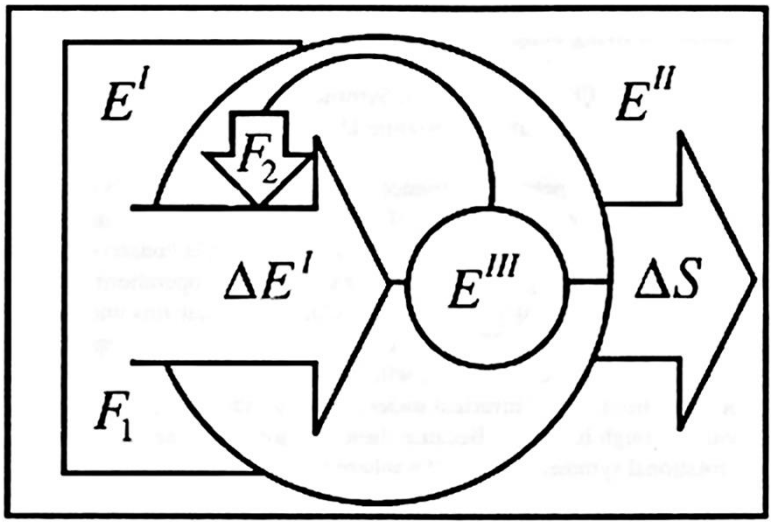

Figure 4. A schematic of a canonical autocatakinetic (ACK) system. $\boldsymbol{E^I}$ (source) is an out of equilbrium region (volume) of $\boldsymbol{E^{II}}$ (sink) the gradient between them constituting a potential with a force $\boldsymbol{F_1}$ the magnitude of which is determined by the steepness of the gradient. $\boldsymbol{\Delta E^I}$ is the flow of energy at the input or drain on the potential which is transformed into entropy $\boldsymbol{\Delta S}$ at the output. $\boldsymbol{E^{III}}$ is the internal

[16] Please see e.g.,[10,13,53], for discussion of why, if it is not apparent, we choose the more carefully defined term "autocatakinetic" in preference to terms such as the less clearly defined, often polysemous, terms like "self-organization" and, or "dissipative structure" where there is clearly some overlap.

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("on board") potential carried in the constitutive relations of the system by virtue of its distance from equilibrium acting back with a force $\boldsymbol{F}_2$ to amplify or maintain the input. (From *auto*-"self" + *cata* "down" + *kinetic* "of the motion of material bodies and the forces and energy associated therewith") [11,13].

5.2.6.3. The Split Balance Equation of the 2nd Law and the Causally Problematic Idea of "Evaders" Fighting Against Physical Law

By the middle of the last century it was widely known (e.g. Haldane [78], Bertalannfy [79], Schroedinger [80], and later Prigogine [81] to name a few) that living things did not violate the 2nd Law of thermodynamics *stricto sensu*. As long as they consumed/dissipated enough potential (energy gradient), "food", or "negentropy", to use Shroedinger's term, so as to produce enough entropy to compensate for their own internal entropy reduction or ordering the net change in entropy would still be positive and the 2nd Law, again, *stricto sensu*, would not be violated. The Carnot-Clausius inequality (or "balance equation" of the 2nd Law) as Bertalanffy [79] showed under the rubric of "open systems" and Prigogine [81] later showed under the rubric of "dissipative structures" could be thus split into two terms:

$$\Delta S_e + \Delta S_i \geq 0 \quad (3)$$

where the first term is a measure of the change in entropy due to the "negentropy", disequilibrium, or the potential on which the system "feeds" and is imported into the system, and the second term is the entropy produced by the system and dissipated into the environment as a consequence of the system's ordering (its constitutive autocatakinetic relations) and departure from equilibrium (ΔE^{I} and ΔS respectively in Figure 4).

This is clearly an important point, but theoretically contextualized as it was as an explanation for how life, in Schroedinger's [80] terms "evades the decay to equilibrium" has been unfortunately *causally misleading* at best. This theoretical framing, and in-kind declarations, for example, that an organism "avoids the rapid decay to…equilibrium" by feeding on "negentopy" as we will show puts the *causality upside down* and obscures the universal nature of it. It still has living things (and all ACK systems by extension) as a result of some autonomous internal unidentified *telos* or *ad hoc* Kantian "natural purpose" inside them, fighting *against* the laws of physics rather than just the other way around. It casts all the increasingly more concentrated, differentiated and more highly-ordered states that have progressively populated the universe all as "evaders" of physical law. In any case, at best it leaves the physical question of the universal ordering that characterizes the world completely begged and unanswered, but at worst it has been extremely causally misleading.

Even though Bertalanffy was one of the first to recognize that given the split balance equation (3) such states were "permitted" to exist without violating the 2nd Law *stricto sensu*, he still, along with Schroedinger, showing the impress of Boltzmann, viewed them as systems that "maintain themselves..(in a state of)..fantastic improbability" [82].[17] The central problem, then, still remained, namely why is the reality of our world/the universe, including us and our measuring devices fundamentally characterized, or made up of systems that *universally* seem to "defy" or "evade" what are taken to be the laws of physics? What was "most in need of explanation," as Nobel Laureate Konrad Lorenz [83] put it, "is that in apparent contradiction to the laws of probability…(the universe) seems to develop from…the more probable to the less probable, from systems of lower order to systems of higher order." Each of these pioneers in science from the middle of the last century was clearly bothered by this fundamental problem and each in their way imagined there was likely to be a then unknown fundamental law to solve it. "We must be prepared to find a new physical law" wrote Schroedinger [80], "prevailing (in these cases). Or are we to (imagine it a) non-physical, not to say super-physical law?". Roughly a half century later we now have the law. And it is the 4th Law of

[17] Bertalanffy [82] who was so far ahead of his time in so many ways certainly well-understood the problem of "increasingly higher order..(at all levels) in embryonic development as well as evolution" as a whole, was perhaps the greatest issue for theoretical science and thermodynamics.

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Thermodynamics. An explication of the law and the path that gets us to it are shown in the next sections.

5.2.6.4. Coupling Probability One with a Deeper Look at the Balance Equation of the 2nd Law Is the Game Changer That Flips the Entire Theoretical Script

The structural, and behavioral isomorphisms or symmetry over transformations of scale we see with the autocatakinetics of spontaneous universal ordering suggests, if not already demonstrates in advance that we are clearly seeing the operation of a universal law. At the historical point where trail-blazers like Schrodinger, Bertalanffy, and later Prigogine (who underscored order *can* arise "far from equilibrium" but never was able to give a reason *why* it should) left the law frustratingly begged [6]. With the Benard case (Figure 2) we have shown very literally (and can show over and over) that the production of spontaneous order from disorder rather than being "infiinitely improbable" per Boltzmann, or "fantastically improbable' as the otherwise prescient Bertalanffy (and of course many others) held, occurs opportunistically every time, that is deterministically with a *probability of one* as soon as it gets the chance. Looking at this seriously for the remarkable thing it shows, it turns the whole theoretical notion of the "infinite improbability" of spontaneous ordering completely upside down, literally flipping the entire theoretical script.

If we then take this script flipping seriously (and how can we not?) this compells us to do the conceptual or theoretical transformation all the way through, and this takes us to some very dramatic realizations. That is, if we get rid of our paradigmatic preconceptions about what the split balance equation of the 2nd Law is *supposed* to explain and instead turn the causal structure upside down so that it corrresponds to things we *actually* see in repeatable physical experiments and observations we are immediately given some illuminating insights. More specifically, the theoretical assumption or causal structure that gets flipped is the demonstrably false belief that we are dealing with infinitely improbable states that causally (forcefully) use the disequilibrium (negentropy, potential, motive force) or ΔS_e term to "evade" the laws of physics in their own (extra-physical) service (the second term ΔS_i). This then instead is replaced with a theoretical causal structure that is effectively its opposite. So, now, instead, the second term ΔS_i (the ordered state) is taken as the law-driven causal (forceful) consequent or manifestation of the first ΔS_e (the disequilibrium, potential, gradient or motive force) rather than the other way around.

5.2.6.5. The 4th Law of Thermodynamics (LMEP) and Derivation of the Universal Ordering Principle

This, to be sure, does not yet explicitly give us the law that explains this symmetry-breaking behavior or the selection of macro from micro that characterizes spontaneous ordering. By implication, however, it gives is a very strong indication of what the form or shape of it must be, and this takes us back again to the Carnot-Clausius inequality or the split balance equation of the 2nd Law to put a light on something that Bertalanffy, Schroedinger, and Prigogine, and others from their perspective at that time (how such states can persist without violating the 2nd Law), explicitly did not see. The illuminating insight that puts us within palpable reach of the law we are seeking is thus not the point made by Bertalanffy, Schroedinger and Prigogine that ordered flows are *permitted* to exist as long as they produce enough entropy to compensate for their internal entropy production. It is instead that by virtue (by ontic necessity) of the split balance equation with the symmetry-breaking selection of macro from micro (spontaneous ordering, the production of an ACK system) *the rate of entropy production* ***must*** *always go up*. That is, the more order produced the greater the rate of entropy production is going to be. This fact or universality, symmetric under all transformations of scale or location, is not in itself anything new at all, or something that has to be proved or demonstrated in and of itself because it is already given. It is, once again, universally given by the balance equation of the 2nd Law itself and its entailments. It is, however, a script-flipping or paradigm-inverting view of what it actually means, what the real significance of it really is, and thus what the underlying explicating law might be.

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More specifically, the light that this "right-side up" way of looking at this, inspired not by paradigmatic causal misconceptions but instead by repeatable experimental and other empirical observations, is that it gives us a previously missed universality, or isomorphism applying to *all,* that is the entire class, of macro (order) from micro (disorder) processes (flow). Pulling the implications of all this a little further together, we have noted that the origin and production of ordered macro from disordered micro flow (the production of an ACK system) is a process of selection, more particularly, the *selection of one path vs. another*. And this then begs the question Bertalanffy, Schroedinger and Prigogine never asked specifically about paths and rates, and it is "which paths out of available paths will a system (the universe) take to get to equilibrium (maximize the entropy or minimize the potential)?" The 2nd Law alone, of course, says nothing about rates or path selection at all. All it says is that all natural processes proceed so as to increase the entropy. This then takes us immediately to the 4th Law of Thermodynamics, or the Law Of Maximum Entropy Producton (LMEP)[6,12,13,23,30,53,60,84,85], which answers the question and thereby solves the mystery of progressive universal ordering. It says:

A system (the universe or any arbitrary out of equilibrium subsystem volume within it) will select the path or assembly of paths out of available paths that minimizes the potential or maximizes the entropy at the fastest possible rate given the constraints

The 4th Law, as is clear, says nothing about spontaneous ordering *per se* but when combined with the causal insight regarding the split balance equation of the 2nd Law we have already understood from above, the derivation of the universal ordering principle is easy to do. In particular,

IF the 4th Law of Thermodynamics (the world selects paths…fastest rate etc.)

AND IF ordered flow produces entropy faster than disordered flow (as it must given the split balance equation of the 2nd Law)

THEN the world (the universe or subvolume within it) can be expected to select/produce order from disorder whenever and a soon as it gets the chance

By thus providing a universal causal (forceful) account of the progressive opportunistic ordering or level-building differentiation that characterizes the evolution and development of the visible universe the 4th Law dramatically expands the explanatory scope of thermodynamics and evolutionary theory at the same time. Like the 1st and 2nd Laws, the 4th Law is entirely *level-independent applying to all ranges*, near and far from equilibrium all the way up and down, but most significantly explains *why there is any level building at all.* Additionally, like the 1st and 2nd Laws, the 4th Law meets the most rigorous standards possible in scientific or physical theory. That is, like either of them, it is subject to Popperian [40] falsifiability by simple reproducible physical experiments using classical thermodynamic tools and methods, and on the question of "elegance", or ontological parsimony ("Occam's Razor") it clearly takes a very big game-changing leap accounting for universal evolutionary ordering and all that it includes while at the same time eliminating an almost immeasurable amount of excess (imaginary) ontology or special purpose devices (every and all *ad hoc* "magic makers") across the disciplines. Finally, it scores the highest possible marks by the Lakatosian [86] measures of "sophisticated falsificationism"[18][29][19].

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[18] According to "sophisticated falsificationism" since there is always an existing theory (or theories) T^1 a new theory T^2 is only considered "confirmed" if it falsifies the previous theory (or theories). T^1 is considered falsified **IIF** T^2 meets the following three criteria: 1) T^2 must have additional or "excess" empirical content over T^1 namely, it must be able to predict of postdict facts that are improbable or forbidden according to T^1 ; 2) T^2 must subsume or account for the unrefuted content of T^1; and 3) At least some of the excess content claimed for T^2 must be corroborated (see the Appendix in [29] for further discussion)[86].

[19] It would be remiss in here not to acknowledge a recent paper by Beretta [87] where he says he is "reveal[ing] another great law of Nature" he "propose[s] to call the "Fourth Law of Thermodynamics". Although clearly expressed in different terms and reached from different starting place (there is nothing *per se* about the explanatory power of the law in regard to macroscopic ordering)), his statement *is* effectively a restatement of

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5.2.6.6. The Generics of Selection, Constraint Creation, Macroscopic Causal Closure and the Expansion of Dissipative Dimensions

The origin or "birth" of an ACK, its "entification", when it becomes a new macroscopic more highly ordered flow structure distinguishable from its environment by virtue of its constitutive relations always, as noted, universally begins with a symmetry-breaking event [60]. From the moment this symmetry break occurrs, through the full extent of an ACK's evolutionary growth, development, differentiation and eventual "death" we are witnessing a *process of selection* [53]. That is, as previously discussed, an initially discontinuous and then progressive selection of some vastly reduced number of accessible microstates M_2 (the ordered ACK flow structure) from some much vastly larger number of accessible microstates M_1 (the dis- or less-ordered prior regime) following the 4th Law. ACK systems, as "things" that achieve their *identity through flow*, thus in each case have a "life" beginning with an origin event (the discontinuous symmetry-breaking event), then growth and development over that "life", decline or senenscence and then "death" (e.g., the death of a main sequence star in a supernova explosion, late-stage senescence and collapse in generalized ecosystem succession, the collapse of civilizations, senescence and death as usually understood in living systems at the organismic level as some of any number of examples).

The legend with Figure 3 highlights the fact that with the selection of macro from micro and the symmetry breaking that defines it the intrinsic spatio-temporal dimensions of the system (the universe or subvolume within it) are dramatically increased [11,13,23]. This is an ontological point. The origin and development of such a system literally, meaning measurably, and by orders of magnitude, increases the spatiotemporal dimensions or extent of that system. This is an absolutely fundamental point in the understanding of how such order building *functions*[20] (a term I use advisedly here) in the progressive generative evolution of the universe as a consequence of 4th Law path selection. The non-trivial formal relation between symmetry breaking and the differentiation and the extension of spatiotemporal dimensions in a system should not be missed. When a physical symmetry breaking occurs in a system it means it has lost its invariance under some number of transformations, and this, in turn, by definition, means it has become more differentiated. Likewise this quite literally means its spatiotemporal dimensions have been, also by definition, variously

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LMEP (the 4th Law) and the two are convergent. Although to say he is now "revealing" the law is thus certainly questionable, overall there is nothing wrong in restating it. To the contrary, there are many statements of both the 1st and 2nd Laws (although not all good) that are useful for their domains of applicability. What is a plus here is that it seems to me Beretta understands the law— a universal law about local path selection. While his model is a little mechanistic for my taste he seems to be well aware of the difference between abstracted models and the world they model. As it is, his model minimally seems to provide a kind of metamodel or constraint on modeling in general including course graining (and thus misguided claims on ontology) which strikes me as moving in a very right direction. Further discussion of his paper here is well beyond the scope of this paper, but I did not want it to go acknowledged.

[20] The word "function" is used intentionally and advisedly here noting with full awareness that from orthodox (Darwinian) view of evolution, the position from the "autonomy of biology" discussed at length eariler, the word "function" is something only living or cognitive systems can have. It is supposed to be *de novo* with life and explained by natural selection. The problems with what is essentially a Kantian teleomechanical view is completely rejected here and has been discussed at length eariler in the paper. The 4th Law brings the term universally into physics, a physics that brings biological systems into the world as an intelligable product of universal evolution, and not as noted before as an anomolous unexplained reality or agency extra-physically fighting against it. Biological (and also cognitive) functions, discussed somewhat further in the next section, are special cases, or higher-ordered evolutionary processual developments of this, and the expansion of the spatio-temporal dimensions of the universe across all scales is the world *functions* to get this done.

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extended, and in a processual universe this *identically* means the extension of its dissipative dimensions or surfaces has occurred.

Understanding this puts a light on how the evolutionary development of increasingly more highly ordered states functions as *increasing levels of causal (forceful) constraints* to increase the rate of dissipation that the Carnot-Clausius inequality *requires* in such cases and the 4th Law as path selection universally *explains*. Returning to the BC experiment allows us to easily and directly observe exactly how this works, and how significant this process of spatiotemporal expansion is in evolutionary ordering. First let me underscore what we are interested in and will look at is the evolutionary *process* of spontaneous ordering beginning with the symmetry breaking event and through the main part of its evolutionary "life". Unfortunately, this is exactly what is *left out* of typical earlier mentions of the BC as an example of a spontaneously ordered or self-organizing system where we are presented with a stock photo of the static final end state of fairy regularly arranged hexagonal cells artificially maintained in a laboratory. Remarkably, what is left out of the discussion or illustration is what actually *happens* during the *process of its evolution* that gets it there. With the whole process effectively left out the largest part of the theoretical and evolutionary substance of the experiment is missed.

So, first, the progressive selection, that is the reduction, of accessible microstates that occurs with the origin and evolution of an ACK system (M_1 to M_2) is, by definition, from a different view but *identically* the progressive production by selection of a set of *constraints* that in a circularly causal fashion causally (forcefully) controls/selects/determines the microcomponents. The structure of the system, the *constitutive relations* that define it *are* the constraints [10,30,60]. The system *is* a circularly causal (forceful) set of macroscopic constraints, that comes into being from the time of the original symmetry-breaking event, as a differentiation from, or through and out of its immediate environment and then continues to grow and develop during the course of its "lifetime". It is by virtue of this circularly causal ACK force structure, that the system refines and amplifies component control, and typically component production, through a process of continued progressive specification or differentiation.

Figure 3 (a) takes us back to the disordered regime where the heat flow from source to sink is accomplished by the stochastic collisions of components with intrinsic spaciotemporal dimensions defined by mean free path distances and relaxation times (of the order of 10^{-8} centimeters and 10^{-15} seconds). From a strict Boltzmannian causally closed or micromechanical account this regime, that is simply the stochastic or incoherent probabalistic collisions of the components, this is where the system should stay. To the contrary however, the point of emphasis here is that it is precisely the *intrinsic causal limit* or causal closure of the spacio-temporal dimensions of this regime (generalized conduction, diffusion) that make it an extremely inefficient or slow way to move energy and thus leads to its instability. Where the disequilibrium, or gradient is steep enough, the simple mechanistic side-side or "horizontal" dynamics of stochastic collisions defining this regime (where all causal or forceful relations between components are ontically reduced to *efficient cause*) itself becomes an actual severe and forceful barrier or limit to equilibration. The symmetry-breaking that characterizes the origin of an ACK system, or macro from micro path selection following the 4th Law is the causal (forceful) breaking of that barrier so as to access otherwise in inaccessible spatiotemporal dimensions and consequently (identically) dimensionally expand the system's dissipative surfaces. ACK systems, in effect, are self-amplifying developing, evolving differentiating sinks that *function* in that regard.

To motivate a feel for just how dramatic the scale change, and concomitant expansion of dissipative surfaces is in these transitions if, as in the Figure 3 legend, the BC molecular or micro mode to macro ordered transition (10^{-8} centimeters and 10^{-15} seconds in the disordered regime to centimeters and seconds in the ordered regime) is scaled (very roughly of course) to human size then the macro ordered regime would be many times greater than the circumference of the Earth persisting over time scales greater than the 4.5 years of Earth's evolution. This is a remarkable ontological point to ponder.

Beyond this, the first thing that is typically not appreciated when the BC system is viewed simply as a stationary unchanging, static end state is that what happens with the "origin event" is actually a *multiple origin event*. That is, the occurrence, not just of one but of a large population of multiple orgin

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or symmetry-breaking events each arising as an *individual separate* ACK system. Initially each, referring back to our discussion above, is a "population of one" which then quickly becomes a member of a population of many as multiple separate origin events occur, although initially with no causal relation *between* them. Figure 5 shows a time slice from the BC experiment right after the minimal threshold of ***F*** has been crossed and two individual origin events have occurred and two initially independent cells consequent on 4th Law macro from micro selection come into being (are "born"). Each, at this point as an individual self-amplifying sink, is an evolving differentiating force structure or set of top-down level of macroscopic constraints acting back with an internal force to amplify the gain (F_2 in Figure 4) through increasing forceful control of its components in the expansion of its dissipative surfaces.

Box Essay (Figure 6) details how this generative process of *constraint creation* happens. That is, it shows how *macrocausality or circularly causal "downward causation"* arises spontaneously as a consequence of the *4th Law and progressive path selection in the proccessual evolutionary differentiation of the system*. When F_1 in Figure 6 is increased above the critical minimum level it results in the *average* amplitude of stochastic fluctuations increasing above the minimum amplitude required to puncture the dissipation barrier and tilt the force structure of the system in a way that, in a macrosopic circularly causal fashion, differentiates the force structure further establishing autocatakinetic closure to initiate the process of autocatakinesis. The process is completely scale invariant and fundamental to the progressive production of more highly-ordered systems in the generative or creative evolutionary development of the universe (e.g., the collapse of interstellar clouds and the "birth" of main sequence stars).

Figure 5. A time slice of the Benard experiment shown right after the minimal amplitude of ***F*** has been crossed and two individual ACK cells have been produced. Note, it is significant here that these are two separate origin events, each being selected, produced, evolving at this point as a "population of one" where competition following the 4th Law is between micro and macro modes or paths. In fractions of a second the entire system will be filled with cells. Each as a separate origin event [30,53].

Here, in the particular case of the BC experiment the "seeding" of the origin event or symmetry breaking begins, when, as discussed, F_1 is increased above a minimal level. When this happens the average amplitude of the fluctuations (or "parcels" of fluid) rises above the minimum level, but in addition, since density varies inversely with temperature, it further tilts the force structure by creating a positive upward buoyancy force F_2 that causally (forcefully) drives the parcel upward. **IFF** but as soon as any macroscopic parcel (fluctuation) carries heat *faster* than it is dissipated by the stochastic collisions of the disordered regime making up its surrounds, following the 4th Law, macro is selected from micro by rate, the symmetry of the force structure is broken, then it further differentiates to establish autocatakinetic closure and an ACK system which continues as a self-amplifying sink in its own expansive evolution and development (see Figure 6 legend) is "born". The process of internal differentiation of its force structure is identical to the production of selective

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constraints that macroscopically and progressively (forcefully) controls the degrees of freedom of the components internal to the system.

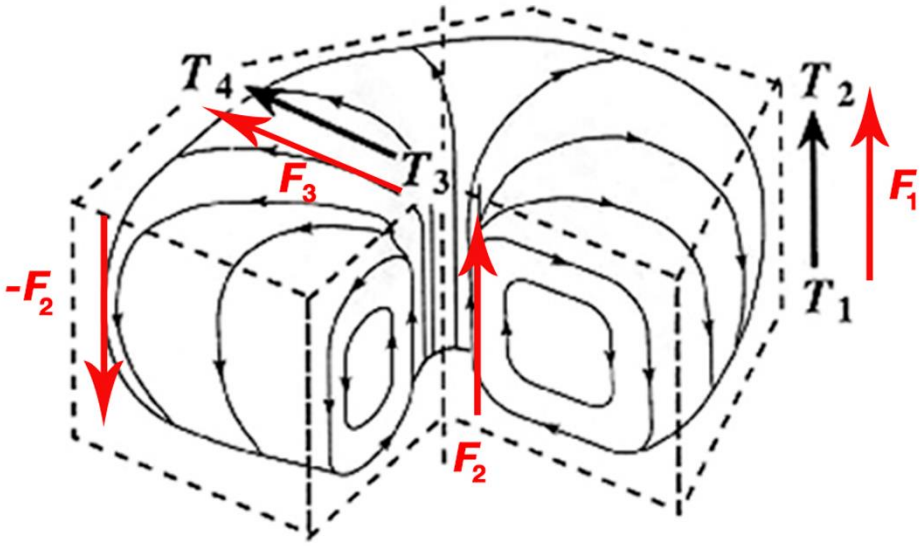

Figure 6. A generalized schematic showing the autocatakinesis of macroscopic flow in a BC as hundreds of millions molecules move in collectively together. $T_1 \rightarrow T_2$ is the *temperature gradient* between the source (below) and sink (above) with a force F_1 (measured by the steepness of the gradient) that causally drives the flow. Because density varies inversely with temperature there is also a *density gradient* from bottom to top giving groups of molecules ("parcels") displaced upward by stochastic (indeterministic) collisions ("fluctuations" = "deviants" or "outliers") an *upward buoyant force* F_2. Path selection of **macro** from **micro** initiates and symmetry breaking occurs *opportunistically as soon as* the gradient is steep enough such that a parcel ***carries the heat faster*** towards the heat sink above than can be dissipated by disordered collisions (conduction) to its surrounds. The upward flow of heat with the parcel at the same time increases the temperature of the upper surface directly above it breaking symmetry with the surface temperature creating a *surface temperature gradient* $T_3 \rightarrow T_4$ with a *force* F_3 which acts to further *amplify the rate* of the macroscopic upward flow by pulling the hotter fluid to the cooler surroundings of the surface around it. This cools the flow increasing its density effectively reversing *buoyant force* F_2 to drive the flow back down to the bottom again where it is heated to begin the autocatakinetic cycle again. At this point through these *constitutive releations autocatakinetic closure* the macrostructure is established [23,53].

Although selection of macro from micro is itself deterministic (it happens opportunistically with a probability of one by virtue of the 4th Law) it works on the stochastic or indeterminate disordered behavior of the components. This *macro determinacy/micro indeterminacy* relationship is also entirely level-independent and fundamental to the creative or generative evolutionary behavior that characterizes the observable universe. In the case of the BC it means that while it is known that symmetry breaking ordering will occur as soon as F_1 increases above the minimal threshold and the system will rapidly spawn a population of cells until the entire system is full, due to the stochasticity of the fluctuations it cannot be known exactly which fluctuation will happen to get there first, second, third and so on. That they will not get there at exactly the same time and consequent on things like "founder advantage" (the earlier ones will have a competitive advantage, e.g. for size) the initial population will be highly varied. This can be seen clearly in Figure 3 (b) where at this stage in the evolution of the system the now crowded population of cells shows high variability which then with the progressive reduction of accessible microstates, largely gets eliminated over the evolution of the system. This process of "progressive determinism", or "progressive mechanization, or what Bertalanffy [82] called "equifinality" in developmental biology, is seen clearly in the BC system as 4th Law selection takes the system from the stochastic incoherent collisions of the disordered regime through macro from micro symmetry breaking to a "population explosion" with high variability to a relatively highly uniform widely known late stage of hexagonal cells where "conformity rules

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Figure 7 shows the new level of selection that occurs in the BC "ecosystem" (the dish, single-molecule fluid, and gradient) after it fills with initially independent cells. It shows the universality in this simple single-molecule fluid system of complex developmental behavior grounded in the 4th Law usually reserved for or taken to be the sole property of living things. In particular, after the system fills with initially separate cells (Figure 5), generalized "Malthusian closure" (= ACK closure) conditions occur as the growing cells start to forcefully impinge on each other effectively competing for fixed resources (gradient/potential) within the finite spatiotemporal limitations of the system. Selection is now no longer simply between micro and macro but now between the cells themselves—we have a new level of selection. Figure 7 shows three of the most generic kinds of behavior we find universally in spontaneous evolutionary ordering, development and differentiation, namely, *spontaneous fission, competitive exclusion, and subsumption*.

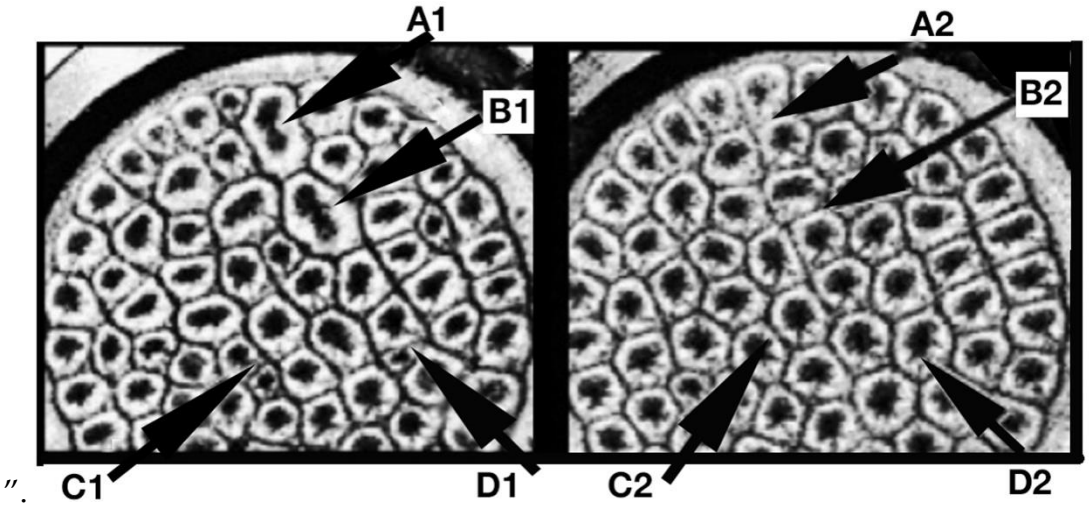

Figure 7. Two time slices in the Benard experiment showing competition and selection operating *between* originally separate cells (ACK systems) (see Fig 5) following the 4th law. After the "ecosystem" (dish, fluid and gradient) fills with cells (Figure 3 [b]) they start to impinge on each other creating a generalized "Malthusian closure" condition (= ACK closure) at a new higher level. **A1→A2** and **B1→B2** show spontaneous fission as two cells become four, and **C1→C2** and **D1→D2** show competative exclusion and subsumption as four cells become two. This illustrates two of the most generic kinds of behavior universally evidenced in evolutionary structuring and differentiation following directly from the 4th Law. In the first case, spontaneous fission (the selection of four from two macrostates) occurs because due to generalized surface/volume ratios (S/V ratios) as each cell grows its internal gradients decrease (e.g., surface tension $\boldsymbol{F_3}$ in Figure 6) and its efficiency as a heat transport path therefore declnes (viz., the specific heat transport and specific entropy production) leaving the cells unstable to fissioning which results in two more efficient cells (paths). In the second case, where one cell is smaller and one is bigger but it is not big enough to be at the fission tipping point, bigger simply means better in terms of rate and the smaller of each of the pair of cells loses (is unstable to) simple competative exclusion or subsumption consequent on path selection by rate. It is worth noting that if we take any one of these originally independent cells (e.g, Figure 5) and held the expectation following the erroneous MEP_w "principle" (see text and Appendix 3) that the entropy production of each would evolve monotonically to a final maximal steady state we would be *wrong in every single case*. The 4th Law explains the structuring. MEP_w to the contrary is simply wrong and misleading [53].

In particular, **A1→A2** and **B1→B2** show spontaneous fission as two cells divide to become four, and **C1→C2** and **D1→D2** show competitive exclusion and subsumption as four cells become two. Due to generalized surface/volume (S/V) allometry (surface increases as the square and volume increases as the cube) the input and output of the system ($\boldsymbol{\Delta E^I}$ and $\boldsymbol{\Delta S}$ respectively in Figure 4) depends crucially on the extent of its surfaces, a measure of its differentiation relative to the volume it occupies. Thus as each cell grows *ceterus paribus* its internal forces decline (e.g, surface tension, $\boldsymbol{F_3}$

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in Figure 6) and its efficiency as a transport path (viz., here the specific heat transport and specific entropy production) decreases making it unstable at a critical path-selection tipping point or critical threshold where symmetry breaking by fissioning and differentiation into two more efficient cells *increases the rate*. Whereas in the fissioning case increased size (without additional internal differentiation) at the tipping point, becomes a liability, in the case of competitive exclusion and subsumption the size of a bigger cell vs. a much smaller one, where the bigger cell is not at the tipping point, works as an advantage and the smaller cell loses out to the larger size with much stronger forces and rates.

5.2.5.7. The 4th Law and Life and Intelligence from First Principles

The 4th Law [21] gives us the fundamental explication and account of the progressive, opportunistic generative ordering and differentiation (complexification) that characterizes universal evolution or the processual generative ontology of the universe with life and its evolution as an intelligible level-dependent processual manifestation. With this universal evolutionary embedding the central problems with Darwinian evolutionary theory outlined in Section 5.1 are each and every one of them, as the reader will have seen, dissolved. In, particular, the fecundity principle or the active, end-directed "striving" of living things to "fill out the economy of nature" and the "struggle for existence" that follows, the supposed *sine qua non* of the living, is rather than an extra-physically ("magic") property "breathed into" living things or dualistically assumed unexplained *ad hoc* by which they somehow fight against the laws of physics is instead seen as an entirely generic special case manifestation of the opportunistic universal ordering and differentiation (complexification) that follows directly and causally (forcefully) from them [12.13].

Malthusian closure and the consequent "struggle for existence" under fecundity principle pressure leading to the selection of the fittest variants is likewise a special case of this same entirely universally generic process. In particular, the selection of internal microstates, components and component relations processually entailed with ACK causal closure and the consequent progressive production of constraints on those components under 4th Law forcing (e.g. Figure 7 for the generic abiotic case/exemplar). Darwinian "natural selection" is thus readily subsumed as a special case of 4th Law forcing and generic ACK microstate/component selection/production where the ACK system is *replicative* (an ACK system with component replication)[22] (for further discussion see [53]).

Likewise, as we have seen both the issues of the directed or progressive and generative nature of evolution and the problem of the population of one are generically folded into 4th Law universal ordering. With this fundamental (universal) theoretical grounding established we are in good position to circle back and address in more detail the specific evolutionary nature of terrestrial life and intelligence (cognition or "mind") or more generally the epistemic dimension of the world, the dimension typically dualistically separated by the generalized measurement problem and all the various "cuts" from Parmenides through Descartes, Kant, Heisenberg and onward that brought us into this paper in the beginning. If we are to have a fundamental physical theory, which is to say as is promoted here, a processual universal evolutionary theory or coherent processual ontology then the epistemic part of the world cannot sit outside the world (as an illusion or not) as it did for Parmenides and heirs and must be included in causal explicable intelligible terms within it. Put in

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[21] The reader should understand that without repeating it each and every time, it should always be understood that this is in concert with the irreducible entailments of the 1st and 2nd Laws.

[22] *cf.* a "replicating" system. The distinction is important when understanding, for example, in terrestrial evolution the primary unit is the planet as a unitary entity. The system does not replicate itself, so is not a "replicating" system. It is, however, a "replicative" system because it evolves with component replication. This is generic to universal evolution where as we have tried to articulate the fundamental unit at all levels is or in any case originates as a single entity or population of one. This is generic to macro/micro selection the underlying form of all universal evolution [59]

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terms of the generalized case of measurement, it must be able to include the thing being measured, the act or measurement, the result of the measurement and last but not least the intentional epistemic agent ("observer") performing the act. And, following Planck (as above) to put this in very simple (but not reducible to) very simple terms it must do this without invoking perpetual motion (of either kind). Elaborating how this works is the content of this final section of the paper.

5.2.5.7.1 Level-Independent Universal Law Acts on Level-Dependent Initial Conditions

The largest part of this paper has been focussed on the fundamental level-independent laws of thermodynamics, and paritcularly how the 4th Law, in irreducible concert with the 1st and 2nd, provides the universal basis, or first principle ontic or causal account of universal evolutionary ordering [6,10,11,23,60,88]. The fundamentality of these laws, as discussed above, is grounded in the fact that they not only operate across all levels and scales, but most significantly in the case of the 4th explains *why* there are any levels, level-building, or any macroscopic ordering or differentiation to begin with. Here in this final section of the paper, building out from this theoretical ground, we effectively do the inverse of what we have done in the earlier parts of the paper and focus on the *level-dependent* properties of life and cognition that causally account for them and their differentiation as particular, individuated ("special cases") in, out of, and through the general process of universal evolution following from universal law [53].

Level-independent universal law acts on level-dependent initial conditions consisting of level-dependent micro components and their accessible level-dependent component relations or constraints that have been previously processually evolutionarily produced (call the current level of observation the "focal set"). This evolutionarily produced focal set of level-dependent initial conditions then becomes the new ground or "material cause" for the next stage or macroscopic level, the next particular, differentiated or *special case* in the processual process of progressive, generative universal ordering. In this section, where we address the nature of life and intelligence or cognition (the epistemic act) we bring all the causal and explanatory force of the 4th Law and the entailments of the 1st and 2nd Laws with us but then focus on the level-dependent special case properties (constraints) that distinguishes living and cognitive systems as living and cognizing — what their evolutionary function is—that is *why life and cognition* and how they formally distinguish themselves,, viz. minimal and necessary (the **IFF**) conditions that define them [14,89,90].

5.2.5.7.2 Epistemic Ordering and the Fundamental Nature of Life and Cognition

Nailing this down a bit further, we have shown how 4th Law universal ordering subsumes the fecundity principle as a special case higher-ordered differentiation or manifestation. If we look at the statement of the principle further however we can immediately see, if we take the language literally, how the "special" or the level-dependent dynamics breaks out. It is in the words "striving" (as in "striving to fill out the economy of nature") and the "struggle" (as in the "struggle for existence") and the *intentionality* they express [89,90]. Now in this paper we have already noted intentionality-loaded words such as Clausius' "striving" and his underlying understanding or sense of the active end-directed nature of the 2nd Law, where it is used metaphorically for 2nd Law forcing vs. the Darwinian case where it is certainly not, and here we need be very careful with our words. At the same time as we do want to soundly reject causally-closed onto bottom-level reductionism (where macrocausality is denied) what we do want to stringently reject is the illegitimate (magical, extra-physical) *ad hoc* smuggling of false causal or teleological terms. This is after all is just what onto reductionists are metaphysically forced to do (e.g. all the "cuts" we have discussed) and precisely *what we deny and what, as has been shown, 1st and 2nd law entailments forbid*.

"Intentionality" is a deeply substantive word expressing a property of behavior that is more often than not explicitly ignored (unmentioned) but at the same time widely simply assumed or smuggled in *ad hoc* unexplained or else if explicitly recognized typically taken to be outside the reach of the supposed physical world and therefore assigned to the other side of various dualist cuts as typically an immaterial "mental" property of (Cartesian) "minds" (*res cogitans*). Viewed this way, that is from within the broken framework of Cartesian metaphysics the "problem of intentionality", what it is ontologically to the world and what the basis for its epistemic or semantic content is, has

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dominated discourse across many disciplines. Sayre [91] has called it the most challenging and fundamental problem for cognitive science today [89], but it is the same problem that sits at the core of every other discourse by whatever name that deals with, or depends on, the epistemic dimension of the world (e.g., psychology, philosophy of mind and theories of consciousness, cognitive neuroscience, the social sciences, theories of culture, biology and evolutionary theory, and as we have seen, although not typically acknowledged as such certainly physics too).

There are two, but intimately connected, main components in the discourse on intentionality growing largely out of the late 19th century work of Brentano [92], and these are the ideas of *directedness towards*, and that this directedness towards *be distinguished or determined by semantic content, or meaning ("aboutness")*. Despite the importance of Brentano's work, it was grounded in Cartesian metaphysics and postulates, where an autonomous "mind" (the Cartesian self) is left in the end perceiving itself (the "Cartesian circle") with no principled way in or out, and as a result largely voices from within the Cartesian echo-chamber. The vast majority of theories of perception ("indirect perception") even today still begin with tributaries from these postulates where perception and cognition are taken to be of and *about mental states rather than of and about the world*. The most widespread view, still largely present today, is thus that "meaning always involves human intentionality [and] intentionality is primarily a property of mental states" ([93]. But if the world, excluding human "minds" is entirely meaningless (there is no meaning in the world) then there is no way human minds (or any other living thing) can have epistemic (or semantic) relations with it.

We know, as we have shown, for a multiplicity of reasons, but with 1st and 2nd Law entailments being more than sufficient, why such an incommensurable view cannot hold (Cartesian interactionism). The bottom quite literally fundamentally falls out from under the ground of modern science on this issue alone since every human discourse (including physics) is itself an instantiation of the epistemic act (or epistemic dimension) and characterized by intentionality. It re-capitulates the Problem of Parmenides of which the generalized measurement problem we began with is just a specific unavoidable example.

5.2.5.7.2.1 The Behaviorally Level-Dependent Defining Property of Life Is Its Intentionality

Beyond this is the undeniable empirical fact that *life itself* and its evolution on which the intentionality of humans is itself parasitic as a higher-ordered evolutionary differentiation *is an epistemic process* [11,24,89,90]. We have already broken the epistemic act out of its Cartesian box in Section 4 with its 1st and 2nd Law entailments. Here we need to do the same for intentionality, that is decontaminating it from the idea of "ends-in-mind" or confinement to (immaterial) human mental states. Expanding on Brentano then, and removing the incommensurable Cartesian "mentalism" more typically associated with it, intentionality is defined as *end-directed behavior prospectively controlled or determined by meaning or information about (or semantic content)*[10,14,90]. Along with the universal (level-independent) entailments of the 1st, 2nd, and 4th Laws, intentionality is the fundamental (although in this case level-dependent first principle) entailment required to cross the Parmenidean cut and each and every one of its heirs from Descartes, through Kant to Heisenberg, and we see it first in universal evolutionary ordering with the origin and evolution of life where it becomes the *defining property that separates the living from non-living*.

Unpacking this distinction further, all systems displaying intentionality (and thus all cognitive, intelligent or epistemic systems) are end-directed systems (ACK systems in particular), but not all end-directed systems or ACK systems possess the processual property of intentionality[14,90],. We do not (unless we are panpsychists) invoke intentionality to causally explain the flow of heat down a temperature gradient from hotter to a cooler, or the flow of a water down a slope from higher to lower, or the "selfish" self-amplifying heterostatic behavior of abiotic ACK systems such as tornadoes, dust devils, hurricanes, main sequence stars, or experimental Benard cells because their behavior is both driven and causally determined by *local potentials* and laws [13,93]. In dramatic contrast, however, when we observe the behavior of any living thing from the simplest bacterium or prokaryote say moving *up* a chemical or temperature gradient (chemotaxis, thermotaxis) (e.g.,[95,96]) or eukaryotes of any, all, and every kind we see their behavior go in directions that are causally

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different, often completely opposite than processes that causally follow from mass-energy forcing of local physical potentials [10,13,14].

Behaviorally, then the difference is quite clear. Non-living end-directed systems are "slaves" or captives to their local gradients or potentials, e.g., remove the local potential or gradient in any and all cases and the system "dies" (heat stops flowing at equilibrium, water does not flow down a slope if there is no slope, Benard cells dissapear if the heat source is removed, and a main sequence star "dies" when all the hydrogen is burned). In contrast, when the local potential is removed from a living ACK system (e.g, a food source is depleted) its behavior is typically quite different, or as noted above, even directly opposite to that determined by local potentials. It may go temporarily dormant, or actually increase its activity (its "striving" using that word advisedly) as it seeks, oftentimes initially randomly, new spatio-temporally *discontinuously* located potentials to feed on or otherwise connect to. Living systems, in other words, constitute their ACK over times and distances that are *arbitrary with respect to local potentials* using their stored or "on-board" potential (***E***III in Figure 4) and meaning (information about) to access otherwise inaccessible spatio-temporally located potentials and dimensions of dissipative space [13]. In short, they exhibit end-directed behavior prospectively controlled or determined by meaning or information (about)[23]. *They exhibit intentionality* [11,14,90]. The connection of this property and its processually inherrently self-amplifying access to otherwise inaccessible spatio-temporal dimensions of dissipative space and its direct relation to 4th Law path selection (discussed further below) should not escape the reader. Here, however, we need to ground this further in two very important and also (level-dependent) fundamental ways.

5.2.5.7.2.2 Universal 1st Law Time-Translation Symmetry and the Physical (Level-Dependent) Basis For Meaning, Information, or "Aboutness"

It is all well and good to say that the end-directed behavior of living things towards their intentional ends is prospectively controlled or determined by meaning or information but it is not at all given ontologically *where* this information is and thus *how* an epistemic connection can be made with it given the Cartesian, or physical onto-reductionistic assumptions inherent in orthodox and most widely held views of intentionality, perception, cognition, or the philosophy of mind still remarkably prevalent today. In fact, it is one of the central issues central to the "problem of intentionality" in most of these discourses. Given the ontic reductionistic physics assumed by most of them, if the reduction is taken literally (and sometimes it is and sometimes it is not) it is, of course, more than a problem it is an *impossibility* since ontologically it begins with the generalized Parmenidean cut, or Cartesian circle. "Mind", as previously discussed, in a physical world reduced to reversible causally closed "meaningless particles" has no way of epistemically connecting to an outside world. Meaning or information on this view as we have already pointed out becomes something created *ab initio* in "minds" in a process of mental operations or computations not something existing "out there" in the world[24].

The "problem of intentionality" is in fact not a problem with intentionality *per se* it is actually only a problem that follows from of the assumptions of Cartesianism and the Cartesian or generalized

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[23] Up to this point I have used "information about" to designate that we are using the word "information" in its ordinarily understood meaningful or semantic sense. In other words inforamtion *about* something. I have done this to firmly disambiguate the term from the Shannon or information theoretical sense which having *nothing* to do, as Shannon clearly noted, to meaningfullness or semantic content. The unacceptable erroneous conflation of these two uses unfortunately continues to be rampant. From this point on, having said this I will simply use the word "information" without adding "about". But it is semantic content of the world that we are writing about here and on which a great deal of theoretical import hinges.

[24] For further discussion of current widely held versions of this such as the computational theory of mind (CTM) or "perception as predicting" a very widely held current view where perception is taken to be the probablistic computation on models in the brain" see (e.g, [10,29,98].

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Parmenidean cut. We have already shown how 1st and 2nd Law entailments cross levels and irrefutably (viz., else make us a perpetual motion machine) show the ontic unity of the otherwise imagined two sides (the active or agential epistemic "side" on the one hand, and the ontically and causally impoverished "physical world" or side on the other). The 4th Law, as we have seen not only crosses all cuts but shows why rather such incommensurable dualist cuts are instead rather than incommensurable cuts actually fully commensurable higher-ordered differentiations in the causally driven process of universal ordering. Coupled with the generic relational, self-referencing, and self-amplifying circular causality of ACK systems the 4th Law gives us, in different terms, the agential or motivated heterostatic (other directedness or directedness towards) behavior of which the epistemic act is a differentiation [90,97]. But, what is still missing is literally what the *ontology of information* is and hence what this epistemic relationship is, by what and how is it constituted? In short, what is the physical basis or ontology of meaning, information or "aboutness"?

We return to first principle entailments for the answer which has already been foreshadowed in Section 4, in particular, the deep and powerful universal time-translation symmetry of the 1st Law. We noted that without 1st Law symmetry there could be no act of measurement, no measurable quantities, no epistemic act, and, in fact, no projectable predicates of any kind at all. We already thus know that any epistemic act at all entails the 1st Law. We of course know that it also entails 2nd Law asymmetry and of course importantly the 4th Law. But the latter two laws are specificaly about change (viz., in the first case why it hapens at all, and in the second why it happens the way it does) so they cannot be what we are looking for here. We are looking not looking for change *per se* but macroscopic observables that capture the nomological relation *between* persistence and change of the distal objects of intention with respect to the proximal or local position of an epistemic agent. If we look a little further at the implications of the 1st Law we see, remarkably, the answer is already given.

Living things are embedded in ambient energy gradients or non-equilibrium distributions of energy and their respective flows, e.g., optical, mechanical, an chemical, which typically include numerous different kinds of gradients other than what they use to power their intentional acts [13,99]. As a consequence of 1st Law time-translation symmetry lawful and invariant relations exist between these ambient energy flows and their sources, and it is precisely because of this invariance that they *lawfully* carry information *about* distal sources for the prospective determination or control of an epistemic agent's intentional ends (e.g, chemotaxis, phototaxis, thermotaxis, and haptics). This deceivingly simple (in hindsight of course) insight dramatically deepens our understanding of 1st Law time-translation symmetry by recognizing an additional feature that inheres in it that is often unrecognized [10,11,90].

More specifically It takes the understanding that without this symmetry there could be no laws of physics, no acts of measurement, or epistemic act of any kind (an understanding of which we credited first most generally to Leibniz) and takes it (literally) to another higher level. Namely, it provides the ontic ground for the *property* of carrying meaning and "information about", a first principle requirement, that affords both the possibility and more importantly the *opportunity* for intentionality or epistemic ordering to occur. It answers the question of what the physical basis for the epistemic (that is meaningful, or semantic) relational connection living things have with the world that enables them to seek and intentionally locate and establish paths to spatio-temporally discontinuosly located potentials to use and dissipate in the constitution of their autocatakinesis [13].

In a universe causally driven by the opportunistic physics of 4th Law ordering it is hard not to appreciate the role that 1st Law symmetry plays by providing the ontic opportunity for intentionality, that is, end-directed behavior determined by meaning, or most generally the epistemic act, cognition, or the time-asymmetry processual act of knowing. From the productive, generative view of the 4th Law it provides a new higher-ordered self-amplifying and differentiating process of novel *path production and selection* for finding and connecting otherwise discontinuously located potentials recursively generating more ordering and differentiation with the property of increasing more knowledge over time of how to amplify the process of doing so [24]. In short, a dramatically new self-amplifying way of increasing by increasing orders of magnitude the extension and progressive expansion of the spatiotemporal dissipative dimensions of the universe where the condition occurs.

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It reveals the evolution of life on/of Earth and the progressive opportunistic evolutionary ordering that characterizes it as an epistemic process from its origins [10,11,23,24,89,90]. The origin of life and *the origin of the epistemic act or cognition are one and the same*, a special case (level-dependent) evolutionary higher-ordered manifestation (product) of generative level-independent universal law.

The minimal but sufficient (**IFF**) test according to which we can identify from a behavioral/processual point of view (by watching what it does) whether a system is alive and consequently because their defining properties are dentical, know at the same time if it is a cognitive (an "intelligent") system or not can be seen at this point as straight forward. Namely, observing a system from an external behavioral point of view **IFF** it displays *intentionality* (if it behaves arbitrarily with respect to local potentials and instead coordinates its end-directed behavior over times and distances so as to seek, find, access and connect with/to non-local spatiotemporally discontinuously located potentials) *then* it is a living/cognitive system [89].

5.2.5.7.3 Rate-Independent Constraints (RICs) And Replicative Ordering - A First Principles Systems Theoretical Look At Life And Cognition

The previous section which looked at at life/cognition behaviorally is essentially a look from the outside, what it is and what it does, minimally defined, that processually distinguishes it or evolutionarily establishes its identity and its function in and as a product of universal ordering. This final section is a look at the inside because to effect the remarkable symmetry-breaking behavior that living/cognitive systems accomplish that from the view of the 4th Law effectively repeatedly punctures an otherwise stringent spatiotemporal barrier to universal dissipative ordering requires a very particularly differentiated minimal ontology, set of internal constraints, and systems logic. Living (and thus cognitive) systems at a minimum must first be ACK systems. This we should already know. Without the 4th Law driven self-amplifying, reflexive (circularly causal) irreversible generics of autocatakinesis there could be no life or cognition [10,23]. The minimal ontology and relational generics of ACK systems as we have shown is an entailment or primitive, or first principle, we must thus begin with (Figure 4).

So here we start with the fact that ACK systems are evolving differentiating force structures that do so in a reflexive process of component/microstate selection through processual constraint production and consequent further reflexive differentiation (Section 5.2.6.6). Generically they are thus component selecting, producing, differentiating systems (e.g, see Figure 7 for the Benard cell example, or nucleosynthesis inside stars) driven and governed by 4th Law path selection. From a systems-theoretical point of view, living/cognitive things (processes) take this process of differentiation, component selection and production one very big distinguishing symmetry-breaking process further. In particular, living/cognitive systems are *replicative systems*, a term we introduced in Section 5.1.3[25]. They produce components by replication. Further to this property is that this component replication process is seeded with stochasticity, or variation (the degree itself selectively macroscopically determined). This allows, again within selective limits, for a creative component in this process, that is the generation of new or novel "things" or structural differentiations (e.g.,"perceptual sensors") that afford the ability using physical information carried in the invariant properties of ambient energy distributions to search, find, and access new and otherwise unaccessed unknown potentials.

In addition to minimally being an ACK system, and a replicative one, there is on further or irreducible ontic primitive to the minimal systems logic of the level-dependent minimal ontology or constitutive ACK relations of living/cognitive things that makes the behavioral property that defines them possible that is that gives them the behavioral ability to act arbitrarily with respect to local potentials possible. And this is an *arbitrary function in the replicative component production process*, or

[25] Again cf. *replicating* systems. As we have seen, in terrestrial evolution the fundamental evolutionary uniit in the evolution of/on Earth is the planetary system itself which (at this point anway) is not a replicating system. It is however an ACK system with component replication (replcating components). It is thus a *replicative* system.

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more specifically a set of internal *rate-independent constraints* (RICs). More particularly, formally or generically defined, RICs are a set of internal constraints that are discrete, sequential and rate-independent relative to the rest of the ACK cycle. The order of the sequences, like the words on this page (an example of an evolutionarily later higher-ordered case), or the sequence of base pairs in a DNA string, is *thermodynamically arbitrary* relative to the rate at which they are "written" and "read" [13,90,100](e.g., the amount of ATP needed to replicate a DNA string of the same length is the same regardless of the sequence).

Highlighting now "written' and "read", while stressing the importance of these very particular kind of constraints as an irreducible component or ontic primitive of the systems logic of living/cognitive things we need to underscore everything already said in Section 5.1.3 (The Myth of the Selfish Replicator). Allowing, as we did above, that it is reasonable to see RICs as kind of minimal algorithmic code (as symbol strings, or syntactic constraints) it is crucially important here to underscore again that imparting agency or intentionality to these otherwise extremely evolutionarily important kind of constraints is absolutely denied *a priori.* It is exactly their inertness, relative thermodynamic arbitrariness, or *rate-independence* on which their function entirely depends. By themselves RICs have no meaning, or function at all except within the replicative reflexive (circularly causal) 4th Law driven act of the ACK cycle that "reads" them and "writes" them. RICs are an irreducible component of the **IFF** minimal ontology that constitutes the level-dependent distinguishing property of intentionality that distinguishes the living/cognitive level of universal ordering, but they crucially depend on the whole system to function.

With the epistemic functionality of this new macroscopic level of generative ordering that is life/cognition ("intelligence") driven by 4th Law opportunistic path selection but now reflexively (autocatakinetically) grounded in physical information universally available with 1st Law time-translation symmetry, the universe evolutionarily reflexively turned back on itself to effectively gaining information about itself, building increasing knowledge about itself towards the end of further discovering new paths towards further universal ordering, and differentiation ("complexification")—the production of new kinds, and greater numbers of kinds and numbers within kinds of "things" to extend its dissipative spatiotemporal dimensions.

This same systems logic, gets progressively self-amplifying, with progressive symmetry breaking to higher levels of evolutionary ordering with e.g, human language, written language, and contemporaneously algorithmic code, and AI systems. It is beyond the scope of the present paper to catalog all the concomitent symmetry-breaks ("revolutions") this 4th Law path selection process has and continues to produced in the context of epistemic cultural ordering—agricultural, industrial, digital connectivity and information processing, all constituting new access to new pathways driven by 4th Law path selection in the process of generative universal evolutionary ordering and differentiation and production of "things". The increasing speed with which this has been going on in recent times, however, is unlikely to have been missed by the reader.

6. Conclusion

This paper, among other things, argues that the universe, to the extent we know, experience, and observe it is at present time fundamentally, that is, irreducibly, processual. The initial conditions, that is some hypothesized start for this processuality, for example that it began as some imagined non-processual state of perfect symmetry that spontaneously broke (its own) symmetry to our processual universe is not here being addressed. Excepting to say such ontological claims unless they assume some extra-physical, extra-universal magical agency (something that *has* been addressed at some length in this paper) always if not beg then regress the problem therefore at the same time compounding it. In simplest terms they need to explain why such a universe, or ontology defined by such perfect symmetry would suddenly break its own symmetry excepting on pain of contradiction—it was not really in a state of perfect symmetry to begin with, or else destabilized by something extra-universal that was *not* in perfect symmetry. If this sounds like the Problem of Parmenides and its heirs discussed in this paper, it should because it is exactly the same problem—a problem of insisting

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on an ontology that does not include in it the actual world, or the epistemic act of those insisting on planting their flags in an ontology where there are no flags and is no planting.

So we start with our approach to the fundamentality of universal evolutionary ordering, what is fundamentally given and not what we wish were given. And the point here is that wherever we decide to jump into the early universe regardless of taking a fine position on which of the various most accepted and received views of it might be, at whatever fraction of a second we care to do it in regard to inflation and the Big Bang it is all fundamentally and irreversibly processual. And in this processuality we immediatley recognize the universal evolutionary generics we have addressed in this paper that were in operation from that point on and have continued to operate to present times. In particular, the transformation from an initially homogeneous or relatively undifferentiated or disordered state (e.g, an undifferentiated plasma) through a progressive process of local symmetry-breaking—-the production of "things, more kinds of things, and levels of things that processually constitute the world we observe, know, and experience.

This progressive generative evolutionary ordering, is not reducible to the variously closed reversible laws of physics (e.g., quantum mechanics, clearly not classical mechanics, nor is Boltzmann's, as we have shown, failed reduction of the 2nd Law of Thermodynamics). Despite their great utility and value, none of these qualify as fundamental or universal in the sense we mean it. The fundamental fully level-independent universal laws, applying to and across all levels, and most significantly, with an expanded view of thermodynamics we describe here, causally explain why there is any macroscopic level-building to begin with *are* the laws of thermodydnamics. Specifically, 1st Law time-translation symmetry, 2nd Law assymetric forced mass-energy displacement, and crucially 4th Law path selection. Again, for emphasis, we do not in any way disavow the value of quantum mechanics (or of statistical mechanics or information theory) but one cannot get a causal account or explanation of the progressively developing evolving macroscopic world from them. Instead it is 4th Law local path selection (and always dependent on the entailments of the1st and 2nd Laws through mutual entailment) that spontaneously and selectively produces the *macroscopic constraints* that harness the micromechanical degrees of freedom quantum or otherwise (effectively naturally collapsing the wave function) to make the indefinite definite, the indeterminate determinate, in the production of increasingly more macrscopically ordered and differentiated states.

We have shown how 4th Law path selection works to account for differentiation and macroscopic ordering in simple physical systems, and shown how it accounts for the otherwise paradigmatically unaccountable (the "big problems") in the origin and evolution of life and cognition. The entire universal generative and progressive evolutionary ordering of the universe, from few things (e.g., a relatively homogeneous quark-gluon plasma), or no things *per se* (and we do not honestly know) to increasingly more differentiated and macroscopically ordered things—more kinds of "things", greater numbers of things, and more levels of things follows directly from this law. Each and every production of order, or differentiation is locally symmetry breaking—a physical selection process that locally reduces the degrees of freedom or accessible microstates in the universe or sub-volume within it, taking it from higher to lower symmetry. And each and every one of these processual transitions when it occurs, most generally from stochastic fluctutations in the microcomponents at critical minimal energy gradient thresholds, is a case of opportunistic path selection that locally (then and there) increases the dissipative rate through the extension of the dissipative dimensions of the the system (universe or subvolume within it). In this way, the 4th Law of Thermodynamics effectively "makes the world".

Appendix. The Importance of Drawing a Hard Line Between the 4th Law (LMEP) and the Non-Universal Erroneous Look-Alike MEP$_{W}$

It is unfortunate to have to detract from the coninutity of the present paper to adress the issue addressed here but confusion and erroneous conflations still exist in the literature that are theoretically damaging (and get compounded by re-citings) that it seems important to do it. Many readers will already understand this point and it has been already discussed elsewhere more than once (e,g, see [6] and Appendix B [10]) so for readers who already understand it and are already

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familier with it please do not waste your time here and skip this section. For those who are not, then, it is important to know that decade or so ago (see further discussion and [6]), there was a flurry of papers in the literature that adopted the acronym "MEP", the term we coined and introduced initially over three and a half decades ago to refer to what is now known as the 4th Law or "LMEP", (e.g, [30] and others), for an entirely different, non-universal, and erroneous (easily falsified) principle that we have called "MEP_w" (with "*w*" for "wrong")(e.g, [10]). Briefly, MEP_w says that far-from-equilibrium systems —and *only* for that range—evolve to a final steady state where the entropy production is maximum. So, point blank, this principle is erroneous in its central claim and entirely empty in the most important way (it does not cross levels, account for level-building or most generally explain universal ordering) and in fact has no causal ground for the single claim it makes, it just asserts that it happens.

To distinguish in most basic terms the 4th Law is a *physical path selection law* while MEP_w is an imaginary *state selection principle* referring to the selection of postulated end-states without any causal or physical basis as to why or how this "selection" might work. In different terms by its own definition MEP_w applying only to far-from-equilibrium systems (and not to ones closer to equilbrium) loses the universality of the 4th Law and thus with it all its explanatory power regarding universal ordering. In fact, as the reader might know at this point it is the identification of a physical selection principle that would account for the selection of macro from micro and the symmetry-breaking event that takes a system from micro to macro flow that led to the identification of the 4th Law. To provide a causal account for this as the 4th Law does the selection principle had to be a law in operation across both ranges near and far-from-equilibrium ranges to do it. Thus to make the erroneous conflation that equates MEP_w with the 4th Law (LMEP) is to make an error that carries with it a failure to understand the actual law. Specifically to rephrase for emphasis it has no causal account, and with its limited range can never have one, for the universal transition from or selection of macro order from micro disorder.

To underscore how broken this idea is it imagines that one side of the transition (the ordered macro side) is governed by one principle (MEP_w) while the other side (the micro) is governed by an opposite one typically Prigogine's $Min_{ep.}$ This effectively doubles the problem by misunderstanding Prigogine's principle (which is just that, a very limited *principle*—not a law), applying to only very near equilbrium and very particularly constrained states. It should be pointed out here that is in no way in conflict with LMEP, or the 4th Law which applies universally including this narrow range, and every other (see for further discussion on this point e.g,[6]). Opposing the 4th Law and Prigogine's Min_{ep} is essentailly a category error. In fact Prigogine's principle can be derived from the 4th Law. But returning to MEP_w and discussion in the main text of this paper, it has in Crumpa's terms of fundementality no "cross-sectionality". Effectively it sets the thinking decades back to when this post-Prigoginean idea was first considered for a while (including by us) and then rightly abandoned. It was abandoned not just because for the reasons above it clearly did not and could not provide an answer as the 4th Law did to the question that people were largely trying to answer—the problem of universal ordering. But beyond this, however, aside from this very crucial theoretical point while the 4th Law is a falsifiable (but has never been falsified) MEP_w is on its own terms as the study of living systems as well as a biotic ones readily show, and as discovered by many people (including us) many decades ago, is on its own terms simply false (easily falsified).

Why is MEP_w so easily falsified? Very simply (and see e.g., [6} Appendix B additional detail), other than of course its complete lack of explanatory power which goes a long way towards the essence of Lakatosean falsification (see footnote 18 in section 5.2.6.5) it is easily falsified on basic Popperian terms. Whereas it can certainly be said, and we have said ourselves many times, that ACK systems evolve or develop, as self-amplifying sinks, so as to maximize the extension of their dissipative surfaces, this is accomplished entirely through *local*, here- and-now *path selection* following the 4th Law (local path selection—fastest descent of the potential, or fastest ascent of the entropy). What it certainly does not say, however, is that all ACK or "far from equilibrium" systems will universally develop to steady state end states where the the entropy production is maximum. In fact, to the contrary, as the discussion with Figure 7 shows, the more generic expectation, and precisely

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due to 4th Law path selection in a far-from-equilibrium universe, a typical system will break symmetry and differentiate further by any number of generic symmetry-breaking processes.

Typically, due to general "laws of form", or generalized allometry (e.g, surface/volume ratios, or generalized senescence or freezing out of degrees of freedom) as a system grows and the specific entropy production goes down and the system becomes unstable *precisely because of 4th Law path selection* to symmetry-breaking and differentiation that thus while *falsifying* MEP_w *at the same time demonstrates and confirms the 4th Law.* And *that* is how different they are. *The falsifying instence of the first is simply a confirming instance of the second*. Main take away here is that it is theoretically disastrous to conflate MEP_w and the 4th Law (LMEP). It is important to be on the alert for this erroneous conflation.

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