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The Unbecoming of Being: Thermodynamics and The Metaphysics and Ethics of Entropic Decay

Drew M. Dalton

Abstract

Like the Copernican revolution which initiated the Modern project, there has been a thermodynamic revolution in the empirical sciences in the last two centuries. The aim of this paper is to show how we might draw from this revolution to make new and startling metaphysical and ethical claims concerning the nature and value of reality. To this end, this paper employs Aristotle's account of the relation of the various philosophies and sciences to one another to show how we might assert a new theory of being, moral value, and practical action from the primacy of entropic decay asserted in the contemporary mathematical sciences. This paper proceeds to show how, from what the contemporary sciences have concluded concerning the primacy of entropic decay within reality, unbecoming might be forwarded as a new account of the essence of existence: i.e., the first cause and motivating principle of reality's formal, material, efficient, and final nature. The paper concludes by arguing that a new and surprising account of universal ethical value and normative duty can be deduced from such a metaphysics of decay.

Keywords:
Metaphysics, Thermodynamics, Entropy, Decay, Ethics, Aristotle

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The Question of First Philosophy and the Possibility of the Good:

Towards the start of Book IV of his *Metaphysics*, Aristotle makes a seemingly innocuous observation. It is an observation, however, which organized and framed the subsequent history of Western philosophy. According to Aristotle, though "there are as many parts of philosophy as there are kinds of substance, […] there must necessarily be among them a first philosophy," or a "primary science," which endeavours to explain what is observed within and gleaned from the other philosophical sciences by theorizing some unifying principle or substance which stands behind, above, and between all other observable things binds them together, motivates their activity, guides their potentialities, and gives them form and purpose.[1] This first philosophy or primary sciences is, of course, what we now call metaphysics, that mode of inquiry which, as he puts it "investigates the first principles and causes" of the nature, movement, structure, and form of every things which exists.[2]

Note that for Aristotle, the priority of metaphysical inquiry in relation to the other sub-fields of philosophy and theoretical science is not, however, *chronological*. By his reckoning, one need not study metaphysics *first* before turning their attention to the other sciences, as if in fulfilment of a prerequisite which clears the way for the analysis of "higher level" material. Metaphysical inquiry is not for him a prelude to or condition for the other theoretical sciences, like mathematics and physics. To the contrary, he insists, in many ways these other sciences are in fact "more necessary than" metaphysics for the study of reality.[3] Indeed, he argues, it is only from what we learn in and through them that we can even begin to make any sufficiently grounded conclusions concerning the metaphysical first principles which, he thinks, must logically organize the world which they observe. Metaphysics, it follows for Aristotle, therefore merely *logically* precedes the other theoretical sciences. In fact, he argues, it is the study of these other sciences which should *chronologically* precede one's forays into metaphysics. This is perhaps why Aristotle's own reflections on the nature of this "first philosophy" come after (*meta*) his explorations of the nature of material reality itself in his *physics*. From this it becomes clear that though Aristotle identifies metaphysics as "first philosophy," for its analysis of that which possess a *theoretical priority* over reality, nevertheless, it is physics and mathematics that should *actually* be attended to first if we are to understand the whole of reality properly.

The supremacy of metaphysics as "first philosophy" for Aristotle is therefore merely the logical consequence of what he thinks it pursues: the *primal* cause, *fundamental* nature, or

1 Aristotle, *Metaphysics*, trans. W.D. Ross, in *The Complete Works of Aristotle: The Revised Oxford Translation*, Volume Two, ed. Julian Barnes (Princeton: Princeton University Press, 1984), BK IV (Γ), 1004a 1–5 & 1004a 25–30, 1585 & 1596.

2 Aristotle, *Metaphysics*, Book I (A), 982b 8–9, 1554.

3 Aristotle, *Metaphysics*, Book I (A), 983a 10, 1555.

architectural structure of that which is observed within and accounted for by mathematics and physics. Its "priority" over these other sciences comes merely for him, in other words, from the fact that metaphysics attempts to move from what is observant of material reality (*hyle*) and its mechanical movements (*kineo*) to ascertain the formal order (*eidos*) and final aim (*telos*) motivating, structuring, and guiding its nature and movement; or, as Aristotle calls it "the good, i.e. that for the sake of which," everything else happens.[4] It is only for this reason, then, that Aristotle places metaphysics above the other theoretical sciences; for it is only from its study, he concludes, that we can finally know not merely the *what* of observable reality (its material cause) and the *whence* of its movement (its efficient cause), but the *why* of its being and the *for the sake of which* of its movement (its formal and final causes, respectively). Nevertheless, as he makes clear, the capacity to speculatively contemplate this *why* and *for the sake of which* is possible only if we have properly understood the *what* and the *whence* first. In other words, we can only proceed to metaphysics through the door of mathematics and physics. It is the study of these theoretical sciences which, he thinks, must therefore precede and condition the study of metaphysics.

It is only through the proper ordering of these theoretical sciences in relation to one another, Aristotle thinks, that we can then apply ourselves to the study of the other, more practical sciences and sub-fields of philosophy, like ethics and politics. Hence Aristotle's claims that while a proper understanding of mathematics and physics must precede and condition the study of metaphysics, the study of metaphysics must in turn precede and condition the study of ethics and politics.[5] After all, according to Aristotle, how can we claim to know how someone or something *ought* to be, either singularly (in and through ethics) or collectively (in and through politics), if we do not know both the formal (*eidos*) and the final (*telos*) causes of its being? In other words, to know what is *good* for something, one must know *why* to what *purpose* it is, and moves, and has its being. And, as he further details, this knowledge requires not merely an understanding the first causes of its individual *physical/material* existence (its *hyletic* substance) and the nature of its singular *efficient* action (its *kinetic* cause), but a proper understanding of the whole of existence itself (its *eidetic* structure and *telic* aim). Only through such a metaphysical appreciation of the formal unity of the whole of existence, Aristotle thus concludes, can we hope to know the way in which that individual being might fulfil its function *effectively* or *well* (*eû*); that is, be good. In this regard, the study of metaphysics must not only precede and condition the study of the practical sciences like ethics and politics, but moreover there must be some metaphysical unity to ensure the possibility of goodness in the first place! Without the existence of this primal organizing structure operating over, within, throughout, and

4 Aristotle, *Metaphysics*, Book I (A), 982b 9–10, 1554.

5 For an example of Aristotle's analysis of the implications of metaphysics within ethics see: Aristotle, *Metaphysics*, Book IV (Θ), part 9, 1660.

between all that is, not only would it be impossible to regulatively order reality through ethics and politics, there would be no order to justify these normative endeavours. Indeed, there would be no right or wrong at all.

From this it should be clear that for Aristotle the supremacy of metaphysics over the other theoretical sciences, not to mention its propaedeutic value to the practical sciences, hinges on the speculative assertion that some universal "eternal unmovable substance," exists which infuses, motivates, directs, and gives purpose to the existence of everything which is observed and studied in and through mathematics and physics.[6] This primary "uncaused cause" or "first metaphysical substance," this "perfectly actual" and, as he identifies it, "unmoved mover" of reality, is therefore for him both the proper domain of metaphysical inquiry and the necessary precondition for the possibility of the meaningful order, shared purpose, and ethical significance of reality. Hence his observation that "if there is no substance other than those which are formed by nature, [then] natural science will be the first science," for, he thinks, if there is no unifying essence or singular being which organizes the otherwise disparate and nominal motion and existence of observable reality, then no substantial meaning or value could be attributed to the beings which constitute it.[7] And, if this is the case, then not only must we abandon metaphysics as a useless enterprise, but so too must we jettison the other practical sciences, both ethics and politics alike; for no logical ground would exist for the normative regulation of the activity of reality. After all, he argues, if there is no unifying formal structure (*eidos*) which guides, directs, and gives purpose (*telos*) to the movement (*kineo*) of each and every observable being in its material singularity (*hyle*), then the existence of those beings would consist solely in what is observable of their being alone. In other words, each object would have to be understood on its own, as if existing wholly independently of its other, with nothing but emptiness reigning over, above, behind, and between its activity and the activity of every other being. In such a world, each being would exist as if suspended within a void, wholly alone, separate, and distinct from every other existent object, much less reality as a whole.

Hence Aristotle's assertion that if there is no principal being which exists behind and between every existent object, uniting, motivating, ordering, and directing their activity in relation to one another, then not only is metaphysics a meaningless enterprise, but so too is ethics and politics. Indeed, he notes, if this were the case, then all we could do with what we learn from the theoretical sciences (i.e., mathematics and physics) would be how to apply our understanding of material reality (*hyle*) to some efficient (*kineo*) end, which is the aim what he calls the productive sciences (e.g., agriculture, medicine, transportation,

6 Aristotle, *Metaphysics*, Book XII (Λ), 1071b 5, 1693.

7 Aristotle, *Metaphysics*, Book VI (E), 1026a 28–29, 1620.

etc.). For Aristotle, then, the existence of this formal unifying and organizing first principle over, within, and between all apparent beings is what makes possible not only a metaphysical understanding of the unity of reality, but the idea that beings can be more than merely useful but can also be directed towards some theoretical good. Hence his conclusion that without some primal unified being "the good is impossible."[8]

Fortunately, he assures us, this "primary cause" and "immovable substance," *does* exist—indeed, he claims, it *must* exist. Thus, he promises us, that the ethical value of reality is secure, and we are free to investigate the practical duties we might have within and to reality as a whole.[9] In order to ground and justify his account of this possible good, Aristotle starts by using what he knows from the mathematics and physics of his day to speculatively surmise what he thinks the underlying metaphysical and universal structure of reality—that is, the essence of existence—must be. According to Aristotle, given the testimony of the sciences as he understood it, the unifying structure of reality must be: 1) fully *actualised*, 2) sound and *eternal*, and finally 3) unmoving and *static*.[10] Hence his identification of this unifying being as the "unmoved mover" of reality. On the basis of these conclusions, he goes on to argue that every other thing which exists must be a finite and singular expression and extension of this one metaphysical being and, as such, understood as: 1) the *potentiality* to become fully actualized like its metaphysical ground, something which he thinks it attempts to achieve by way of 2) growth, increase, and *change*, such that it is, by definition, 3) *dynamically* moving towards its true and final form. In as much as each individual being can be said to move according to its own nature thusly, in pursuit of its dynamic potentiality, Aristotle thinks, it can be considered virtuous and good. For these reasons, Aristotle argues that despite the various ways in which each individual being might become incombered in its development such that its growth becomes stalled or its movement perverted, ultimately, he concludes, every element of reality is organized (*eidos*) towards the final goal (*telos*) of its own flourishing (*eudaimonia*); that is, towards that which is, in the end, good (*eû*) for it.

The problem, of course, is that much of the physics which Aristotle used to develop his metaphysical conclusions and, from them, his ethical and political systems, was overturned by the subsequent history of scientific development. This fact calls into question, therefore, both his metaphysical conclusions concerning the overall structure and nature of reality, as well as the alleged moral value of reality. The aim of this paper, then, is to update Aristotle's metaphysics and ethics by asking: 1) what new metaphysical conclusions concerning the formal organizing principle (*eidos*) and final aim (*telos*) of reality might be developed from the testimony of the contemporary mathematical and

8 Aristotle, *Metaphysics*, Book XII (Λ), 1072b 13, 1695.

9 Aristotle, *Metaphysics*, Book VI (E), 1026a 29–31, 1620.

10 Aristotle, *Metaphysics*, Book IX (Θ), 1050b 6-1051a 3, 1659–1660.

physical sciences regarding the structure of material nature (*hyle*) and the efficient motion (*kineo*) of reality as we understand it today; and, 2) what, if any, moral conclusions might be developed from such a new metaphysics? To these ends, we must first understand what the contemporary sciences have to say about the fundamental nature and motion of the universe.

The Thermodynamic Revolution of the Contemporary Sciences:

Commensurate with the so-called "Copernican revolution" which initiated and inspired so many of the developments in modern philosophy from the 16th century onwards, there was a veritable "thermodynamic revolution" in the empirical sciences of the 19th and 20th centuries which inspired its own set of philosophical conclusions.[11] Our aim is to extend and expand those conclusions to metaphysics and ethics by examining them within the framework of Aristotle's account of the systematic relation of the various modes of scientific and philosophical study. For this thermodynamic revolution has yielded a set of first principals which are so universally accepted in the mathematical and empirical sciences today that Frank Wilczek, a Nobel laureate in physics, has suggested that in many ways they can be treated as a new set of "fundamental" truths or first principles from which every other subsequent principle and truth should measure and relate itself.[12] It is only through an understanding of this new set of fundamental truths and its various applications then, that we can attempt to reconstruct an Aristotelian account of the metaphysical essence of being and endeavour to extract from it a new account of the moral value of reality.

The general study of thermodynamics, that is the analysis of the movement and exchange of heat energy, has been around since as early as the 18th century when it was first developed to improve the efficient operation of steam engines. It was not until the early 19th century, however, when Nicolas Leonardo Sadi Carnot, the so-called "father of thermodynamics," defined the first of the underlying laws which govern the flow of heat energy (now counted as the 2nd law of thermodynamics), that thermodynamics was formalized as an area of study and a more systematic account of energy exchange was eventually developed by Rudolf Clausius and William Thomson, the 1st Baron of Kelvin. Thereafter, through the work of J. Willard Gibbs, James Clerk Maxwell, and eventually, most famously, Ludwig Boltzmann, the statistical methods needed to measure heat exchange were clarified and the thermodynamic sciences slowly grew into what they are today. Since then, the field has

11 For an excellent survey of where and how the scientific principles of thermodynamics have been employed within 19th and 20th century philosophy see: Shannon Mussett, *Entropic Philosophy: Chaos, Breakdown, and Creation (*London: Rowan and Littlefield, 2022).

12 Frank Wilczek, *Fundamentals: Ten Keys to Reality* (New York: Penguin Press, 2021), xiii.

only improved and expanded to the point that in recent years it has become increasingly relied upon in nearly every scientific discipline to explain the nature of the transformation and operation of energy in and between its various forms, whether mechanical, acoustic, thermal, chemical, electrical, nuclear, or electromagnetic/radiant.[13] As a result of this work, today the laws of thermodynamics are used to explain nearly everything we know about the nature and movement of the material world, from the formation and eventual dissolution of stars, galaxies, and the universe as a whole, to the emergence and evolution of life therein, not to mention its basic function and even its eventual fate.[14]

Indeed, given their nearly universal use in the contemporary sciences, eminent physicist Carlo Rovelli has gone so far as to propose that the history of scientific development in the 20th century can in many ways be accounted for as the history of the expansion and application of the laws of thermodynamics: "In the course of the twentieth century," he writes, "thermodynamics (that is, the science of heat) and statistical mechanics (that is, the science of the probability of different motions) were extended to [even include] electromagnetics and quantum phenomena."[15] As a result of this extension, he goes on to note, thermodynamic principles have subsequently come to dominate nearly every branch of the material sciences.[16] Thus, the same basic notions that were first used by Carnot in 1824 to improve the efficiency of steam engines and were then formalised into laws by Clausius in 1865 have increasingly become viewed as the singular regulating principle of "*all* material systems," as Addy Pross puts it.[17]

The universality of the application of laws of thermodynamics within and across the contemporary sciences is so complete, in fact, that none other than Albert Einstein noted that "it is the only physical theory of universal content concerning which I am convinced that, within the framework of the applicability of its basic concepts, will never be overthrown."[18] Einstein's confidence in the profound constancy and universal power of thermodynamics to explain the order and operation of reality was so great that he even determined them to be the "firm and definitive foundation for all physics, indeed for the

13 For more on the history of the development and application of thermodynamics see: Robert Hanlon, *Block by Block: The Historical and Theoretical Foundations of Thermodynamics* (Oxford: Oxford University Press, 2020).

14 See, for example: Peter Atkins, *Four Laws that Drive the Universe* (Oxford: Oxford University Press, 2007), v–vii.

15 Carlo Rovelli, *Seven Brief Lessons on Physics*, trans. Simon Carnell and Erica Segre (New York: Riverhead Books, 2014), 57–58.

16 Rovelli, *Seven Brief Lessons on Physics*, 57–58.

17 Addy Pross, *What is Life: How Chemistry Becomes Biology* (Oxford: Oxford University Press, 2012), 80.

18 Albert Einstein, *Autobiographical Notes*, trans. and ed. Paul Arthur Schilpp (Chicago: Open Court Press, 1991), 31.

whole of natural science."[19]

The Content of the Thermodynamic Revolution:

At first glance, the content of the basic laws of thermodynamics is relatively straightforward and easily understood. When those simple laws are applied to diverse systems, however, their meaning and significance becomes extraordinarily profound. The first of these laws, known as the law of the conservation of energy, states that energy, as motion, matter, or heat, can neither be created nor destroyed within a closed system, but can only ever change states within that system. Thus, while the total amount of energy within a system may appear to lessen as matter dissipates, motion slows down, and/or things cool off; the total amount of energy within that system is in fact always constant, albeit manifest in different forms. It is upon this law that Einstein famously established his equation governing the conversion of matter into energy and it is upon this same law that we can predict the productive power of every heat engine, from the small machines which sputter away inside of backyard mowers to the nuclear fusion which fuels the twinkling of stars.

The second and perhaps most famous law of thermodynamics states that statistically energy flows within any given system in such a way that over time it becomes evenly distributed across that system, moving generally from more organized and concentrated towards being increasingly less integrated and more dissipated. This tendency towards disorder, known as entropy, means that every closed system tends towards a state of absolute energy equilibrium where no one thing in the system possess any more or less energy than any other thing in that same system, whether as motion, matter, heat, etc. It is this law which physicists use to explain that, in the words of William Butler Yeats, "things fall apart," and that time moves in one direction only: towards disintegration—which is to say, energy distribution.[20] It is this same law, moreover, which physicists use to explain the material differences between the past, the present, and future and which undergirds what we experience as the "arrow" or "flow" of time. In fact, it is on the basis of this law that the operant understanding of temporality in contemporary physics is founded, for it is this law which guarantees that reality proceeds as it appears to, from one causal step to another, such that, in the words of Steven Hawking, while we may reasonably expect a cup which has fallen from a table onto the floor to shatter into a number of smaller pieces with the movement of time, we cannot reasonably expect "[to] see broken cups gathering themselves together off the floor and jumping back onto the table" as

19 Einstein, *Autobiographical* Notes, 19.

20 William Butler Yeats, "The Second Coming," in *The Collected Poems of Y.B. Yeats* (London: Wordsworth Editions, 1994), 158.

time progresses.[21] The second law of thermodynamics assures us, to the contrary, that as the entropic disorder of a system increases everything within that system will likewise "shatter" into increasingly smaller parts until everything within that system is relatively equal in energic size and all disequilibrium has been "destroyed." It is from the regular governance of the second law of thermodynamics, then, that our contemporary scientific understanding of the *nature* and *operation* of not only time, but existence itself emerges.

An extension of this law ensures us that since entropy must necessarily increase within every closed system in the way outlined above, the only logical *end* to this perpetual dissipation and collapse is a state in which every existent thing possesses the lowest total amount of complex energy possible, and no further energy exchange or distribution is necessary to achieve energy equilibrium. The ultimate expression of this state is, of course, a system in which there are no complex forms of energy at all, like mechanical motion nor even classical objects themselves, but only a low-level background radiation which is evenly distributed across a system. It is this application of the second law of thermodynamics which allows us then to know with absolute certainty that while energy can neither be created nor destroyed, in keeping with the first law of thermodynamics, it can nevertheless "burn out," as it were, and reach a state in which it has no effective mechanical power, demonstrate no motion or change, nor contain within it any potential for objective existence as we understand it.

Empowered by the basic laws of thermodynamics contemporary scientists have been able to speculatively construct a nearly complete picture of our universe and explain the *origin*, material *order*, mechanical *operation*, and *final end* of almost everything observed in the various branches of the material sciences, from the initial rapid expansion of the cosmos themselves roughly 13.7 billion years ago, as is testified to by the background radiation of the cosmos, to the advent and evolution of life on this planet around 3.5 billion years ago, as is testified to by the radio-carbon dating of fossil matter, to the eventual explosion of the star around which our planet revolves in approximately 5 billion years, through analysis of the ½ life of its chemical composition—an event, incidentally, which will eradicate any life still left upon our planet at that time and erase every evidence that life ever existed and flourished here in the first place.

Indeed, within astrophysics, the laws of thermodynamics have allowed contemporary scholars to estimate the age of the cosmos within which all this has and will occur, explain the nature of its sudden appearance and expansion, from an extremely dense, hot, and low entropic singular point in time/space to the ever expanding and cooling state in which it exists today, and even account for the formation of all of the relatively less entropic material

21 Stephen Hawking, *The Illustrated a Brief History of Time* (New York: Bantam Books, 1996), 191.

objects we find therein, like galaxies, nebulae, black holes, quasars, stars, planets, moons, meteors, and asteroids. Not only can astrophysicists use the laws of thermodynamics to explain the accretion, nature, and celestial movement of such objects, they can use them to predict their relative distribution within the universe as well as the eventual collapse of all these things into relatively simpler energetic forms all through application of the same basic statistical models that Boltzmann pioneered in the 19th century to establish the constancy of heat dissipation across any given system.

And, as we have already seen *in breve*, it is from these same laws that the very understanding of the nature and operation of *time*, in which this expansion, distribution, and collapse will occur, has been developed. Hence Sean Carroll's conclusion that, ultimately, the "property of entropy is responsible for *all* of the difference between past and future that we know about. Memory, aging, cause and effect – all can be traced to the second law of thermodynamics and in particular to the fact that entropy used to be low in the past."[22] It is from this law then that anything and everything that has, will, and can even *potentially happen* can be understood as an expression of the arrow and operation of time, as that wherein the very concept of *happening* itself occurs.

On a much smaller scale, Erwin Schrödinger was the first to endeavour to show how the laws of thermodynamics might govern, ground, and structure even the seeming random nature of quantum systems.[23] His ground-breaking work to this end has more recently developed into one of the most dynamic areas of contemporary physics, "Quantum Thermodynamics," which was first pioneered by John Von Neumann in his 1932 classic *Mathematical Foundations of Quantum Mechanics*.[24] There, Von Neumann proposed a new model of entropic decay which was more equipped to predict quantum motion than Boltzmann's original atomic model. As a result of this work, the vast majority of contemporary physicists agree that it will be by increasing our understanding of the operation of thermodynamic principles at the sub-atomic level that the ultimate ground and condition for quantum laws and phenomena will eventually be explainable within the existing laws operant at the atomic level and the long sought "Grand Unified Theory" of reality might eventually be discovered.[25] So it is within the laws of thermodynamics that most contemporary theoretical physicists turn to discover and account for the founding

22 Sean Carroll, *The Big Picture: On the Origins of Life, Meaning, and the Universe Itself* (New York: Penguin, 2016), 59.

23 Erwin Schrödinger, *What is Life? The Physical Aspects of the Living Cell* (Cambridge: Cambridge University Press, 1967), 57.

24 John Von Neumann, *Mathematical Foundations of Quantum Mechanics*, trans. Robert T. Beyer, ed. Nicholas A. Wheeler (Princeton: Princeton University Press, 2018).

25 See, for example: Johnjoe McFadden and Jim Al-Khalili, *Life on the Edge: The Coming Age of Quantum Biology (*New York: Crown, 2014), 291.

principles which govern the order and operation of the entirety of material reality itself, from macro to micro. In this way, the laws of thermodynamics have steadily come to pervade and reign in nearly every field of contemporary physics, from the most practical to the most theoretical.

Within chemistry, through the innovative application of Willard Gibbs analysis of the movement of energy within thermodynamic systems, Gilbert N. Lewis, Merle Randall, and eventually E. A. Guggenheim were able to determine and define the total set of laws which govern chemical reactions, laws which are still taught in chemistry labs across the globe today.[26] Even more famously, Marie Skłodowska-Curie used the laws of thermodynamics to identify and define the principles which give rise to radioactive decay within chemical structures and show how those laws allow us to predict with absolute certainty the slow dissolution and transformation of chemical elements into more basic elementary components through a process which could be described as a kind of entropic alchemy. And it is of course these same principles which were subsequently used to explain the emergence of every existent chemical compound and substance in the first few moments of our universe as well as to predict their eventual dissolution into pure heat energy at the distant end of time.

Perhaps nowhere has the explanatory power of the laws of thermodynamics been more controversial and impactful however than within biology where they have become increasingly relied upon to explain both the basic nature and function of living organisms as well as their initial development from inorganic matter and subsequent evolution into more complex forms. Such an application was of course first suggested by Erwin Schrödinger in his 1944 lectures *What is Life*; but, it was through the detailed lab work of Jacques Monod and others that the role of thermodynamic exchange in the evolution of living DNA self-replicators from mechanical RNA engines, and from that the explosions of complex life *in toto*, that the application of thermodynamics fully flourished within the biological sciences.[27] Today, thermodynamic principles are the bedrock of every accepted scientific account of the nature, operation, and evolution of life.[28] Indeed, contemporary biologists are increasingly convinced that life is best understood as nothing more than the consequence of thermodynamic principles in certain conditions. Hence contemporary bio-chemist Nick Lane's conclusions that life itself might be defined as little more than a highly complex "dissipative structure;" one which is, in the end, merely "the visible

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26 J. Bevan Ott and Juliana Boerio-Goates, *Chemical Thermodynamics: Principles and Applications* (Amsterdam: Elsevier, 2000), 1–2.

27 Scrödinger, *What is Life*, 68; and, Jacques Monod, *Chance and Necessity: An Essay on the Natural Philosophy of Modern Biology*, trans. Austryn Wainhouse (New York: Vintage Books, 1971), 123.

28 Eric D. Schneider and Dorion Sagan, *Into the Cool: Energy Flow, Thermodynamics, and Life* (Chicago: University of Chicago Press, 2002).

product of sustained far-from-equilibrium conditions."[29]

Read through the lens of the laws of thermodynamics, most contemporary biologists in fact agree that not only does complex life appear to be an effect of the dissipation of energy across a system; but, moreover, that all living things are best understood as ultimately highly complex and efficient agents of entropy—little more than more than a highly effective way in which energy can be broken down into its simplest structures and evenly dissipated and distributed across the cosmos. As bio-physicist Peter Hoffman explains, "[l]iving systems are 'dissipative systems' because they continuously dispute free-energy into high-entropy energy."[30] This basic insight has inspired contemporary bio-physicist, Jeremy England, to model in his lab how the dissipation of heat across a system in accordance with the second law of thermodynamics might lead to the self-organization of atoms into the kinds of structures necessary for the development of life and to show thereby how the laws of thermodynamics might be used to explain the evolution of life into its more complex forms.[31] This work has led England to conclude that ultimately the only satisfactory explanation for the "*why*" of life is that it is the "aim" or teleonomic function of all life is to aid entropy. Life, England therefore argues, is simply a kind of dissipative machine, one which uses its complexity to destroy other complex energetic forms by breaking them down, through consumption and metabolization, into simpler forms, like heat and mechanical motion, that can be more quickly dissipated and distributed across the system. In this regard, he concludes, life is nothing more than a product of and aid to the eventual dissolution of matter into heat and, through this, the eventual collapse and destruction of the universe as it currently exists and the steady progress of its relentless march towards a null state at the distant end of time in which no matter or mechanical motion will existence.

As England puts it "many of the properties of living things might be explainable as 'dissipative structures' that arise from a general thermodynamic tendency to reduce the rate of entropy production."[32] "Thus," England concludes, "the empirical biological fact that reproductive fitness is intimately linked to efficient metabolism now has a clear and simple basis in physics."[33] "[S]uch a process," he writes, "must invariably be fuelled by

29 Nick Lane, *The Vital Question: Energy, Evolution, and the Origins of Complex Life* (New York: W. W. Norton and Co., 2016), 94–95. See also Pross, *What is Life*, 118.

30 Peter Hoffmann, *Life's Ratchet: How Molecular Machine's Extract Order from Chaos* (New York: Basic Books 2012), 86.

31 Jeremy England, *Every Life is on Fire: How Thermodynamics Explains the Origins of Living Things* (New York: Basic Books, 2020).

32 Jeremy England, "Dissipative Adaptation in Drive Self-Assembly," *Nature and Nanotechnology*, vol. 10 (November 2015), 920.

33 Jeremy England, "Statistical Physics of Self-Replication," *The Journal of Chemical Physics*, vol. 139 (2013), 141.

the production of entropy." Hence Sean Carroll's assessment that the "purpose" of life, from a material and scientific perspective, in keeping with the application of the laws of thermodynamics across the field, might be, in the end, nothing more than the destruction of matter through its conversion into higher entropic energy states in the service of its dissolution and dissipation across our system. Indeed, he notes, the ultimate "purpose of life" might be summed up in a single word: *metabolism*, "essentially 'burning fuel."[34] This makes sense, he concludes, given the simple fact that living organisms, "[l]ike no other chemical reactions or combinations thereof, proceeds by converting free energy into disordered energy."[35] Or, as Nick Lane, puts it, "[l]ife is not much like a candle; more like a rocket launcher."[36] In fact, England has suggested, there appears to be few agents of entropy which are more effective to this end than living organisms, few things which are as efficient as us at transforming energy from a low entropic state, like matter, into a relatively high entropic state, like heat, in such a way that it can be more quickly and evenly distributed across a system.

It is thus through the application of the laws of thermodynamics within biology that we have finally discovered that life does not in the end violate or work against the laws which govern the inorganic physical universe, nor does it operate in obedience to what Erwin Schrodinger initially thought must be some "other," or "higher," set of laws, despite appearances to the contrary.[37] Life is not, in other, more poetic words, "a struggle against entropy," as Vaclav Havel put it.[38] To the contrary, everything that life is and does is perfectly explained according to the same basic principles which were first identified by Carnot, Clausius, Gibbs, and Boltzmann as governing the order and efficient operation of steam engines. Like those engines, and every other heat engine which exists, life is powered by the exchange of energy according to the laws of thermodynamics which necessitate the even distribution of energy across any given system and between every existent object within that system. In this regard, life, in the end, is little more than an agent of entropy, one which works alongside other existent objects towards the eventual end of everything—that coming null state in which no further energy exchange or action can or will occur. So it is that Peter Hoffman has concluded that "[l]ife does not exist despite the second law of thermodynamics; instead, life has evolved to take full advantage of the second law whenever it can."[39] Or, as Sean Carroll has it, "complex structures can

34 Sean Carroll, *The Big Picture: On the Origins of Life, Meaning, and the Universe Itself.* New York: Penguin, 2016, 264.

35 Carroll, *The Big Picture*, 274.

36 Lane, *The Vital Question*, 64.

37 Schrödinger, *What is Life?* 68.

38 Vaclav Havel, "Letter to Dr. Gustav Husek," in *Vaclav Havel: Living in Truth* (London: Faber and Faber, 2000), 23.

39 Hoffmann, *Life's Ratchet*, 87.

form, not despite the growth of entropy but *because* entropy is growing. Living organisms can maintain their structural integrity not despite the second law but because of it."[40]

In this way, the apparently "negentropic" nature of life first suggested and theorized by Erwin Schrödinger in the early 1940s, and subsequently explored philosophically by Bernard Stiegler and others—the appearance that complex living organisms seem to employ the power of entropy negatively "to compensate the entropy increase it produces by living," in such a way that they appear to "maintain [themselves] on a stationary and fairly low entropy level"—has been thoroughly explained by contemporary biologists as a product of entropic decay.[41] Indeed, as we have seen, complex living organisms are not only a direct and natural product of entropic decay, but they function *not* "to compensate the entropy increase it produces," but to *accelerate* that decay. As a result, we might conclude that complex living organisms are ultimately less an expression of something like negentropy, but rather something like hyperentropy!

Thermodynamics and the End of Existence:

Interestingly, this application of the laws of thermodynamics across diverse fields of scientific inquiry from the 19th century onwards has not only been used to explain the emergence, growth, increase, and operation of seemingly negentropic complex objects, but to speculatively deduce the ultimate end of all those objects as well—indeed, the very end of everything.[42] Within biology, of course, this end is already well known. All living things must die. This simple fact is an inherent and inexorable element of material life, structured and determined as it is by the second law of thermodynamics. Despite our best efforts and all of the ingenuity of the modern sciences, death inevitably awaits every living thing. It is in fact this constant decay within and around us which is the very condition for the possibility of life, as we have already seen. What's more, it is this same constant decay which defines the nature of our growth and apparent flourishing in the meantime, fuelling as it does our need to eat, work, and reproduce. So it is that the perpetual entropic decay which will eventually conclude in our complete collapse drives not only the *final* conclusion of life, but it also appears to *motivate* its secret heart and ultimate *essence* as well. Put in Aristotelian terms, entropic decay could in many ways be seen as the material power (*hyle*), motivational drive (*kineo*), defining structure (*eidos*), and eventual end (*telos*)

40 Carroll, *The Big Picture*, 240.

41 Schrödinger, *What is Life*? 73. For an example of how the concept of "negentropy" has been operationalized by philosophers see, for example: Bernard Stiegler, *The Neganthropocene,* ed. and trans. Daniel Ross (London: Open Humanities Press, 2018), 51–75.

42 For more on how the concept of heat death was developed and variously applied in 19th century philosophical thought see: Mussett, *Entropic Philosophy, 83–105.*

of all that we are and do.

While we may hope, and perhaps even strive to delay the eventual fulfilment of our final end through diet, exercise, and the machinations of medicine, leaning in, in these ways, to our apparently negentropic potency, we must come to terms with the inescapable and assured fact that despite all our best efforts, we will perpetually lose ground before the steady march of entropic decay, disintegration, and dissolution within us and will necessarily contribute to the acceleration of the entropic decay of our immediate environment, even in and through all of these efforts. Indeed, through the application of the laws of thermodynamics as they are currently understood, we can know with certainty that our ultimate demise must eventually come—is, in fact, always already coming—even in and through our desperate attempts to keep it at bay. For, as the contemporary biological sciences assure us, this perpetual death is integral to and inexorable from the very nature and definition of life as such. All of this is well understood. What is less well known, however, is how much the second law of thermodynamics allows us to understand the order (*eidos*), operation (*kineo*), and perhaps even purpose (*telos*) of material (*hyle*) life in the meantime. And yet, as we have just seen, from the pioneering work of Jeremy England and others, we now understand that with every beat of our heart and pull of our lungs we increase the dissipation of energy across our universe. In this regard, even the most complex lifeform is, from the perspective of contemporary biology, an incredibly efficient entropic engine, despite all negentropic appearances to the contrary. Nevertheless, it is now clear that the second law of thermodynamics circumscribes the whole of our existence, from beginning to end, top to bottom, order and operation, aim and accomplishment. We exist, we must now acknowledge in accordance with the testimony of contemporary biophysics, by virtue of entropic decay and live merely to serve its ultimate aim: to accelerate decay in the accomplishment of the eventual end of everything.

Within chemistry, as we have already seen, the second law of thermodynamics can be used both to explain the origin and formation of elementary particles into their current stable chemical structures as well as the conditions for the possibility of the construction of more complex compounds. It can also be used, however, to predict the eventual collapse of every such compound and element into its simplest energetic form, a process which will eventually result in a homogeneous soup of elementary particles and low-level radioactivity at the distant end of time. In fact, by measuring the extremely low level radioactive output of even the most stable elements, chemists can speculatively predict the eventual entropic collapse of the entirety of chemical matter itself, and from this the eventual conclusion of chemical activity in the distant future, a time they refer to as the cosmological "dark era."[43] "In this bleak epoch," the astrophysicists Fred Adams and Greg Laughlin write,

43 Fred Adams and Greg Laughlin, *The Five Ages of the Universe: Inside the Physics of Eternity* (New

"the universe [will be] composed only of the smallest types of elementary particles and radiation of extremely low energy and long wavelengths. Protons [will] have long since decayed and no ordinary baryonic matter [will] remain."[44] So it is in accordance with the second law of thermodynamics within inorganic matter that chemists can predict that "[i]n the far future, the universe [will] contain no complex structures," for "all conventional composite entities [will] have decayed away."[45] In that distant future, the cosmologist Lawrence Krauss notes, "matter will disappear, and the universe will approach a state of maximum simplicity and symmetry."[46]

This process further allows contemporary astrophysicists to predict the eventual end of our cosmos as a whole.[47] As the theoretical physicist Alan Lightman puts it, as a result of the entropic directionality assured by the second law of thermodynamics, physicists today know with absolute certainty that "the universe is relentlessly wearing down, falling apart, [and] driving itself toward a condition of maximum disorder."[48] As such, they can predict, in the words of the science reporter Philip Ball, that "[e]ventually all the universe will be reduced to a uniform, boring jumble: a state of equilibrium, wherein entropy is maximized and nothing meaningful will ever happen again."[49] There is, of course, still robust debate amongst physicists exactly *how* and *when* this eventual collapse will occur. The various positions within this debate hinge on whether the universe should be interpreted as an open or closed thermodynamic system, a distinction which depends in turn on whether the universe is still expanding at a constant rate or whether its expansion is slowing down and, if so, why, how, and what will happen once that expansion ends. In fact, in recent years a virtual cottage industry has cropped up within physics predicting which of these apocalyptic ends awaits our universe.

However, this debate might eventually be settled, nearly every contemporary physicist is in complete agreement that the end of everything will eventually come, all in accordance with the laws of thermodynamics. Thus, while some cosmologists, like Lawrence Krauss and Glenn Starkman, argue for what has been called the eventual "heat-death" of the universe on the basis of the "most recent cosmological observations," which, they argue, "suggest that [the] universe will continue to expand forever," while other cosmologists,

York: Touchstone Books, 1999), xxviii.

44 Adams and Laughlin, *The Five Ages of the Universe*, 155.

45 Adams and Laughlin, *The Five Ages of the Universe*, 155.

46 Lawrence M. Krauss, *A Universe from Nothing: Why There is Something Rather than Nothing* (New York: Atria Books, 2012), 179.

47 See, for example: Katie Mack, *The End of Everything (Astrophysically Speaking)* (New York: Scribner, 2020).

48 Alan Lightman, *The Accidental Universe: The World You Thought You Knew* (New York: Pantheon Books, 2013), 26.

49 Philip Ball, "How Life (and Death) Spring from Disorder," *Quanta Magazine* (January 26th, 2017).

like Steven Frautschi, conclude the opposite, arguing that "heat-death" will not occur, and that a "big-freeze" is more likely, a condition in which the "universe [will] 'die' [...] in the sense that the entropy in a comoving volume asymptotically approaches a constant limit," all parties are in complete agreement that the cosmos must, in accordance with the laws of thermodynamics, eventually come to a complete and total end.[50] Thus, as the noted biologist and science writer Richard Dawkins has concluded, however it might eventually happen, eventually, "finally, and inevitably the universe will [be reduced] into a nothingness that mirrors the beginning. Not only will there be no cosmologists to look out on the universe, there will be nothing for them to see even if they could. Nothing at all. Not even atoms. Nothing."[51] This eventual annihilation is guaranteed with complete certainty given the absolute and universal reign of entropic decay over and within existence, whether living or non-living, organic, or inorganic.

A Thermodynamic Metaphysics of Decay:

From this survey of the content and consequence of the thermodynamic revolution in the contemporary sciences it becomes clear how entropy holds fast over the whole of reality and determines all that is, all that can be, all that will ever happen, as well as the end of every possible happening. In this regard, it is not hard to speculatively deduce from the testimony of the contemporary sciences a new theory of universal being as Aristotle first suggested. Only, from what we have seen, this being can no longer be asserted as something which is perfectly *actual*, *static*, and *eternal* as Aristotle would have it. Instead, from what we now know concerning the reign of entropic decay over and within all that is, we can only speculatively conclude that this being can must be counted as: 1) a destructive *potency* that achieves its aims by 2) *unbecoming* in and through all that is, and is therefore, also, 3) fundamentally and irrevocably *finite*. Being, we might conclude, appears to be something which is steady slouching towards its ultimate obliteration in and through the growth and increase of everything which it generates. The logical consequence of a proper reckoning with the content of the theoretical sciences today, in other words, is not the affirmation of the metaphysics proposed by Aristotle, but a new metaphysics—a metaphysics of entropic decay, a metaphysics of annihilation and unbecoming.

Within such a metaphysics we must acknowledge that while at present beings may appear to proliferate and grow in complexity, operating negentropically to maintain themselves

50 Lawrence M. Krauss and Glenn D. Starkman, "The Fate of Life in the Universe," *Scientific American* (November 1999), 60-61; and, Steven Frautschi, "Entropy in an Expanding Universe," *Science* 2017, no. 4560 (August 13, 1982), 597.

51 Richard Dawkins, "Afterward," in *A Universe from Nothing: Why There is Something Rather than Nothing* by Lawrence M. Krauss (New York: Atria Books, 2012), 188.

against the flow of entropy towards its eventual abolition, ultimately this development is not an act of rebellion or resistance against the inviable slide of being towards absolute zero. Instead, it is the very condition and practical way, which is to say the material nature and efficient mechanism, in which this nihilation is operational and actualizes itself fully. Indeed, as we have seen, the growth and proliferation of existent beings within the cosmos are therefore nothing more than the *material* (*hylectic*) and *efficient* (*kinetic*) modes in which the nihilative order (*eidos*) of this ultimate null-state end (*telos*) is achieved. Even complex living beings then, which seem to function, at least temporarily, negentropically, must be seen as ultimately little more than modalities of the dissipation, expiation, and ultimate extinction of being itself. Within such a metaphysics it becomes clear, in other words, how existent objects like ourselves are, in the end, simply agents of oblivion.[52]

These seemingly counter intuitive metaphysical conclusions are simply the logical extension of the current understanding of the universe as it is accounted for within the contemporary sciences. They are, in other words, merely an extension of what we now know from the absolute reign of the laws of thermodynamics over and within all material systems. If we are to follow Aristotle's advice, then, and guide our pursuit of some primal substance with the testimony of the "more necessary" theoretical sciences, then we can only conclude that such a metaphysics of decay is likely and that being itself is best understood as something that is fundamentally unbecoming. For, as we have just seen, this metaphysics of decay follows necessarily from the contemporary scientific account of reality in its *material* structure (*hyle*), *efficient* driving force (*kineo*), *formal* organizing principle (*eidos*), and ultimate teleological *aim* (*telos*). So it is that entropy can be read as the very *essence* of existence in the Aristotelian sense: the universal ground and first principle of all that is. For these reasons we are justified in concluding that *to be* is nothing more than *to unbecome*—to unravel, decay, dissolve, and destroy.

The Moral Value of Being and the Ethics of Resistance:

Being, it seems, contrary to all appearances, is not something which is ordered towards actualization and flourishing. To the contrary, it is an unbecoming and devouring beast—one that consumes itself over time, slowly digesting all that it is until nothing at all remains. And, in this endeavour it is fundamentally antagonistic not only to its own perpetuation and development, but to the growth and development of every other existent being as well, each of which is generated according to reality's ultimate entropic aim: to destroy itself and everything else with it. In this regard, this ultimate or primal being, qua unbecoming, might be framed as opponent to itself; one that produces singular beings only to toy with

52 Schneider and Sagan, *Into the Cool*, 299 & ff.

them for sport in the ring of reality before eventually dispatching with them forever. In this way, the universal aim of being, to steadily winnow itself away into nothingness in pursuit of ontic annihilation, is slowly and painfully achieved. Within such an account of being it becomes clear that even the most complex and seemingly negentropic beings are not created ultimately to thrive and flourish, but solely to destroy and to be destroyed and, moreover, to experience this destruction, where they have developed the complexity to sense and respond to their environs, as rot, ruin, sickness, and death; in a word, suffering. For these reasons, we might conclude with Arthur Schopenhauer, one of the first philosophers to wrestle with the potential metaphysical and moral significance of the then newly emergent science of thermodynamics, that suffering and anguish could be counted as "the closest and most immediate goal of life."[53] Being, it would indeed seem, is *unbecoming* in every sense of the word. Such a pessimistic evaluation of the meaning and value of life in particular and being in general appears to be a natural consequence of this speculative extension of the laws of thermodynamics into metaphysics. Indeed, Fredrick Beiser has argued that much of the pessimism which appeared in the early 19th century emerged precisely from such an attempt to explore the metaphysical and ethical implications of material laws, including those which would eventually become fully formulated in the laws of thermodynamics.[54]

After all, from what we now know, at least one thing is certain: everything eats and is eaten. Everything destroys and is destroyed. If any ultimate *aim* (*telos*) or order (*eidos*) of being as whole can be deduced from the contemporary scientific account of the *operation* (*kineo*) of material reality (*hyle*) then, it is this: that we, and indeed everything else, exists solely to consume, exterminate, and eventually annihilate; and, in this way, to ultimately obliterate being itself; and that this process is experienced by sensate complex beings as suffering. From this perspective, beings are best framed as cogs in a giant cataclysmic machine, and that living, organic matter is merely one of the many pistons organized by the entropic principle of reality to achieve this ultimate and final aim more efficiently. What's more, we might say that suffering is simply how sensate living organisms experience the very essence of their being. In this regard, it is an essential element of their being – an inescapable and necessary fact and consequent of their complexity. So it is that we might conclude that not only is being fundamentally and irrevocably *finite*, structured as it through its *unbecoming*, but moreover that existence is fundamentally *antagonistic* to itself, both metaphysically and existentially, requiring as it does that each being maintain itself negentropically through the destruction of other existent beings, a process which

53 Arthur Schopenhauer, *Parerga and Paralipomena: Short Philosophical Essays, vol. 2*, trans. and ed. Adrian Del Caro and Christopher Janaway (Cambridge: Cambridge University Press, 2015), 262.

54 See, for example: Frederick C. Beiser, *Weltschmerz: Pessimism in German Philosophy, 1860–1900,* (Oxford: Oxford University Press, 2016)*, 8–10 & 38.*

ultimately accelerates the entropic decay of the system as a whole.[55] What this means concretely is that the only discernible meaning and purpose we might deduce from the testimony of the contemporary theoretical sciences concerning the nature of being is that to be is to decay, dissolve, and disappear and to dismantle, damage, and destroy every other being in the process—and, for us and every other sensate animal, it is to suffer this agonizing process until all our complexity is used up and we collapse.

If we are to follow Aristotle's suggestions that the practical sciences like ethics and politics—and, indeed, moral value itself—must flow from the metaphysical conclusions which are suggested by the testimony of the other theoretical sciences, then we might tentatively suggest that, contrary to Aristotle's claims, being cannot be evaluated as good (i.e., organized toward our actualisation and flourishing). Neither can we maintain the much more palatable modern claim that existence must be fundamentally value neutral. Contrary to these conclusions, given the entropic antagonism which seems to be inherent to reality as it is accounted for within the contemporary theoretical sciences, we might more naturally conclude that the moral value of existence is less than zero. Indeed, if any moral value can be speculatively extracted and rationally deduced from this account of being qua unbecoming which we have speculatively derived from the testimony of the contemporary sciences, then it is this: that existence is *evil*. This is, of course, precisely what Schopenhauer himself concluded from his own analysis of the testimony of the sciences concerning the reign of entropic collapse within and across all material systems. Indeed, as Schopenhauer makes clear, the order and operation of material nature according to the laws of thermodynamics suggests that it can only be evaluated as the very essence of practical evil itself; or, "radically evil."[56]

To see how such a pessimistic evaluation of the moral status of being qua unbecoming might be justified further clearly requires more work, work I have attempted elsewhere.[57] But it should be sufficient from what we have seen here to conclude, at the very least, that the testimony of the contemporary sciences requires that we break with Aristotle's classical metaphysical conclusions, and therefore too his ethical evaluation of the moral

55 For more on this idea see, for example: Joel White, "Outline to an Architectonics of Thermodynamics: Life's Entropic Indeterminacy," in *Contingency and Plasticity in Everyday Technologies*, eds Natasha Lushetich, Iain Campbell and Dominic Smith (Maryland: Rowman and Littlefield, 2022), 189.

56 Schopenhauer, *Parerga and Paralipomena: Short Philosophical Essays, vol. 2, 196 & 274*; see also, Arthur Schopenhauer, "On Will in Nature," in *On the Fourfold Root of the Principle of Sufficient Reason and Other Writings*, trans. and ed. David E. Cartwrights, Edward E. Erdmann, and Christopher Janaway (Cambridge: Cambridge University Press, 2012), 444.

57 To see how this might be worked out in more detail see my forthcoming: Drew Dalton, *The Matter of Evil: From Speculative Realism to Ethical Pessimism* (Northwestern University Press, 2023).

status of existence. Indeed, against his assertion that it is good to be, it is much more logical to assert that it is *not* be good to be, as I have argued in greater detail elsewhere.[58]

It is important to note, however, before concluding, that this analysis of the potential moral value of being as a radical evil does not preclude the possibility of developing some practical politics and ethics from this metaphysics of decay; that is to say, these conclusions do not forestall the possibility of developing legitimate and logical philosophical claims concerning the practical pursuit of the good, i.e., normative ethics.[59] To the contrary, it is entirely possible to deduce some practical good from such a moral evaluation of being qua unbecoming *negatively*, as Schopenhauer first suggested; namely, as a potential which can be pursued negentropically, in resistance to the consuming maw of reality. To wit: if it is demonstratively evil to be, then goodness might be defined as that which actively kicks against the nature and structure of reality, however flutily. So it is, that we might follow Schopenhauer in defining goodness as that which endeavours to bend the entropic thrust of existence back upon itself in such a way that it is momentarily neutralized; for example, in acts of compassion or ascetic renunciation.[60] But, there might be other, more active ways to achieve this end as well, as Philip Mainländer has argued, and I have outlined elsewhere.[61]

No matter how it is practically achieved, when we envision and pursue goodness negatively in this way, as something which is only possibilised through the dialectical *negation* of reality via its own potency for and tendency towards destruction, we might justify the pursuit of a universal ethical good negatively and ground in this way a new, potentially universal and practical normative ethics. To aspire to do good within such a metaphysical system would mean fighting to dismantle, resist, and rearrange every structure which exists within us, as well as the sociopolitical order of our day, that is complicit in the dissipative, destructive, and violent will of nature. Only by pursuing the possibility of goodness negatively in this way, as the duty to perpetually resist that which works alongside and with the trajectory of being itself, might we reanimate an account of universal ethical normativity from this thermodynamically informed metaphysics of decay.

58 See, again: Dalton, *The Matter of Evil*, 4–7 & 127–136.

59 See, for example: Dalton, *The Matter of Evil*, 275–286.

60 See, for example, Arthur Schopenhauer, "Prize Essay on the Freedom of the Will," in *The Two Fundamental Problems of Ethics*, trans. and ed. Christopher Janaway (Cambridge: Cambridge University Press, 2009), 57. See also, Arthur Schopenhauer, "Prize Essay on the Basis of Morals," in *The Two Fundamental Problems of Ethics*, trans. and ed. Christopher Janaway (Cambridge: Cambridge University Press, 2009), 200.

61 See, for example, Dalton, *The Matter of Evil*, 235–243 & 273–274.

Ultimately, of course, such a pursuit of the good is destined to fail. In a universe entirely governed and determined by the principle of entropy, every project which strives to maintain life and well-being against the destructive will of nature and the suffering will prove to be futile. No matter how fully we may ethically commit ourselves to act negatively in perpetual resistance against the forces of nature, we must acknowledge the irrefutable fact that we can never transcend or escape the conditions of our own existence. No supernatural power can aid us in this project, nor can any rational hope be maintained for some final or transcendental salvation from the brutal facts of our own nature. So it is that within the logic of the metaphysics asserted here evil must ultimately win the day. And we cannot work towards any good which is deducible from this system under the false pretense that we might somehow extricate ourselves from the evil of existence or expiate ourselves from the suffering and destruction that existence itself seems to entail for sentient animals. Such moral purity, ethical perfection, or virtuous blamelessness should never be the aim of any practical normative ethics which is derived from this metaphysics of decay. Its aim must be instead merely to resist however possible the tyranny of decay negatively in the hopes that we might achieve and provide some temporary respite from the otherwise relentless march of being towards nothingness, a march which, as we have seem, is experienced as suffering by sufficiently complex organisms. Such an ethics of resistance would therefore define its aims not in the construction of anything positive, but in the opposition to everything which contributes to the annihilative death march of being towards its final goal: absolute obliteration. The aim of such an ethics of resistance, in other words, must be only to use the entropic power of nature to dismantle, disassemble, and dissolve its own structures, however fleetingly, such that some passing sense of relief, calm, and peace might be wrested negatively, if only momentarily, from the otherwise ceaseless progress of being towards nothingness.

Within such a metaphysics and ethics, it becomes clear that though existence is a fixed match, one that we're all destined to lose, this should not prevent us from getting a few good licks in along the way. And it is here, in the possibility of striking back at the moral horror of existence, that a new universally normative ethics might be developed from the unbecoming of being which is assured by a metaphysics of entropic decay. So it is that we can conclude with the claim that the only *ought* which we might speculatively deduce from what we now know *is* the case, is that it is our duty to strike back at the universe, not merely in spite of the utter futility at doing so; but precisely because of it.

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Entropy's Critical Translations: Following Serres's Path through the North-West-Passage

Lilian Kroth

Abstract:

It is, according to Serres, the "greatest discovery of history that entropy and information are connected"—a line of thought he pursues throughout epistemological questions, aesthetics, cultural analysis, and a theory of differential mattering. By following Serres's work, one finds negentropy, entropy, chaos, local orders, the "soft," and the "hard" almost everywhere in his writings. The intellectual context and sources that Serres draws on are an important support in understanding the coupling of informational and thermodynamic entropy, and how it becomes a key operator of entropic differentiation. This text draws a combinatorial map of how Serres connects entropies across a range of areas of knowledge. In this specific context, Serres's path of translation harnesses the so-called "hard" and the "soft" forms of entropy in his investigations of literature and art, but also in order to discuss social phenomena and the formations of societies. By drawing attention to the negative spaces in Serres's connective path of translating entropies and in the course of reading his work in context with other philosophies of entropy, this essay aims to explore Serres's translations in the way it both *connects* and *leaves gaps*. Approaching Serres's criticality in this way brings one to the critical, difficult, icy landscapes of the North-West-Passage. The North-West-Passage epitomises a method to conceive the difficult path between the natural sciences and the humanities—exactly the kind of path that entropy often meanders on. In fact, entropy itself plays an important role regarding the icy landscape's ecology, e.g., to the degree to which the passage is melted or frozen, and thus, to the possibility of the passage as such. Bringing these lines of thought together, entropy appears as a condition to think Serres's method of translation. By considering these multi-layered aspects of entropy as a material, aesthetic, and critical factor, this contribution places Serres's approach to entropy as an eco-critical path in the face of the melting of icy landscapes.

Keywords:

entropy, Serres, North-West-Passage, translation, transdisciplinary, environment

 Corresponding author: Lilian Kroth, lvlk2@cam.ac.uk

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1. Entropy in Translation

During the last Ice Age, a glacier pushed forward a massive flow of material in an area that is close to what is now Emmen in the Netherlands. The quarry, deposits of sand and gravel in multiple colours and a lake filled with jade green water carry a geological history that tell of these ancient glacial movements. In the 1970s, American artist Robert Smithson became interested in the site, and just after realising his famous *Spiral Jetty* (1970) in Utah, USA, he carved *Broken Circle/Spiral Hill* (1971) as an answer to the Dutch site of the sunken landscape with its cone-shaped hill.[1]

It stages Smithson's thinking about entropy in a site-specific artwork. Entropy as a concept has developed in the course of the artist's working and thinking about time, sites, decay, and creativity, which he has made productive by writing *about* art, that is, engaging with what he calls a new monumentality;[2] as well as by integrating it *into* his own artistic practice. Smithson's work on entropy can be read as one way to translate the concept into a form of knowing that is different from its disciplinary origins. It is an attempt to make the concept of entropy tangible, experienceable and to switch registers of abstract knowing, verbal understanding and sensual experience. Taking Smithson's *Broken Circle/Spiral Hill* as an entry into entropy's translations, we encounter that, in general, the concept has been mobilised in many ways, and has been historically open to being translated from its formulation in thermodynamics into many other realms, such as information theory, biology, economics, history, art, and literature.

Within the numerous approaches to transfer and reformulate the meaning of entropy into other areas of knowledge, it seems particularly interesting to see how exactly these shifts take place. I turn to Michel Serres in this context for two reasons; firstly, due to his simultaneous scientific and poetic engagement with the concept of entropy; and secondly, because he has developed the idea of translation as a philosophical and critical method. What it means to translate is mostly demonstrated in his theory-practice rather than explicated in a meta-theory. In some places, such as in the first pages of *Hermès III. La traduction*, he gives some insights into his method of "traduction," which differs from both "deduction" and "induction."[3] Translation is oriented by "traduction" and, for Serres, follows the passages or interconnected knowledges across different ways of understanding, which itself is strongly informed by his reading of Leibniz and

1 https://holtsmithsonfoundation.org/broken-circle-and-spiral-hill-having-entropy-dutch-way

2 Robert Smithson, *Robert Smithson: The Collected Writings*, ed. Jack Flam (California: University of California Press, 1996).

3 Michel Serres, *La Traduction* (Paris: Éditions de Minuit, 1974), 9.

mathematical structuralism.[4]

In this context, translation cannot be abstracted from being a form of communication, which, due to noise and miscommunication, can be successful as well as unsuccessful.[5] It raises questions of trans-disciplinarity similarly as "a- and pre-disciplinarity" and the relations between philosophy and science that have been historically heterogenous.[6] Translation in Serres, as Chris Watkin notes, imply the many substitutions and non-linear analogies involved and suggests a "non-trivial isomorphism as opposed to a simple correspondence."[7] What remains important overall and especially also in the context of entropy is that Serres's translations refrain from employing a centre of origin, which is why they explicitly do not hold an "ultimate key" to a universal model, neither do they proceed by "umbilical thinking" with an ultimate source.[8]

Having started from Smithson's *Broken Circle/Spiral Hill* in the Dutch landscape, I will in the following move through Serres's combinatorial maps of entropy, to then take the passage through the material and symbolic Arctic landscapes or what Serres calls the North-West-Passage as a metaphoric multidisciplinary environment. Serres's reading of Leibniz shapes much of his topological operation—it is not only Leibniz's *ars combinatoria* that informs Serres's structuralism and that inspires his method of translation; but also a topological map of connection in a fluid landscape that grounds important aspects of his theoretical practice: it is his explicit wish to "finish drawing this navigational map, this inventory–fluctuating and mobile–before I die."[9] The North-West-Passage appears as a thoughtspace, as one might call it, accommodating Serres's critical translations between the sciences and the humanities in a difficult, icy, and moving landscape. Within this setting, the concept (or concepts) of entropy plays an important role for, on the one hand, a paradigmatic interdisciplinarily shaped function; and, on the other hand, the idea of

4 Michel Serres, *Le Système de Leibniz et ses modèles mathématiques* (Paris : PUF, 1968); Lucie Kim-Chi Mercier, "Michel Serres's Leibnizian Structuralism," *Theory, Culture & Society* 24, no.1 (2019): 3–21.

5 Steven Brown, "Michel Serres: Science, Translation and the Logic of the Parasite," *Theory, Culture & Society* 19, no. 3 (2002): 1–27; Michel Serres, Josué V. Harari, and David F. Bell, *Hermes. Literature, Science, Philosophy* (Baltimore: Johns Hopkins University Press, 1982), 80.

6 Lucie Mercier, "Introduction to Serres on Transdisciplinarity," *Theory, Culture & Society* 32, no. 5–6 (September 2015): 38; Michel Serres, "Transdisciplinarity as Relative Exteriority," *Theory, Culture & Society* 32, no. 5–6 (2015): 41–43.

7 Christopher Watkin, *Michel Serres: Figures of Thought* (Edinburgh: Edinburgh University Press, 2020), 406.

8 Watkin, *Michel Serres: Figures of Thought*, 38–43; Vera Bühlmann, *Mathematics and Information in the Philosophy of Michel Serres* (London: Bloomsbury, 2020), 53, 145; Serres, Harari, and Bell, *Hermes. Literature, Science, Philosophy*, xiv.

9 Michel Serres and Bruno Latour, *Conversations on Science, Culture, and Time* (Ann Arbor: University of Michigan Press, 1995), 105.

entropy shapes decisively the ecology of the landscape in which these critical translations take place.

Throughout Serres's work, from his earlier to his later writings, we encounter an engagement with entropy through the history of physics and information theory, yet, also in his readings of literature or the history of art. In fact, entropy and entropic differences are a key to understanding Serres's work more broadly.[10] His writing on various issues is imbued with the language of entropy, that is terminologies of decay, dissipation, reservoirs, temperature differences, homeorrhesis, chaos, local orders, negentropic islands, and most significantly, the "soft" and the "hard." The latter two are terms with which Serres articulates two meanings of entropy, that is the thermodynamic (hard) and the informational (soft), the particular relationship of which has sparked much interest in the literature on Serres.[11]

In negotiating entropy and negentropy, Serres approaches a multiplicity of phenomena, and, in fact, world views. He develops a negentropic epistemology, a negentropic subject, and extends these entropy-related figures into his ideas of religion and social theory. The interpretation of entropy is not necessarily that of decay, but takes it from its potential of beginnings, as *La distribution* narrates: the beginnings of knowledge, of life, of time, of signals, of the world.[12] Serres's philosophical reflections take into account phenomena such as "energy reserves according to Brillouin," "differences according to Carnot," "dissipative structures in the sense of Prigogine," or "metastable equilibriums according to Wiener."[13] As shown elsewhere, this entropic difference is an operator that drives Serres's thinking at large; namely, a difference which can be understood as a deviant differential and as a processual distribution of chaos and order as co-dependent categories.[14]

It seems worthwhile to pay particular attention to the theoretical path and the combinations Serres's work on entropy establishes. In doing so, I will mark decisive orientations and sources that define a conceptual net of connections, as well as look at some of Serres's writings to trace entropy that might be a bit off the radar, namely those that concern theories of social relations and social phenomena. His translations between history of

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10 Lilian Kroth, "Entropy and Entropic Differences in the Work of Michel Serres," *Theory, Culture & Society* (2023): 1–15.

11 Bernadette Bensaude-Vincent, "Connecting the World and the Word: The Hard and the Soft in Michel Serres's Philosophy," *Technology and Language. Introductions* 1, (2020): 12–15; Bühlmann, *Mathematics and Information in the Philosophy of Michel Serres*; Connor, Steven. "'The Hard and the Soft,'" *Available at Http://Www.Stevenconnor.Com/Hardsoft/*.

12 Michel Serres, *La Distribution* (Paris: Éditions de Minuit 1977).

13 Serres, *La Traduction*, 48.

14 Kroth, "Entropy and Entropic Differences in the Work of Michel Serres."

science and art seem to have been more broadly received, such as on how J.M.W. Turner's paintings translate Carnot's thermodynamics, or how Émile Zola's fiction epitomises a steam engine.[15] Yet, Serres also expands his entropic translations through the "hard" and the "soft" into cultural and social theory more broadly. To give an example: the entropic difference is even present in Serres's theory of religion. The interplay between the hard and the soft explains what Serres calls "hot spots," "those places where, at a given moment, another world manifests itself in ours."[16] This other world, as Serres calls it, "abstract, virtual, possible, whatever else it may be, sometimes manifests its existence in our world by suddenly emerging in places of exceptional heat that, once they have cooled, are so long-lasting that their traces lie outside the boundaries of historical time."[17] In these moments and places of "hot spots" Serres is concerned with how these interfere with "vertical binding," that is, how the religious bounds of individuals and collectives is described as equivalent to the coming together of the "'hard' and the 'soft'"[18]—which is one of the examples of Serres's usage of terminology of thermodynamic and informational entropy in contexts that are conceivably different from their disciplinary origins.

2. A Combinatorial Map of Entropies

How does Serres arrive at his translations of entropy, what are his sources, and how does he connect these different occasions of entropic thinking? And, within these many connections, what does he *not* connect in pursuing entropy's translations? Within the broad disciplinary scope of translatability, it is particularly insightful to pay attention to some of the gaps, and negative spaces regarding how entropy can or has been translated in his work.

Let us start with Serres's approach to entropy as it emerges between thermodynamics and information theory. It is, according to him, the "greatest discovery of history that entropy and information are connected, in epistemology as well as in the theory of matter."[19] The intellectual context and sources that Serres draws on are an important support to understanding the way in which the coupling of informational and thermodynamic entropy takes place. His early *Hermès*-series is imbued with a broad range of topics and histories, notably a theory of communication and information, as well as the history of

15 Serres, Brown, and Paulson, "Science and the Humanities"; Serres, Harari, and Bell, *Hermes. Literature, Science, Philosophy*; Serres, Michel, *Feux et Signaux de Brume* (Paris: Grasset, 1975).

16 Michel Serres, *Religion: Rereading What Is Bound Together*, trans. Malcom DeBevoise (Stanford University Press, 2022), 5.

17 Serres, *Religion*, 4–5.

18 Serres, *Religion*, 11–13; 21; 27–29; 54–66.

19 Serres, *La Traduction*, 71.

thermodynamics. Serres follows, amongst others, Clausius, Boltzmann and Carnot and their contributions to understanding the transition from dynamics to thermodynamics, the arrow of time, motors, and more generally, the concept of entropy from the 19th century onwards. In his historical approach, he reformulates the relevance of this history for philosophy and how it fundamentally reconfigures conceptions of time and space that are implicitly oriented by dynamics, towards a philosophy that integrates temperature differences and irreversible time. Similarly, he introduces a notion of communication which goes against the grain of fundamental classical philosophical frameworks of subjective existence and respective forms of interaction; and he proposes a deeply relational philosophy that is grounded in differentiating noise and information.[20]

When drawing the combinatorial maps of Serres's translations of entropy, there are different sources to be considered, which range from Lucretius—whose natural philosophy Serres formulates in terms of a language around entropy and therefore reads the history of ideas connected to the concept of entropy somewhat recurrent—as well as 20th century thinkers, such as Léon Brillouin, Henri Atlan, Ilya Prigogine, Isabelle Stengers, and Jacques Monod. In order to understand how Serres is able to couple entropy in the thermodynamic sense with that of information theory—an endeavour which others have pursued in relatable ways[21]—we need to understand Serres's combinatorial map of connections.

In information theory, Serres refers, for example, less to the work of Shannon whose use of the term entropy points to an average level of information in a message, but to that of Brillouin: in *Science and Information Theory,* Brillouin reversed the notion of entropy and negentropy that made it compatible with entropy and negentropy as in the thermodynamic notions of chaos and organization.[22] The important contribution that Serres adapts from Brillouin is the connection between negentropy and information. By stressing that exactitude comes always with costs, Brillouin came up with an economic conception of entropy and a critique of determinism that also proved to be highly influential for Serres; namely, that negentropy comes with a price to be paid.[23]

20 Serres, *La Communication*; Serres, *La Traduction*; Serres, *La Distribution.*

21 Terrence Deacon, "Shannon – Boltzmann – Darwin: Redefining Information (Part I)" *Cognitive Semiotics* 1, no.1 (2007); Jeffrey Wicken S. "Entropy and Information: Suggestions for Common Language" *Philosophy of Science* 54, no. 2 (1987): 176–93.

22 Léon Brillouin, *Science and Information Theory* (New York: Academic Press Inc., 1962); Serres, *La Distribution.*; Bühlmann, *Mathematics and Information in the Philosophy of Michel Serres*, 34–42.

23 "A very large amount of information", he writes, "shall cost a very high price, in negentropy. An infinite amount of information is unattainable. An infinitely short distance cannot be measured, and a physical continuum in space and time is impossible to define physically." Brillouin, *Science and Information Theory*, 303. Bühlmann notes that what Brillouin means by the price of information is not only metaphorical. In mathematical physics, the Price of Information can be quantified precisely; it can be indexed even with a number (10^{-16} in Brillouin's 1956 book, a number which by the state-of-the-art

Connected to that, Serres holds strong ties to research on the concept of entropy in the context of far-from equilibrium thermodynamics from the 1960s onwards; that is, respective notions of chaos which are not simply opposed to order, but which provide a potential ground for order. Crucial for that is Prigogine's work on "dissipative structures" as well as Prigogine and Stengers's collaborative work *Order Out of Chaos.* These approaches have not only been ground-breaking for research between physics and chemistry, but also entail crucial insights for philosophical approaches to questions of decay and the emergence of orders. Research in far-from-equilibrium thermodynamics discovers entropy as a potential for order, which Serres regards as an important task to be integrated into philosophy more broadly. It is in this sense that Serres develops philosophical conceptions of structure, locality, and globality through his engagement with the sciences.

Prigogine and Stengers notably share less fascination for influences on Serres such as Brillouin[24] and his concept of negentropy. Yet the two authors of *Order Out of Chaos* and Serres prove to have been reciprocally familiar with and influenced by one other's work.[25] Prigogine, Stengers, and Serres share an interest in Lucretius, in the history of thermodynamics and the meaning of an entropic world vision, as well as in contemporaries such as Jacques Monod. There are further crossovers in terms of the readjustment of the human-nature-relationship towards a pact or alliance with nature, a critique of disenchantment, the emphasis on uncertainty and contingency, as well as an understanding of nature which is built on concepts such as self-organization, spontaneity, temporality, multiplicity and complexity.[26] What is crucial in this respect, however, is that Serres relates to an understanding of entropy which is not equivalent to decay, but which comprehends a potential for organization exactly within processes of dissipation.

We can see how this differs from the networked maps others have drawn of the concept of entropy. In many cases, this also depends on the sources harnessed, and the connections that are made possible with respective takes on entropy. Thus, Serres's approach differs from other philosophers who have mobilised entropy in French thought, such as, for

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particle physics of today has reached 10^{-32})" Bühlmann, *Mathematics and Information in the Philosophy of Michel Serres*, 41.

24 Ilya Prigogine and Isabelle Stengers, *Order out of Chaos* (New York: Bantam Books, 1984), 216.

25 The points of contact between the authors are manifold: Serres directly refers to Prigogine's "dissipative structures" (Serres, *La Traduction*), and he wrote a review of *Order out of Chaos* for *Le Monde* in 1980; and vice versa, Prigogine and Stengers come back to Serres in *Order Out of Chaos* several times (Stengers and Prigogine, *Order out of Chaos*, 141; 303–5).

26 Henry Dicks, "Dossier: Le Groupe Des Dix, Des Précurseurs de l'interdisciplinarité – Physics, Philosophy and Poetics at the End of the Groupe Des Dix: Edgar Morin and Michel Serres on the Nature of Nature," *Natures Sciences Sociétés* 27, no. 2 (April 2019): 169–77"; Stengers and Prigogine, *Order out of Chaos*, xxvii; 22; 32; 165–67; 304.

example, Bernard Stiegler or Gilles Deleuze. Serres does not identify entropy with decay only, but as a potential for order, which is why the notion of it having to be "overcome" (Deleuze) did not find entry into Serres's philosophy, neither did a diagnosis of entropy's application into terms such as "hyper-proletarianization and a generalised form of automatic piloting" (Stiegler) take place in such form in the translations Serres pursues.[27]

In his translations of entropy, one can see further contrasts to other approaches and generally highlight that Serres is interested in art history, yet less in relations with more recent or contemporary art practices. The same holds true for literature: whereas there has been a notable interest in entropic literature or the application of concepts related to entropy in literary studies in the later 1980s and 1990s,[28] Serres seems to somehow participate in this historically situated momentum of interest himself, yet the literary sources he works with, Zola or Woolf, for example, indicate that his research seems rather directed towards an established literary canon and not necessarily concerned with contemporary works.

Many passages between entropy and social theory are possible, many of which Serres does not choose to take. For this reason, firstly, I would like to acknowledge a gap in respect to the absence of translation into a wide range of possible "social" dimensions. Serres does, unlike others, not make use of figures or expressions such as "social entropy" to explain or criticise social crises or society as "ungovernable."[29] Furthermore, Serres does not mobilise Prigogine's "dissipative structures," thermodynamic decay, or the idea of auto-poietic systems for a naturalised understanding of social regulation. His naturalism follows along different lines and is particularly sceptical of such direct applications of scientific terms into social theory. In that, Serres's implementation of entropy into a theory of hominization differs from, for example, Hayek's application of entropic vocabulary. Hayek referenced not only Spencerian evolutionism, but exactly the idea of "dissipative structures" to give his theory of the market quasi-scientific underpinning.[30] Hayek would have "claimed natural science foundations for his own theory of spontaneous

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27 See Deleuze's take on entropy in *Difference and Repetition* (London: Athlone Press,1994), and Stiegler's approach on the concept in *The Neganthropocene* (Open Humanities Press, 2018); for a more detailed analysis of the comparison between Serres and Stiegler and Deleuze, see Kroth, "Entropy and Entropic Differences in the Work of Michel Serres."

28 Katherine Hayles, *Chaos and Order: Complex Dynamics in Literature and Science* (Chicago: University of Chicago Press, 1991); Katherine Hayles, *Chaos Bound: Orderly Disorder in Contemporary Literature and Science* (Ithaca, N.Y.: Cornell University Press, 1990).

29 Wolfgang Streeck, "The Post-Capitalist Interregnum: The Old System Is Dying, but a New Social Order Cannot yet Be Born" Juncture 23, no. 2 (2016): 68–77

30 Geoffrey Hodgson, "Hayek, Evolution, and Spontaneous Order," in *Natural Images in Economic Thought: Markets Read in Tooth and Claw*, ed. Philip Mirowski (Cambridge: University Press, 1994), , 408–48.

order, aligning his project with "autopoesis, cybernetics, homeostasis, spontaneous order, synergetics, systems theory" and claiming the far-from-equilibrium thermodynamics of Ilya Prigogine as support for his work."[31] Serres's naturalism, by contrast, does not claim *such* continuity between the natural and social world. The continuity runs differently, with a caution for the difficulty of taking (transdisciplinary) passages and with a sensitivity for scales.

Keeping in mind these differences and disruptions on a map of connections, one can further follow the paths with which Serres establishes relations between entropy and a theory of the social. The influence of René Girard is not to be underestimated, especially in regard to the question of how social order may emerge out of disorder.[32] The 1981 Stanford conference on "Disorder and Order in the Human Sciences" organised by Girard and Jean-Pierre Dupuy is an outstanding example for the search for a dialogue between the physical and the human sciences, which numerous intellectuals such as Henri Atlan, Francisco Varela, Edgar Morin, Cornelius Castoriadis, Heinz von Foerster, Ilya Prigogine and others took part in.[33] Serres is clear about his reservations towards a specific idea of a universal law of entropy—he refrains from universalist explanatory models and tries to establish entropy as locally global rather than globally local, as it were.[34] The attempt to refrain from such universalism makes Serres develop a particular concept of the global, notably active in an idea of "global intuition" and his dedication to a "new universal humanism," encompassing non-human life and the "whole universe."[35]

Particularly in regard to his thinking of the global in alignment with entropy in the realm of social theory, Serres reads as a patchwork: he remains interested in the human condition

31 Jeremy Walker, *More Heat than Life: The Tangled Roots of Ecology, Energy, and Economics* (Singapore: Palgrave Macmillan, 2020), 321.

32 Massimiliano Simons, *Michel Serres and French Philosophy of Science: Materiality, Ecology and Quasi-Objects* (London: Bloomsbury Academic, 2022), 149; 155.

33 William Johnson, "Frères Amis, Not Enemies. Serres between Prigogine and Girard" (Ann Arbor: University of Michigan Press, 2005), 37. Serres aspiration to find passages between the sciences and the humanities stands out of question, yet the passages are not to be regarded as direct, insofar as, for instance, there remains a conditionality of science. "Serres has been situating science as unconditional but conditioned: entropy will always increase in a closed system, but individual societies will deploy their science according to different values." Johnson, "Frères Amis, Not Enemies," 43.

34 In this respect, my reading here differs from Hayles's criticism of Serres (Hayles, *Chaos Bound: Orderly Disorder in Contemporary Literature and Science*).

35 Michel Serres and Bruno Latour, *Conversations on Science, Culture, and Time* (Ann Arbor: University of Michigan Press,1995), 115; Christopher Watkin, *French Philosophy Today: New Figures of the Human in Badiou, Meillassoux, Malabou, Serres and Latour* (Edinburgh: Edinburgh University Press, 2016), 141–42.

(with its multiple genesis as "locally global"); yet still, he often inhabits an authorial voice of a non-specified we/us—which presents a broader topic of discussion with different approaches to reading his work.[36] In the following, we shall now grasp those skeins in Serres's work that seem particularly productive in his combinatorial map of entropy, that is, in the parts that are involved with social theory.

In following Serres's conception of such human condition, we discover the language of entropy as a key to a non-deterministic philosophy: living beings, life as such, and the human condition is in Serres's picture a process between thermodynamic necessity and open contingent future. "Hominization", for him, "consists in this contingent sequence of new deviations, of different equilibriums and new habitats."[37] In his almost cyborgian approach to what can be regarded of the human condition as an emergence out of changing equilibria, his understanding of human existence follows a mixture of the "hard" and "soft" entropies as a "bouquet of times."[38] How does Serres combine and translate entropy here? He explains *processes of globalisation* through "soft" and "hard" entropies, as well as changes in the human condition through his diagnosis that the negentropic "soft" technologies gain dominance over the "hard" entropic decay. In his view, human conditions and societies are formed through negentropic and entropic processes on multiple scales. They emerge in interconnection with technologies, and in doing so, create a movement of "loops" shaping "society."[39] It all revolves around a sensitivity for scales—there are translations and interferences between the (neg)entropic processes on the level of cells, living bodies and co-domestic companionships.[40]

On Serres's theoretical path, however, these intersections of entropies are not to be translated *directly* into a theory of society as "entropic"; rather, it grounds a translation of entropies as operators of difference in historically heterogenous loops and scales of societal formation. "Hominization" describes (neg)entropic processes between cells, "new bodies," "new houses" and "new globalities," revealed through a structural analysis of their relationships. Through a first loop of hominization that Serres calls "exo-Darwinian"[41]

36 Michel Serres, *Hominescence* (London: Bloomsbury Academic, 2019); Michel Serres, *The Natural Contract* (1995). On this point, see also Watkin in regard to Serres's "Great Story" (Watkin, *French Philosophy Today*, 166–70).

37 Serres, *Hominescence*, 35.

38 Serres, *Hermes,* 75.

39 Serres, *Hominescence*, 213, 232, 246.

40 Serres, *Hominescence*, 108, 176, 215–16.

41 "Exo-Darwinism", Serres explains, is what he calls "this original movement of organs towards objects that externalize the means of adaptation. Thus, exiting evolution with the first tools, we entered into a new time, an exo-Darwinian one. So this original duration affected these tools in return. Plunging in their turn into another evolution, they transformed in our stead. So instead of sculpting our bodies, duration fashions these objects through the intermediary of our expert hands and our big

and a cyborgian understanding of bodies as "bio-techno-structures,"[42] he maintains that the question running from biology to technological objects is "humanist" or "new humanist."[43]

It is the figure of a spiralic "loop" with which Serres characterises "hominescences" and the emergence and stabilizations of respective organizations. In this respect, the temporalized loop transforms how we might understand the boundaries of groups; yet that does not necessarily lead to a (liberal or neoliberal) argument of societal self-organization as a whole. The relationship between these different scales of systems thus conceived is marked by keeping its grounding in the coupling of information and matter. Serres stresses that "we are slices of the world"[44]: the social field is not governed by other laws than the physical world. This does not, however, say that societies simply have to be understood as entropic as a whole. It is important to stress that Serres's combinatorial maps do not employ an ideological scientificity in thinking social relations, nor would they apply entropy in a merely speculative manner—it is exactly about working out a how entropies *matter* on different scales of organization forming societies.

3. Making Theory Through the North-West-Passage

The North-West-Passage is a fractal landscape, less under control than an adventure, it is the critical landscape that will concern Serres throughout decades of his work.[45] The North-West-Passage has notably different meanings: (1) it refers to the sea route between the Atlantic and Pacific oceans through the Arctic Ocean, (2) it is the title of the fifth and last volume of *Hermès*, and (3) it epitomises the concrete passage of a method. As this fifth volume of the *Hermès* series addresses methodological aspects of how the passage between different areas of knowledge can run, the book, as Sydney Lévy has noted, "could also be thought of as a meta-hermes where Michel Serres studies the very activity which he has been practicing in the first volumes."[46] Serres appears as an "itinerant theorist" in presenting "a route, a record of a journey, a guidebook," in which he seeks to "weave together the fabric of knowledge."[47]

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brain." Serres, *Hominescence*, 39.

42 Serres, *Hominescence*, 47.

43 Serres, *Hominescence*, 45–46; 196.

44 Michel Serres, "Temps, Usure: Feux et Signaux de Brume" In *Cahier de L'Herne Michel*, ed. François L'Yvonnet and Christiane Frémont (Paris: Editions de L'Herne, 2010.), 212.

45 Serres and Latour, *Conversations on Science, Culture, and Time*, 70.

46 Sydney Lévy, "Review of Hermès V. Le Passage Du Nord-Ouest, by M. Serres," MLN 97, no. 4 (1982): 990.

47 Paul A. Harris, "The Itinerant Theorist, Nature and Knowledge/Ecology and Topology in Michel Serres," *SubStance* 26, no. 2 (1997): 37.

The task is to follow what it means to navigate, with Serres, in a critical and multidisciplinary environment. Taking the North-West-Passage in its metaphoric sense means to be on the spatiotemporal journey of critical translations; it helps him to conceive the difficult path between the natural and social sciences, and to think the relationship between world and thought. The concepts of entropy play a crucial role in this; and my concern here is that Serres not only shows how the concept of entropy is translated, but how entropy in both the "soft" and the "hard" sense relies on entropy, which is itself a *condition* for translation.

Navigating the North-West-Passage requires passing through different state territories, as well as—imagined as a landscape of transdisciplinarity—between the blurry and changing territories of disciplines of knowledge. The North-West-Passage urges Serres to think disciplinary boundaries in the context of the relationship between natural and social sciences; and these boundaries themselves are formally put into question: in terms of their temporality, their states of matter, and interferences between world and mapping. Limits and boundaries in the North-West-Passage are subjected to temperature, and therefore, changes of states. The passage is bound to the effects of freezing and melting. As Yusoff notes, in Serres, "heat" is the (atmospheric, oceanic, terrestrial and solar) "messenger" and as "a form of interference in cold geographies," like a "hot knife," it makes the passage "open up."[48] Ingold and Simonetti, who also refer to Serres to emphasise the continuity of fluidity and solidity in a "world of becoming," incorporate the role of formal and metaphorical aspects of ice between concrete and fluid in a relatable way.[49]

These considerations provide a framework for the critical work of transdisciplinary translations in Serres's North-West-Passage, itself taking into account the second law of thermodynamics, and more broadly, entropy. As shown earlier, entropy is for Serres a condition to think translation in terms of both communication and miscommunication; here, on the other hand, it becomes clear that entropy as a thermodynamic concept is crucial in understanding the conditions of the icy landscapes, which provide Serres the translation space par excellence.

The North-West-Passage is, in Serres's words, the "complicated zig-zag line in between

48 Kathryn Yusoff, "Navigating the North-West-Passage," in *Envisioning Landscapes, Making Worlds*, ed. Stephen Daniels, Dydia DeLyser, J. Nicholas Entrikin, and Douglas Richardson (Oxford: Routledge, 2011), 301–2.

49 Cristiàn Simonetti, and Tim Ingold, "Ice and Concrete: Solid Fluids of Environmental Change," *Journal of Contemporary Archaeology* 5, no. 1 (2018): 29. In a way that recalls Serres's methodological North-West-Passage, they show how in the history of philosophy, states of matter have a profound impact on concepts of change, or, how for instance, the history of glaciology deals exactly with these difficulties of understanding motion of ice between solidity and fluidity (Simonetti and Ingold, "Ice and Concrete," 22–23).

bays and channels, basins and straits, through the tremendous, fractal arctic archipelago," a combination of "disorder and lawful regularity," a "labyrinth of deception and precision." It is a dangerous and difficult route for the ship that navigates the North-West-Passage: the "patterns drawn by the ice" makes the ship "move forward, tumble, turn, stand." The North-West-Passage is, for Serres, therefore exemplary of the fluctuation and interdependence of space and time. He understands the temporal dimension as central to the icy landscape as "a freezing and thawing of time." "Time," in Serres's words, is "starting to resemble space, in a way that ice resembled the map."[50] This also gives a first impression of the complicated relationship between ice and criticality, in this case, mediated by an integration of thermodynamics and the arrow of time, as well as a textual strategy that is characterised by metaphorical shifting. This shifting of meaning related to the metaphor is, in Serres's understanding, strikingly strong, as it enables the transferral of meaning in both directions.[51]

Furthermore, Serres's "methectic" approach, as Watkin calls it, in which thought participates in the world and its materiality rather than mimicking it,[52] makes the metaphoricity of Serres's North-West-Passage read as an explicitly integrative and non-reductionist approach in regard to the materiality and discourse of ice. It is an offer, as Yusoff points out, "to see how differing sets of relations move across space and through time [...]. While these sets of relations are understood as exclusive topographies, be that of science, politics, or myth, they remain at an incommunicable distant, like far-off shores. Serres' work suggests how travel between these shores might be possible."[53]

The relationship between the North-West-Passage and criticality resonates in this respect with the research fields of the *blue humanities* and the *ice humanities* on multiple—yet not all—fronts. For instance, concrete geopolitical embeddedness is less in the focus in Serres's approach than a wide range of other aspects, such as materiality and textuality, and its significance as an epitome in the philosophy and history of science and the politics of disciplines. Serres touches on the history of discoveries which left their traces in the narrative of the North-West-Passage,[54] yet, his strongest considerations turn out to be his reflections on the politics of disciplines, the history of mapping, and its inherent imaginaries. His multifaceted understanding of the North-West-Passage proves particular theoretical potential in respect to the humanities' perspective on ice. The language with which it has been and still is described, is itself a field of debate discussing the imbrication

50 Michel Serres, *Le Passage Du Nord-Ouest* (Paris: Editions de Minuit,1986), 16–18.

51 Serres, *La Distribution*, 253.

52 Watkin, *Michel Serres: Figures of Thought*, 250.

53 Yusoff, "Navigating the North-West-Passage," 300.

54 Serres brushes the dimension of historical attempts to explore North-West-Passage with McLure (later, Sir Robert Le Mesurier) or Roald Amundsen Serres, *Le Passage Du Nord-Ouest*, 19.

with colonial, racialised and gendered imaginaries and marking tensions between, for example, Western and indigenous descriptions of the landscape.[55]

Since Serres published *Le passage Nord-ouest* in 1980, the passage has not lost any of the challenging character that makes it hard for humans to pass through, but it now, more than ever, has come to be one of the more important changing landscapes affected by the process of changing climate. The "opening" of the Northwest Passage, in the way the European Space Agency satellite has envisioned it in 2007, "emerges now as the hot underbelly of that dream of expansion; a line seared through the ice, illuminating global heating".[56] The North-West-Passage's history and presence is not only a technically challenging navigation through icy waters, but also a politically difficult navigation through shifting political territories. At the same time, it is one of the manifestations of the so-called Anthropocene: the passage was last open 8900 years ago, and the emission of greenhouse gas plays an important role in the more recent melting of the ice in this region.[57]

One cannot stress enough how importantly categories such as temperature and the behaviour of ice between fluidity and solidity feeds into the framing of Serres's criticality. Serres's understanding of the North-West-Passage has also been taken up in literary studies as one of the rather rare examples of an ecopoetic approach focusing primarily on *northern* islands,[58] and it is this Arctic setting that requires further conceptual consideration. It is striking how Serres's language particularly seems to resonate with the one of Arctic journals, as Riquet notes: "His difficult and highly poetic style is shaped by this close attention to the material world and the search for a language that corresponds to it to open up thought and generate new ways of thinking; in the process, both the physical world and language become more complex."[59]

The North-West-Passage is Serres's answer to thinking entropy, as a concept that lends itself to translations; yet not necessarily as easily travelable paths. Serres stresses that the icy landscape is the metaphor for a split between natural and social sciences exactly for the reason that it cannot be overcome in a smooth passage—it has to be recognised that its passage is critical, difficult and troublesome. This recalls Anna Lowenhaupt Tsing's idea of friction in the relationship between local and global in an anthropological-

55 Dodds, "Geopolitics and Ice Humanities: Elemental, Metaphorical and Volumetric Reverberations," 1121–23; Bravo, 'Voices from the Sea Ice: The Reception of Climate Impact Narratives'.

56 Yusoff, "Navigating the North-West-Passage," 299.

57 Turney, "The Northwest Passage," 78.

58 Johannes Riquet, "Islands Erased by Snow and Ice: Approaching the Spatial Philosophy of Cold Water Island Imaginaries" (2016), 145.

59 Riquet, "Islands Erased by Snow and Ice," 147.

theoretical context. Her claim that "global nature both facilitates and obscures worldwide collaborations" takes into account the making of different scales, the relation between local and global movements and the unmasking of a "global dream space"[60]. It displays the challenge for the actual "friction" of theory with its matter. Where Serres navigates through the icy waters of the North-West-Passage, Tsing finds "friction" where "the rubber meets the road." Friction is, in Tsing's understanding, not only an attempt to grasp "how things slow down," but also imbedded in the possibilities of roads that "create pathways [...] making motion easier and more efficient, but in doing so they limit where we go."[61]

In this respect, it is of crucial importance how Serres's depiction of the icy landscapes of the North-West-Passage and a philosophy of entropy inform one another. This manifests not only in the difficulty to find a passage, the continuous challenge to map a changing landscape or to think an interrelation between the local and the global; it also shows in the narrative conceptualisation of a critical landscape that profoundly considers thermodynamics, irreversible time, and energy differences. To translate entropy with Serres means to search for and identify similar patterns of thermodynamic-informational entropy across distinct sets of knowledges, rather than speculatively applying them to different domains. With entropy, in particular, these analyses—such as of the social—are grounded in information-mattering. Rather than asking, how would we think society as if it was entropic? Serres's translations follow up on loops of formation that involve entropy, from cells, to bodies, their relationship with technologies, groups, and societies.

The impact and visibility of climate change in the Arctic makes Serres's model of the North-West-Passage a prolific case for eco-criticism and a criticality that attempts to integrate the natural sciences and the humanities. Serres's strong understanding of metaphor, not as an embellishment, but accommodating meanings which can shift in both ways, paths the way for thinking the entanglement between entropic terminology and the North-West-Passage. By bringing these multi-layered aspects of entropy as a material, temporal, and aesthetic factor together, Serres's approach to entropy appears as an eco-critical path within melting, icy landscapes.

60 Anna Lowenhaupt Tsing, *Friction*, (Princeton, N.J.: Princeton University Press,2005), 99, 124.

61 Tsing, *Friction*, 6.

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TECHNOPHANY
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Entropy, Said the Devil (Entropy & its Discontents: From Heat Death to the Eternal Return)

Dorion Sagan

One day though it might as well be someday
You and I will rise up all the way
All because of what you are
The prettiest star.
David Bowie, *The Prettiest Star* (1973)

The Devil:

Entropy is a mark of energy use, I impressed upon my friend, Simon Magus, inside his head in his own language. It is a cold fire. Destruction, I added on a more daimonic note, my breath hot on his labyrinth—life's cool fires. Of course, I exaggerated to him; I called life a cold fire, which for me it is: everything is relative.

Entropy—the heptagrammaton confuses, which is all to the God and the good, as it exemplifies the process it promises to describe. It is like that party game "Telephone," where one whispers a word to one's neighbour in a circle that returns, but never the same. When Claude Shannon sought a name for a quantity of unspecified information, for use in his new information or communications theory, my dear friend, John Von Neumann, whom I've also talked to, told him to use the seven-letter word, "as no one knows what it means anyway." Just so. Von Neumann himself, one hastens to add, was a bit of Brownian atom, his taste for alcohol (plentiful in space) lending his name to a place—Von Neumann's Corner—after a series of semi-stochastic crashes brought him again and again to the same location in Princeton, New Jersey.

You know, despite my bad reputation, I like to help people, and over the years I've had the ears of many famous men, and not a few uncommon women. I like to introduce my

 Corresponding author: Dorion Sagan, gradientor@yahoo.com

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ideas into scientists' dreams. Take Kekulé, who benefited from the image I provided of an ouroboros over a hexagon of six carbon atoms attached to six hydrogen atoms. Ergo the discovery of benzene and thence all aromatic compounds. Ah, superpositions. And sulphur fan that I am, it amuses me no end that your human, all-too-human nose in its nasal appraisal detects jasmine and orange blossoms encountering a certain compound in traces, while at higher concentrations the same compound brings on the distinct smell of poop.

But I digress, like a dancing star crashing to the centre of the Earth, and thus the early human universe, making on its way a pre-Copernican reversal, a punk rock music of the spheres.

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First the good news. Not I, but all of you will all die; however, it is not your entropic fate. I'm not saying you're being punished; in fact, you're lucky in this regard. But it is easy to see—using that bastard child of mine I gifted to you at the beginning of the European Enlightenment, Science—that you could have been immortal.

But you're not. You're merely human, unable to shapeshift, serpentify, become sleeping angels or intellectual monsters here in the fiery pit of your sleeping planet, or here [the Devil switches his position] in one of its outer dens.

Sadly, and it is only a stroke of fate, at best, but you might have lived forever—contrary to the late neo-Darwinist William D. Hamilton. Hamilton, Richard Dawkins's "intellectual hero," and "the nearest equivalent [to Charles Darwin] that the late twentieth century had to offer,"[1] "proved" that aging must exist. An artful pile of equations and syllogisms, Hamilton's monograph asserts that, "senescence is an inevitable outcome of evolution," which "cannot be avoided by any conceivable organism."[2] Fine in theory, but the devil's in the details. While thermodynamic entropy, a measure of the spread of energy, which dissipates on its own but does so more avidly in certain chemical and physical systems, including those of life, might be your fate, it proceeds at different rates. The cool, colloidal fires of life not only produce more entropy than would be the case without them but do so more long-lastingly via genetically supported metabolisms, and, of course, reproduction, which provides a constant supply of cold fires with a tendency for exponential reproduction. It is this very tendency toward excess, this greed and lust, if you will, for concentrated

1 Richard Dawkins, "Foreword," in *Narrow Roads of Gene Land Volume 2: Evolution of Sex,* ed. William D. Hamilton (Oxford: Oxford University Press), xv, xi.

2 William D. Hamilton, "The Moulding of Senescence by Natural Selection," *Journal of Theoretical Biology* 12, no. 1 (1966): 12–45.

energy sources of available energy (and matter) to rape and pillage in conformity with the behaviour described by the 2nd law—going from concentrated to spread out—which causes life forms some of their greatest problems; problems, I'm afraid, prematurely attributed to me.

Of course, I was there for the biblical plagues (and many others), even as I am here before you now. Remember 1874, that neo-biblical United States scourge—the sudden appearance of monstrous dark clouds, collectively half a million square kilometres in area, bigger than the surface of California? I do. Blotting out the sun, the dark clouds descended bringing the wildest weather, a dry hailstorm of huge brown grasshoppers, their thin wings upon disgusted humans hissing and glistening as they pelted down and about from the clouds upon depleted dirt and houses, their claws clinging to the clothes and skin, including me, dressed as a gentleman, unafraid as I stared into the dying bulges of their eyes.

Before you get sick at such a spectacle, or try to blame it on the Devil, please consider your own pest-like behaviour of late, destroying the soils and razing three quarters of Earth's forests—which must, objectively, be considered the highest form of life this planet, and the most angelic—which I'll get to, if we have time, in the last two centuries alone. Before you cry the "Devil did it," or try to play God by "fixing" some of the problems you've created to sate your greed, which is, if I may say, a bottomless pit, take a good hard look in the mirror. There is no edifice for entropy production on this planet smoother or more effective than the arboreal one, rainforests sensuously sweating communicative volatiles and the precious beads of their vegetal sweat, warming them locally but forming energy-reflecting clouds on high, before giving fall to cooling rain.

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But I digress, we were talking about how living forms, the *effort* of living forms to maintain themselves, is naturally entropy-producing. No wonder they want to live—to dance—to do the bidding of an energetic universe.

Aging exists, but not in the universal way Hamilton "proved." The last reported sighting of a Rocky Mountain locust was in 1902. They depleted their amber waves of grain.

If you destroy what you have tried to conquer, you have conquered nothing. Not even, as nothing is better than nothing, and you haven't conquered that. And in any case, why conquer like a brute when you can seduce with logic and love?

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Consider animals. The production of entropy by the cold fires of life, metabolically "burning" merrily away, the evolution of multiple forms of cell metabolism, prokaryotes and archaea permanently merging to make cells with nuclei, starved cells with nuclei devouring one another when starved of nitrogen or other elements needed to keep them going and burning, has taken many twists and turns in its four-billion-year history here on and in Earth, and I have watched closely. The animals themselves, even the ones in your own chordate clade, are instructive in showing the variety of modes of energy use, some of which lead, instructively, to the precipitous, ultimately self-induced slaughter, of those who grow too big, too fast, too monolithically for their ecological britches.

Animal life *within* Earth's variety of sexually reproduced, symbiogenetic organisms includes many entropy-producing forms, all of which may contain a tinge of what we may call "pride," a desire, however pitiful, for their own continuance. The irony of the greedy history of animal life, in some corners of its kingdom, is the recurring necessity for forms that tend to grow so fast they destroy their environment—their food sources, for example, as in the case of "grasshoppers"—now, suddenly, en masse, swarming under the influence of serotonin, not so hoppy as locusts ready to descend for their last supper.

The last reported sighting of a Rocky Mountain locust was in 1902. They depleted their amber waves of grain. One hesitates to speak oracularly to such a literal-minded audience, but there it is.

Life's cool fires always tend to spread, but when they destroy the last of their matter and energy, for whatever reason, they too perish. That is natural selection, of which I am a great advocate.

While all metabolizing organisms measurably produce entropy, their own spread even and especially as entropy-producers imperils them, sometime to their mass death. We can play the blame game. Starvation, Infection, Pollution unto local or global thermodynamic Dysfunction perishing in one's own or others' wastes, the most subtle of which is heat, which is neither liquid, solid nor gas, but which can, nonetheless, mitigate or destroy not just individual species like yours but entire ecosystems. The Four Horseman of the Apocalypse, Pestilence, Famine, War and the final, pale horse, upon whom rides Death, accompanied by Hades.

The last reported sighting of a Rocky Mountain locust was in 1902. They depleted their amber waves of grain.

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But, alas, Death, along with Hades, and Yours Truly, have received a bad name. Fast-replicating viruses, which are not alive because they don't metabolize but, like memes and machines, can become integrated into life's cool fires, which tend to integrate more and more elements in the Periodic Table over the course of evolutionary time, spore-forming and other bacteria, insects (sometimes carrying deadly prokaryotes), rodents, are among the many beings that tend to grow too fast as they pursue—as is their fiery wont—maximal entropy production.

However, neither I, nor natural selection (one hesitates to speak of Capitalism) tolerates this.

Nor do the cool fires of life of which I, alas, am only a small part.

Some age fast. Animals just in humankind's own chordate phylum, one of over fifty animal phyla, that age fast are octopuses, Progeria victims, Dolly the clonal sheep (dead at 6 of lung disease, which typically affects older sheep), Coho salmon that breed only once. Outside your phylum we find the mayflies including *Dolania americana*, adult females of which live only five minutes. Less time than it takes to smoke a cigarette.

Humans, elephants, Atlantic salmon that swim upstream a second time, and naked mole rats age more slowly. Albatrosses show no signs of aging but then drop dead in their early forties. And some organisms, defying the idea that the spread of energy of which entropy is a measure has anything directly to do with aging, include non-agers like Blanding's turtles and lobsters, the latter of which show no decline in fertility as they age. Many-headed hydras rip themselves open to eat and regenerate when they are cut in two.

So too sharks, many protists and bacteria fail the statistical sense of senescence: they are no more likely to die next year than they are this year. While *Sanicula*, a Swedish shrub, lives about 70 years on average, a 70-year-old plant is no more likely to die than a ten-year-old one. The fact that *Sanicula* does not age is a fly in the ointment of Hamilton's argument that all organisms must age.

Some just say no to mortality, although they may still be killed. I belong to the first category; time will tell about the second.

* * *

Octopuses are good examples of the opposite. With light sensors on their tentacles and skin, female octopuses care for their eggs, but if conditions are not right, they dine on their own caviar, fortifying their chances for later. If things look hunky-dory, the octo-mom's mouth seals over and she lives for years in a concentrated state of guarding her eggs; once the young hatch, however, she—dispensable in the same and murderous logic of natural selection for which I confess a distinct respect—dies within days. But not from starvation. Rather two endocrine glands, so called optic glands but unrelated to the eyes, execute her by inner firing squad. The glands secrete substances that control mating behaviour, maternal care, and death. If both optic glands are surgically removed, the mother octopus lives on; if just one optic gland is disabled, she doesn't eat, but still lives an extra six weeks. With both removed, her mouth doesn't disappear, and she resumes eating after her eggs hatch, increasing in strength and size, and sometimes living almost a year longer.[3]

Quite clearly the death of such animals does not come gradually by entropy, but suddenly by natural selection, which has introduced switchblades into the genome and phenome—not to safeguard individuals but to kill them off, the better to continue the larger bio-pyres of which they are part.

✳ ✳ ✳

In my view, the fashion for thinking that aging is universal and traceable to the wear and tear of entropy, simply universalizes humankind's own and highly limited experience as gradual agers; I put it with the 19th century formulation of thermodynamics that led Lord Kelvin unseasonably to prophesy the eventual heat death of the universe, whose antiquity and futurity, while unknown, is presumably infinite. But even the Devil is not qualified to speak of what may happen to the Great Fire of which we cool embers, whose sparks may contain a touch of the infinite, are only small parts.

Beyond fast agers and no agers we have "whoa" agers like F. Scott Fitzgerald's character "Benjamin Button," who grows younger, perhaps finishing outside the story in his parents' simultaneous orgasm, the better to be born again. Nonfiction examples of the process include carrion beetles and the hydrozoan, *Turritopsis nutricula*—"the Immortal Jellyfish." Under stress the beetles revert to larvae, while the medusoids return to a polyp stage. Indeed, even non-living fluid dynamic systems, such as Taylor vortices, return to the past under reduced energy regimes. The laboratory-produced vortices, which appear in pairs and grow in number, appear not as organisms do, between chemical energy (chemolithotrophs) or light gradients (photosynthetic bacteria), but in liquids submitted to rotational pressure gradients between counter-rotating cylinders. When the cylinders rotate more slowly, the loss in their rotational pressure gradient leads them to retreat to earlier levels of organization, for them fewer pairs of counter-rotating vortices. Perhaps

3 Jerome Wodinsky, "Hormonal Inhibition of Feeding and Death in Octopus: Control by Optic Gland Secretion," *Science* 198, (December 1977): 948–95.

an analogy could be made to the Anthropocene or, if that hits too close to home, the city of Florence under Savanarola, suffering from economic hardship, and becoming more autocratic. When acellular slime moulds run out of food, they form a mass structure, a proto-body, a translucent, dancing plasmodium; most of the cells die, but not before releasing new swimming cells. Here we see, in the body itself, a kind of return to earlier stages of organization; here we are looking, as it might be said, directly at evolutionary trauma. One that does not destroy, but preserves, the entropy-producing organism.

* * *

So, no, aging is not an entropic necessity, but naturally selected. I was not here for the origin of life on Earth, but let us assume, as your current science tends to imagine, that it evolved in the Hadean or Archean Eon, in a hydrogen-rich atmosphere more characteristic of the early solar system some four billion years ago, before that lightest of gases in the Periodic Table escaped into space, where it is preserved to this day in the hydrogen-rich gases of the trans-asteroid belt planets. Even if its forms were extremely hardy from the beginning—of extremophiles, such as highly heat-, nuclear radiation-, and desiccation-resistant forms that still exist, materially cycling, growing, reproducing beings always run the risk of destroying themselves by reproducing too fast, and thus depriving themselves of the material or energetic resources they needed to survive.

Unlike humans, early, multifarious microbial life, some of whose forms still survive today, had multiple means of metabolism, only one of which (aerobic respiration—reacting food eaten with oxygen breathed) directly supports human life. Earth's living systems are *open* thermodynamic systems. Although not their moral or aesthetic purpose, their cycling of matter in the service of the dissipation of energy gradients is their physical *raison d'être*, no less than the candle's flame is to burn. There is no entropy production without openings, orifices, no matter how small. It is impossible to imagine a live being that is not an actively entropy-producing one. The idea that life violates the second law of thermodynamics, understood as the tendency for energy to move from being concentrated to dispersed, is, therefore, pablum. And thus, there is no reason to name personalities as distinct as the gobsmacked Pope Pius XII, (who invoked the second law as proof of God's existence, apparently because only He can violate the law of ever-increasing disorder to produce organized life), or the neo-Darwinist analytic philosopher Daniel Dennett, who contended that organisms "are things that defy" or constitute a "systematic reversal" of the second law.

* * *

In thermodynamics a "closed system" (in typically strained scientific language) means closed to matter but open to energy exchange. An isolated system—however, impossible such a thing may be— describes a system protected from flux, inflow or outflow, any kind of exchange with the outside world, even, theoretically, gravity. A perfectly closed system thus keeps all its matter but can accept and donate energy. Metabolising cells and bodies, e.g., your inhaling, eating, excreting, drinking, pissing, farting, sweating, bleeding selves, are open systems.

Ergo your ability not only to take in hors d'oeuvres, the cute Devil's food cake cookies and other assorted goodies I've laid out— please, fear not my fiery eyes, do not hesitate to come and take a bite as I speak—but the sights, sounds and information, if any, imparted by these words. Yes, yes—go ahead and eat, I long to divagate, distract, and delay.

* * *

One almost longs for the early days of this planet, red like my pupils when seen from space, those delicious days of constantly crashing tectonic plates, gurgling volcanoes, so full of hope and violence, with dust-and-smoke-strewn crimson skies, comparable to the smog over Los Angeles which, as your poet Bukowski suggests, is like love, billowing forth before the morning sun burns it off. But I digress, like a selfish meme replicating itself on the internet, like your cell phones and computers, indeed like your whole project of artificial intelligence which, indeed, is justly named.[4] A car may be part of you, you may flinch when the fender bends; you may feel lonely on or off social media, connected or disconnected by the phone. But the unheimlich house, the oikos, has always gone from the ungainly outside to become part of the realm of integration and recycling of wastes, one of life's ancient games. Did not the calcium ions whose over-concentration in ancient marine eukaryotic cells lead to calcium carbonate skeletons and skulls, to marine creatures of surpassing function and beauty, their stockpiled calcium with carbon atoms forming ornate shells, living Venetian blinds adjusting the rates of photosynthesis for maximum energy expenditure, comfort, and survival? Is not my own becoming smile evidence of the surpassing beauty and cunning of microbial teams, stockpiling deadly calcium ions in flashing molars and cutting canines? Forgive my chuckle. It has always been; thus, organisms perceive, they aggregate, they act, they interact, with themselves and their surroundings; and over evolutionary time, as they grow and expand and excrete into the environment, proprioception extends; wastes can become integrated, the house becomes the body.[5] You are in a sense a multi-story moving building made by intelligent bacteria.

4 Bernard Stiegler, "Artificial stupidity and artificial intelligence in the anthropocene," *Academia.edu. https://www.academia.edu/37849763/Bernard_Stiegler_Artificial_Stupidity_and_Artificial_Intelligence_in_the_Anthropocene_2018_* (2018).

5 Lynn Margulis, Luis Rico, and Dorion Sagan, "Propiocepción: Cuando el Entorno se Hace Cuerpo," https://root.ps/download/tecnomagxs/Corr_Margulis_Propiocepcion_cap_1.pdf.

* * *

Like me, and six-sided Bénard convection cells, first found on the underside of photographic plates or, more to the point, like you and your huge brown grasshoppers becoming airborne locust swarms under the influence of serotonin, destroying their food supply and thus wiping themselves out and giving you the Dust Bowl for your troubles, I know a thing or two about nonequilibrium thermodynamic systems that grow too big for their britches.

"What's better than a robot coming out of your head and going to Mars?" asks indigenous philosopher Ailton Krenak. He is annoyed at the sight of a Chinese billionaire wanting to start a health club on the moon. Will it be the first in a chain?

Applying black paint dramatically to his face in the 1980s, Krenak convinces the Brazilian congress to stop their appropriation of the Amazonian rainforest. His last name refers to his tribe. Forcibly separated from his kin, the Krenak, of which today fewer than 200 individuals remain, I was there not only when Jesus had his moment of doubt and pain, but some time ago, in the Amazon, when Krenak encountered another indigenous leader. The other indigenous leader was worried:

> "These white people," he said. "How many are there? Are there more than ten?"
> "Yes," replied Krenak.
> "What do they eat?"
> "Everything. Forests, rock, everything."
> The other indigenous leader's eyes grew wide. "Where do they shit?"
> "Everywhere."

In fact, pollution is a leading cause of human mortality. Particulates from cars, planes, and industry, although they cool incrementally during the daytime by blocking light, more than make up for that sunshield by reradiating solar and terrestrial radiation at night. Moreover, when the upper atmosphere becomes too warm, convection slows to a grind or stops, preventing some of Gaia's swirling currents from dissipating energy into the atmosphere. If only CO_2 were the main cause of global warming, insofar as it exists. But the residence time of carbon atoms in the atmosphere is far longer than particulate pollution, which both accumulates and precipitates out on a much shorter time scale, of days and weeks rather than decades and centuries. This may be good news for those willing to fight against global warming. And as Spinoza pointed out, it is good to know things for their own sake, even if you can't do anything about it. It doesn't help that you latter day great apes—I see a hairy hand there—yes, you!—have razed seventy percent of this oceanic orb's forests in the last two centuries.[6] You are cutting down the trees through whose stomata, holes in the leaves through which comes the water vapor to form light-reflecting clouds and the terpenes and other compounds that form cloud condensation nuclei, make the rain of the rainforests. While Mars and Venus sport burnt out atmospheres of over 95 percent carbon dioxide, Earth's atmosphere remains under ½ percent; and yet every day the chances of Nuclear Hell—not just bombs but the ensuing darkness and heat from reradiating particulates—increases. Such an increase of local entropy would represent an unfortunate increase in an already suggested global thermodynamic dysfunction, a further blow to healthy, unblocked rates of geophysiological entropic release. It is always a mistake to overhunt one's home, as Artemis impressed upon Orion before contract killing the hunter, not for making love to her without saying he was married, but for killing too many of her deer. For such eco-excess the Greeks give us the night sky: if you can even see the stars, let alone the milky galactic centre of the galaxy—the constellations Scorpio, Orion's giant arachnid killer, sent by Gaea to remind humans ever after. (Perhaps she did not predict the future's light pollution.)

While people babble about carbon credits and space travel, vaguely imagining they might escape the mess they've made on the surface of this gravitational well, sleek, silica-extracting diatoms, jewel-like diatoms, whose bodies are like the exploded remnants of multi-coloured stained glass living cathedrals floating in the sea, contribute an estimated 40% of the breathable oxygen per annum to Earth's atmosphere. Oxygen, O_2, which provides you humans with your fresh air, the reactive gas— once a deadly, poisonous gas to Earth's anaerobes—so necessary for your industrial Technosphere, from its automotive urban sprawl to its digital communications and militaristic technics. The waste product of oxygenic photosynthesis, now an invisible medium for energy extraction.

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The last supper for a bacterial colony spreading across a Petri plate is the one indulged in by its largest reproducing population, the one immediately prior to collective collapse.

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Humanunkind threatens long-term entropy-production by destroying long-evolved ecosystems. Masses of living beings, of the same and of different types, with their little purposes and no central planning, have evolved unconsciously intelligent ways of moderating their growth as they live together, the better to survive in the long run. In

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6 John Feldman, "Regenerating Life: How to Cool the Planet, Feed the World, and Live Happily Ever After," 2023, hummingbirdfilms.com/regeneratinglife/.

the wake of too-fast growth one finds degradation, collapse, mass death by starvation, infection, pollution. Wilde may have said nothing succeeds like excess but the Pythian principle once engraved in stone at the temple in Delphi, *meden agan*—"Nothing in excess"—prevails. Everything in moderation, my friends, yes? Including moderation. [And here the Devil gave a throaty laugh.]

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We share a common purpose, my friends: to burn. To keep on burning, to be *on fire*, to *live*. Awareness allows one to be part of an ecosystem, to anticipate, even and especially unconsciously, what is needed to avoid disappearing into the unpublished annals of evolutionary ordinariness. Although the road to immortality is a long run, it thus may interest you, my mortal friends, that nematodes age faster not only if they eat their fill but even if they merely *smell* yeast paste, their food.[7] For life chemicals are not just materials, but signs, as demonstrated by that weird datum that indole, the smell of orange blossoms and jasmine tea, also, in higher concentrations, registers as faeces.

The poison, as my old friend Paracelsus put it, is the dose.

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Believe you me, no one is as big a fan of death and destruction, the licking flames of erotic fires, that sort of energy which Blake reminds us of is "eternal delight." Just so, but forever is a long time. The grace of nature is to keep the torture-pleasure going; it will not surprise you that local diablogenesis has nothing to do with eschatology, soteriology, or ethics, but rather with the history of human culture, its linguistic formulations, and, in retrospect, local planetary biophysics. Speaking as a mixed, imaginary (in the Lacanian sense) being, I want to try to tell you that the djinn or stars don't have sensation and intellection but you, also mixed beings, do. Do you think that my friend, Herakleitos, who compared the universe to a vast fire, when he posited over two thousand years ago, that each human has his own private dreamworld, the *idios kosmos* to which one returns each night during the forty percent of one's life that one sleeps, and that while awake you share a *koinos kosmos*, the shared world of culture; do you think, for a minute, that by shared world, by *koinos kosmos*, the great Herakleitos, who justly compared the cosmos to an eternal fire, was thinking just of humans?

No, of course not, he was a mixed being, a philosopher, who is never just a human. George Bataille[8] writes of writing as bleeding, the slow sacrifice, and imagines the evolutionary

7 Scott D. Pletcher, "The Modulation of Lifespan by Perceptual Systems," *Annals of the New York Academy of Sciences* 1170, no. 1, (August 2009): 693–697.

8 Although Bataille is best known in literary and postmodernist studies, behind his thought is the

history proceeding from knuckle walker to cosmic voyager, the epic journey interrupted only by the unforeseen migration of the pineal gland migrating to the top of the head, humanity thus reaching a kind of happy ending, with the sun, the object of life's desire, aimed at but missed as human bodies ejaculate through their new apertures atop the heads of men, of "Man." The travesty and parody marks an ironic end to a once more promising creature.

* * *

In this sense [said the Devil, and here the roar of his laughter was magically accompanied in the dark- lit grotto by orange, green and blue flames from his mouth, while foul-smelling sulphurous fumes curled up from his nostrils] one must redress your notions of entropy and its relationship to life, equally misguided at times from both the theological and the scientific side—and, of course, the political, but I digress, like static on an intergalactic message.

In your species' current science, especially concerning the thermodynamic quantity usefully but confusingly known as entropy, I'm afraid most of you are quite lost. Entropy is both simpler and more complex than commonly thought. But entropy at heart is elegant in its simplicity, more elegant than I am dressed as a gentleman in evening clothes. It is not synonymous with disorder. As my long lived but now permanently dead friend Frank L. Lambert (1918–2018) pointed out, virtually any collection of particles above the temperature of absolute zero is almost infinitely disordered. At heart entropy—and Lambert was successful in persuading authors of all the main US chemistry textbooks, and

deep thermodynamic reality of solar excess; one might say that, if for Freud and Lacan the phallus is the master metaphor, for Bataille it is the Sun and solar excess. (I would argue that Bataille's analysis of the ways this solar excess feeds into rhetoric beyond discrete signifcation is evident in Jacques Derrida, "La mythologie blanche: la métaphore dans le texte philosophique," in *Marges de la philosophie* [Engl. *Margins of Philosophy*] (Paris: Les éditions de Minuit, 1972): 247–324. See especially the paragraph about "L'ellipse du soleil: l'énigme, l'incompréhensible, l'imprenable.") In his thoughts on the Sun, Bataille was crucially influenced by his 1929 reading in French translation of Vladimir I. Vernadsky's *La Biosphère* (Paris: Félix Algan, 1929), which he references in *The Accursed Share* in a chapter about the "Exuberance of the biochemical energy and the growth." Via Derrida primarily, these thoughts have entered continental philosophy. I would argue that the Sun, the main energy source for surface life forms on Earth, becomes, via Derrida, a post-Lacanian master signifier that does away with the zoomorphism of the phallus, the master signifier of psychoanalysis. The end state of isolated thermodynamic systems may be stasis (*thanatos*), but the open complex systems of living beings actively delocalize concentrated energy (a process accompanied by a generalized eros?) to continue their existence as metastable, nonequilibrium thermodynamic systems whose goal is not so much death as entropy production, made possible by cosmic gradients. See e.g., Dorion Sagan, "Bataille's Sun and the Ethical Abyss," in *Cosmic apprentice: Dispatches from the Edges of Science* (University of Minnesota Press, 2013), 33–40.

some of the physics textbooks to include this in their revised editions—is a measure not of disorder but dispersal. (The notion that it is "disorder" derives from Ludwig Boltzmann's common-language summary of hundreds of pages of mathematics in his *Lectures in Gas Theory*).

Although Lambert did not specifically attend to the thermodynamics of life, let alone of more-than-living things such as my selves, his refurbished summary of the essence of the behaviour described by the second law holds for both equilibrium and nonequilibrium systems.[9] There is no worry (and here one must agree with Nietzsche) that the world will slowly grind to a halt, like a carnival with all its rides stopped, the people gone, the sun gone down and the performers now out of town; no worry such as that portrayed in Pynchon's short story, Entropy, where a baby bird, like America or the blue Earth, may be ending one fine and final tepid day. Rather, as Nietzsche reasoned, if time could have an end, it would have ended already.

But no, things continue, fast and furious, slow and dreary, hot and cold, gravitational and thermodynamic, forever; new stars are born, grow, go supernova, old ones die, their atoms recycled into new systems, the carbon atoms of your body synthesized by the triple-alpha process from He, helium, in the depths of stars. There is no end to the fun, or futility.

Far from violating the second law of thermodynamics, living matter such as yourselves can hardly be understood without realizing that you operationalize a core process of the universe, the tendency, one might even say the compulsion, for energy to spread—which is, quite paradigmatically, *demon*strated by the living beings you all are.

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And here one is amused at the lack of rectitude at both ends of the religio-secular spectrum in maintaining otherwise. Complex materially cycling systems, from swirling storms reducing temperature and bariometric pressure gradients to more long-"lived" fluid dynamic systems such as "Whirlpool" downstream of Niagra Falls and the Great Red Spot of Jupiter, a storm in frozen hydrogen-rich gases at least hundreds of years old whose area encompasses three Earths, to biochemicals-recycling, gas-, solid-, liquid-, and heat-excreting systems of more familiar animal and industrial systems—all of these active cyclers spread more energy than more motley forms of matter. They embody it, their inner

9 For entropy in equilibrium thermodynamics see Harvey S. Leff, "Thermodynamic Entropy: The Spreading and Sharing of Energy," *American Journal of Physics* 64, no. 10 (1996): 1261–71; and Harvey S. Leff, *Energy and Entropy: A Dynamic Duo* (Boca Raton, CRC Press, 2020); for entropy in nonequilibrium thermodynamics see Eric D. Schneider and Dorion Sagan, *Into the Cool: Energy Flow, Thermodynamics, and Life* (Chicago: University of Chicago Press, 2005).

organization crucial to the accelerated local production of entropy. You are no different.

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Now I [spake the Devil, producing between gnarly hands great streams of multi-coloured bank notes of a variety of currencies] am no doubt just an alchemical apparition, a literary phantom with no claim to truth claims or, indeed, anything other than disposable entertainment value, whatsoever. But as you see, these hundred-dollar bills and Euro notes survive burning. Now look at them again and you can see that they've lost their face value, so that they have now become mere blank white strips of paper, worthless because they have no symbols on them. The symbolic is humanity's greatest opportunity, and greatest curse.

Now, look!

[At this point the devil produced an ordinary, blue-back pack of Bicycle playing cards, which he said were fire-proof, and fluttered them from hand to hand, making a series of fiery cardboard waterfalls, fans, florettes, springs, and shuffles, that he claimed demonstrated both the transition of discrete objects into waveforms ("the classical into the quantum"), and solids into fluids ("isolated parts are integrated into the waves"). After this he did a trick with three red and three black cards, alternating them one by one in what he called an "ideal mixture" and a "perfect shuffle." Pattering about God separating the heavens and the Earth in the beginning, he then showed that the cards had "rectified the gradient" without "any work being done." He repeated the trick slowly, alternating the cards and having them separate, with no suspicious movements, three times—the number of times Houdini claimed he needed to see any trick before he could figure it out. At the end he pointed to the designs on the back of the cards; turning the packet of symmetrical pasteboards, he told his audience: "You see, they're not angels, they're demons—Maxwell's demons."]

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Let's review. Matter and mind are connected, deeply, although thermodynamic and informational entropy are not the same thing. Information theory as it is known today began with a book written by Claude Shannon and Warren Weaver in 1949 called *On The Mathematical Theory of Communication* in which they introduced another concept of "entropy." When they didn't know what to call their new mathematical measure of messages, their mathematician friend John von Neumann told Shannon, "call it entropy, no one knows what entropy really is, so in a debate you will always have the advantage." Shannon took von Neumann's mischievous advice. This added to the confusion. In information theory entropy describes the uncertainties associated with the utilization of characters in sending and receiving messages. This is a different use than found in thermodynamics. In a thermodynamic system the basis for assigning an entropy value comes from the uniqueness of a system's matter-energy distribution at a molecular or atomic level. At any one time a system can have just one particular microstate out of many possible. Although there is a similarity in theory here, it is seductive in that it is greater in the equations than in that to which they refer. In fact, much the same equation was applied even earlier to games of chance by French mathematician Abraham de Moivre (1667–1754), a Huguenot pioneer of probability theory who served as consultant for insurance companies and gamblers. As early as 1968 American cancer researcher and photobiologist Harold F. Blum pointed out that, despite the superficial similarities between informational and thermodynamic entropies, seemingly separated only by a minus sign, there was the potential for hybrid equations to be developed that could apply to natural selection. Blum devised a negentropy-like equation that measured what he called the "expectabilty of evolutionary change without being concerned with its probability in the larger system in which it takes place."[10] Today, entropy proliferates in dynamical systems theory: there is metric entropy, topological entropy, algorithmic entropy, entropy as the fractal dimension of an appropriate compact set, even *galois entropy*, which is related to geometrical asymmetry; these various mathematical subspecies of informational entropy share a concern with unpredictability, incompressibility, asymmetry, or delayed recurrence. But none of this will be on the quiz, and Von Neumann's founding confusion holds, the Devil takes it. My friend Dorion Sagan, whose fingers I've used to dictate this essay, noticed that the techniques card counters use in casino blackjack invariably deploy a mathematical system that identifies a gradient—when the deck(s) is/are "hot"—that is, when the shuffled pack or packs, measured by keeping rough track of the cards that have come out, and thus those remaining undealt in the shoe, contain a preponderance of high cards and aces which, other things being equal, can give the good player an average hourly earnings of 1½%. In practice, this means for $100 bet the expected earnings would be $1.50—more than his average gains in the Bahamas, Atlantic City, the Mohegan Sun, and Las Vegas, especially after expenses. But I digress, like the RNA viruses which helped evolve the placenta.

* * *

I've been here a long time, on Earth as well as here to-day, so let me attempt to begin to bring the never-closing, always burning curtains to a close. The biosphere behaves as a behemoth, a beast if you like, its planetary surface (and its deep hot biosphere, where I hang) no more a rock with some life on it than you are a skeleton infested with cells: like

10 Harold F. Blum, *Time's Arrow and Evolution* (Princeton University Press: Princeton, 1968), 207.

the rainforests which are its crowning non-creation, the highest life form, its main waste product is not urine, faeces, or even gases such as carbon dioxide and oxygen, but rather heat into space. Spit, snot, sweat, semen, blood, tears, colloidal substances, phlegm, any number of intricate substances encased in waterproof but permeable keratin-based skin. As a thermodynamic final product, heat, although it can run steam and handheld Sterling engines, is not a concentrated enough energy source to serve any form of living metabolism. (Making the philosophy- dissing Neil deGrasse Tyson scientifically wrong when his voiced narration at the Hayden Planetarium asserted that roiling ecosystems of tube worms, blind shrimp and crabs at the bottom of the sea were fed by heat from Earth's interior.)

Now when Stiegler uses the term Entropocene—and negentropy,[11] neganthropy, neganthropology, and Neganthropocene and so on,[12] the terms multiplying like brooms in *The Sorcerer's Apprentice*—he has a point. Earth's surface is a mess, and it is partly humankind's doing. It is not the only species to do so. The apatite of our teeth, the calcium phosphate encasing of your skull, and your skeletal infrastructure, your walking bones began in the toxic calcium ions nucleated marine cells had to extrude not to be poisoned. Stiegler recognizes the pharmacological nature of writing, the Socratic supplement and Derridean pharmakon or vice versa as it applies to technics. It giveth, and it taketh away. The number in your phone you no longer remember, as it is outsourced to another, not living this time. Writing too is of the earth, a piece of bark, footprints in the mud, blood on the ground symbolically reproduced as plant pigment on a face or in a cave, a heel in the sand or carved stone. (The internet, for which I had such high hopes in influencing humanunkind for the better, the web as nothing but humans and technics but less than the sum of its parts, a less than human brain, has, frankly, proved disappointing). As with the waste products of calcium, from which such unholy temples as that of human and other inner and exoskeleton are made. Or diatom-produced silica exploded from volcanos providing their silicon atoms taken in by new diatom blooms, perhaps to be integrated into future iterations of Macs long after anything recognizably human remains.

* * *

Bataille's evolutionary parody, man's headlessness as he ejaculates his contents, beginning with the pineal eye, migrated to the top of the head, then the brain, into his solar object of desire, illustrates the folly of a *momentary* maximum entropy production that robs a form of the partly stochastic and unconscious process of an *extended* entropy production which

11 Coined but later dropped by Schrodinger, who later admitted that what he meant was Gibbs free energy as the source for life's spatiotemporal organization.

12 Daniel Ross, "The End of the Metaphysics of Being and the Beginning of the Metacosmics of Entropy," *Phainomena,* no. 112/113 (June, 2020): 73–100.

has, so far, in the case of "man," given Earth a mixed bag of everything from baseball trading cards to satellite communications and radio telescopes even as this same anthropic force has decimated forests, and produced, via technics, pollution, and biodiversity loss the equivalent of a global fever, similar to the temperature elevation and biodiversity loss of forest ecosystems exposed to nuclear runoff. Insofar as particulate pollution, including by car pollution and attempts at weather modification, destroy the convective currents that put the literal wind in the sails of the European age of exploration, the biosphere will swelter; while the second, cosmopolitan or aggressive age of human space exploration and colonization, will likely remain mythical. Space is not the ocean. The planets are not islands.[13]

The 21st century ennui with the humanoids of science fiction and false reports of little green men and their ilk is the rage of Caliban seeing his own face in the glass. The 21st century—and other centuries'—feeling of loneliness in an infinite cosmos is the rage of Caliban not seeing his own face in the glass. Life at Earth's surface as each of you very partially experience it is an open thermodynamic system in space, transforming the solar gradient between Sun and space, primarily through the advanced, sensitive natural nanotechnics of water-using photosynthesis, into the redox potential of Earth's highly energized, because continuously oxygen-supplied, biosphere.

* * *

Well hell's bells! people—that you all are going to die individually doesn't mean that the species will expire soon, although it is due anyway, as the average age of a backboned species in Earth's fossil record is four million years. If and when *Homo sapiens* does go, it does not by any means mean the rest of the not as mean biosphere will follow: this is more restless anthropomorphic projection. The apocalyptic tone of philosophy[14] is joined by voices speaking in the name of science. But unlike some other planetary and cosmic concerns analysed by philosophers—e.g., the speculations of Kant, following Fontenelle, on intelligent life beyond Earth, whose existence could provide a context for the desideratum of world peace[15]—the analysis of Earth's planetary condition, is *not* unique: it is an example of thermodynamic dysfunction, which has been chronicled in forest ecosystems exposed to heat and radiation from nuclear runoff, and even non-living complex systems (e.g., Bénard cells, "multiplying" typhoons, and long-"lived" Belousov-

13 See Carl Schmitt, *The Nomos of the Earth* (New York: Telos Press, 2003).

14 Peter D. Fenves (ed., trans.), Immanuel Kant, and Jacques Derrida, *Raising the Tone of Philosophy: Late Essays by Immanuel Kant, Transformative Critique by Jacques Derrida* (Baltimore and London: The John Hopkins University Press, 1993).

15 Peter Szendy, *Kant in the Land of Extraterrestrials: Cosmopolitical Philosofictions* (New York: Fordham University Press, 2013).

Zhabotinski chemical reactions) that exhibit physiological malaise unto "death," when the gradients they are reducing—be they of temperature, pressure, or electron potential—and upon which their continuing organization depends, become too steep or insufficient.[16]

If technical humanunkind is a djinn, a swirling creature of smokeless fire occasionally granting wishes but best kept closed in its bottle, so the biosphere as a whole resembles an angel, a creature not of fire but of light. (And here I speak with some experience.) Like the beautiful ethereal virgins promised to martyrs in paradise, a Persian word, the houris who never micturate, menstruate, or defecate, the Gaian biosphere runs clean, gently using energy and moving it away from its sensitive, living surfaces. It is an angel, subtler than any organism, which cannot recycle its own material wastes. Naturalizing life as a cosmic form of entropy production links mind to matter even as it throws a wrench into humanity's supposed unique and superior intelligence, in part because the long-existing problem of extinction-level imperilment by overpopulation and ecological overuse, although elusive for you big-brained technological apes, appears already to have been solved by the (epi-)genetics of your own bodies, which ensure timely aging and death, thus providing a stopgap against ecological overkill. As shown by my card trick, "Maxwell's Demons" there is a link between physics and metaphysics, from heat death to the eternal return. The latter is clearly more real than the former. Nietzsche experienced being out of time at the rock at Sils Maria, then looked to science, especially the thermodynamics of eternal recursion given an enclosed space and infinite time, to provide a physical justification. He reasoned too, and correctly, that if time could stop it would have already. Of course, Victorian physics did not take gravity into account in their isolated adiabatic boxes. The real cosmos is infinite. It is not the return of the "same," as Heidegger schoolishly argued, but more like the "return of the return," as Deleuze argued. The return, already always, of an entropic cosmos, occasionally revealing itself, and then hiding again, forever and a day. My good friend Anaxagoras, the first philosopher to suggest panspermia, the idea of the cosmos as a wild garden of life forms, travelling from sphere to sphere, also developed the idea of perichoresis, that even an infinite mixture could be recovered back to its beginnings, if any, through nous, mind. The faro shuffle, known to card sharks, shows this: a normal pack of 52 cards, shuffled perfectly, done eight times, will bring the cards back to their exact original order. It is possible to disguise the faro as a corner riffle shuffle.

But alas there is no evidence that we are in a physically closed system. The cosmos may be infinite, in which case you are an infinitesimal part of the infinite, lost and found. I'm afraid that for the moment and perhaps the foreseeable future [here the Devil tapped his formidable forehead], you will be not only a planet-confined but a land-locked (not

16 Schneider and Sagan, *Into the Cool.*

true for me thankfully) species, restricted to the continental land masses, but that does not mean you should not take some Spinozistic joy in knowing for the sake of knowing, looking at life *sub specie aeternitatis*, from the viewpoint of the eternal, or at least cosmic and evolutionary, within your little bubble. And here a simple experiment may help demonstrate the power of those little beings we don't see, the microbes, which have the power to change Earth's surface and make new forms of life, including your own. Although small, their effects have been global (indeed cosmic and panspermic, but we are focusing on your present *oikos*). Before cells with nuclei like amoebae and humans, green bacteria—cyanobacteria (not algae, because algae have cells with nuclei) evolved. The forerunners to water-using green bacteria used other substances as a source of electrons for photosynthesis. Early photosynthesizers—like some bacteria today—used elemental hydrogen, which was more prevalent on the early Earth, not having escaped to space. Others used hydrogen sulphide, which still escapes through the mouths of volcanoes, and was more prevalent in my old world of the more tectonically active early Earth's surface. Today, purple sulphur bacteria, use sulphide—H_2S, the gas that makes portions of the New Jersey Turnpike smell like rotten eggs— using its hydrogen for photosynthesis, and excreting harmless little balls of sulphur as waste.

A simple little experiment with a silk handkerchief may represent for you better than words can convey the power of those little beings we don't see. The yellow of this silk signifies the waste of these sun-loving purple sulphur bacteria that use sulphide rather than water in photosynthesis. They can be found basking in steaming geothermal springs. They can also use H, molecular hydrogen, more common in the early hothouse, as well as nitrogen dioxide and some other tasty compounds. Yellow silk. [The Devil waves it in his gnarly hand.] Earth's atmosphere was reddish at this time four billion years ago, like a sunset seen from the Hollywood hills—the whole Earth. Now, the new green bacteria, by liberating oxygen atoms from the hydrogen molecules of water [and here the Devil could be seen using his forefinger to push the yellow silk handkerchief into the thumb end of his left hand, then pinching and pulling the silk at the pinky end to reveal an emerging corner of blue silk] began to energize the surface of Earth. As it happens, the size of oxygen atoms is such as to scatter light of a blue wavelength.

The result is what you see today—a bracing oxygen-rich atmosphere that turned a pinkish planet blue.

This is the planet you're from, as pure as the driven slush, a pharmacological planet, turning tools into body parts, toxic wastes into skeletons.

* * *

When you look at me, at my horrid face and glowing eyes, my cornus and fiery den with licking flames in the flickering shapes of red and blue temptresses [here the Devil gestured to flames that briefly took the form of copulating women] it probably doesn't occur to you to reflect on your own hot mess. Well, what the—I'm here to tell you.

As the highest life forms on Earth—I jest; trees are literally higher, not to mention metabolically superior and better at cooling the planet, mainly by transpiration through the stomata of their leaves, a major process behind the production of clouds, rain, and rainforests.

You are an animal—and a hybrid, not just of the subspecies neanderthalensis, the first to come out of Africa according to recent genetic analyses, losing melanin in the European sun, before returning to breed with the original, presumably darker *H. sapiens* model before becoming modern "man"; Hell, you may even be a porcine, chimpanzee mix; the freak of a pig mother would have undergone introgression, continuing to breed with chimps. And it would not be the first-time animals sexually reproduced across would-be species borders. The Isle of Mann invertebrate biologist Donald Williamson supported claims that starfish and other metamorphosing sea creatures with distinct larval phases, arose from negotiating dual merged genomes. Butterflies, too, Williamson argued, could be understood as colourful mishap from a forbidden fertilization, the laying of eggs by a winged insect on an oconophoran.[17] Fertilization outside the body makes such fruitful miscegenations more likely but still, some mules are fertile. Even mainstream biology considers your own phylum to be coloured by such events. Comparison of 2000 gene sequences from sea squirts, fruit flies, sea urchins and humans suggest that members of your phylum, which includes the tunicates, the sea squirts, came from a mating between a backboned being and an unknown, but now extinct non-vertebrate, at a very early phase of animal evolution. Considering what I've seen, it wouldn't surprise me at all.[18]

✳ ✳ ✳

You know you people have always liked to blame things on me, the Devil, and not just in passing. Aristotle fan Augustine went so far as to blame tumescence on me. I'm not *kid*ding—I, one of humankind's greatest friends and resources, sometimes given the goatlike appearance of an even-toed ungulate, responsible for a Church father's erections. Me, a would-be cultural phantom, pulling the strings. Talk about blaming the other! But like me, you all, I'm happy to tell you, are cool fires, materially recycling colloidal dispersers, dissipators, and delocalizers of concentrated energy, not just "surfing on" energy gradients, but manifestations of them, living on their active, entropy-increasing

17 Donald I. Williamson, "Caterpillars Evolved from Onychophorans by Hybridogenesis," *Proceedings of the National Academy of Sciences* 106, no. 47, (November, 2009): 19901-19905.

18 Michael, Syvanen and Jonathan Ducore, "Whole Genome Comparisons Reveals a Possible Chimeric Origin for a Major Metazoan Assemblage," *Journal of Biological Systems* 18, no. 2 (2010): 261–275.

degradation.

Prokaryotes actively seek out redox and photosynthetic gradients, and disperse them, spreading energy and producing entropy as they metabolize, grow, and reproduce. So do we. Living systems from cells to multicell organisms to ecosystems are open thermodynamic systems. Fluid dynamic and weather systems such as Bénard convection cells, giant Hadley cells in Earth's atmosphere, dust devils, hurricanes, whirlpools, and chemical clocks are all nonequilibrium thermodynamic systems that tend to swirl into being in areas where there are sufficient temperature and pressure, electron potential or other physical gradients. The temporary organization and cycling of matter they exhibit reduces an ambient gradient, produces heat, and then, when nothing is left to degrade, they disappear. Their organization was for a prosaic purpose, energy degradation. Life on Earth appears to be a similar nonequilibrium entropy-producing system. A difference is that the gradient, the difference across a distance, Earth life is ultimately helping reduce is not a local pressure gradient or a chemical gradient reduced by an autocatalytic reaction, but the relatively immense gradient between incoming short-wavelength solar radiation from the 5700 Centigrade surface of the Sun and 2.7 Kelvin outer space. Despite being marginal in the quantity it reduces, life seems to be organized to reduce this solar gradient. As suggested by the cool temperatures recorded by weather satellites over the Borneo and Amazon rainforest in mid-summer, equivalent to those over Siberia in mid-winter, biodiverse ecosystems actively dissipate energy away from their sensitive surfaces, incrementally enhancing the production of entropy, the spread of heat, which cannot be used for metabolic purposes. If life could, it would swallow the Sun, but it can't. Instead, sophisticated ecosystems move the waste heat away from themselves. Thus, far from violating the process of spreading energy described by the second law of thermodynamics, living systems take in energy, build form, and matter *in order* to degrade available energy. Dissipation seems to be their natural purpose.

* * *

The poetic biologist Johann Wolfgang von Goethe (174–1832), put it more bluntly:

> Why are the people thus busily moving? For food they are seeking, Children they fain would beget, feeding them well as they can. Traveller, mark this well, and, when thou art home, do thou likewise! More can no mortal effect, work with what ardour he will.[19]

19 J.W. Goethe, "Venetian Epigrams," *The Works of J. W. von Goethe, Volume 9*, p.337, 1790, https://en.wikisource.org/wiki/The_Works_of_J._W._von_Goethe/Volume_9/Venetian_Epigrams.

Ah, but I am not a mortal. God and I are front-to-back, or face-to-face, which is why only God's behind shows in the Bible. Long before Renaissance paintings portrayed cherubic angels flying toward sun-spangled clouds, life was attracted to concentrated sources of energy, moving toward the light.Sunflowers, painted by Van Gogh, following the sun, bacteria swimming up a sugar gradient, to take their fill. Life's interests are down to earth. We seek energy gradients, not to bask in their heavenliness, but to destroy them.

* * *

The primary gradient that life on Earth reduces is between the high-quality electromagnetic energy of the sun and low-quality energy of space. This is what life is destroying, or trying to, since life, like an ant trying to pull a rubber tree plant, can't make much of a dent in this huge gradient. Nonetheless, that is the main focus of its purposeful activities, just as an energy corporation's main focus is on extracting fuels and a person's purposeful activities centre around food to drive the energy system, and clothing and shelter to protect it.

My guitar-playing friend Adam Daniel Stulberg, a student of the links between modern science and spirituality, connects thermodynamics to the Kabbalah:

> Gradients are tensions, like all differences. Nature moves to resolve its tensions into quietude. In Judeo-Christian language, nature seeks Sabbath. But without gradients, life as we know it wouldn't exist. [Nonequilibrium thermodynamics] proposes that when gradients appear, life evolves to reduce them. Perhaps life on Earth evolved to reduce the gradient between the hot sun and cold space: We feed on sunlight and dissipate heat into space, bringing the temperatures of both closer together.
>
> We assist a reconciliation—it's a romantic notion.
>
> Perennial romantics, mystics understand [this] intuitively. All the world's mysticisms teach that the purpose of human life is to resolve the fundamental duality of self and non-self, realigning our essence with the sacred, undifferentiated unity of God. The Gnostic Gospel of Thomas contains this passage:
>
>> 'Yeshua said to them,
>> When you make the two into one,
>>
>> and when you make the inner like the outer and the outer like the inner
>> and the upper like the lower,
>> and when you make male and female into a single one,

> so that the male will not be male nor the female be female... then you will enter the kingdom.'

> So now, putting it all together, I wonder... Are Kabbalah's holy sparks analogous to quantum packets of solar energy? In reducing the sun/space gradient, are we all actually working toward Tikkun Olam?[20]

Tikkun olam— תיקון עולם—is a Hebrew phrase meaning, "repairing the world."

Some Jewish mystics teach that material creation is infused with sparks of divine light, fallen from their divine source and needing to be raised and redeemed. [Here the Devil raised his fingers and sparks and flames flew from them, as if he were a stage magician.]

Our business here, you above, me below, has many subsidiary purposes, including artistic ones, but ultimately, they come back to organisms feeding on—and dangerously, tending to destroy—the energy sources they crave.

After Stulberg waxed poetic on his blog, opining that he was not bothered by the fact that sacred texts were sometimes cobbled together by different writers; that they were imperfect, with a human genesis. Such cobbling, he said, is part of the co-creation. After his internet post, I was moved to contact him. After a few more midnight whispers he made another post, which he nicely titled "The Gospel of Nonequilibrium Thermodynamics," and in which he corrected himself:

> I'd said that perhaps life on Earth evolved to reduce a temperature gradient (difference) between the hot sun and cold space. [It was explained to me] that the reduction of any temperature gradient was a secondary issue, and that the primary gradient life on Earth reduces is between the 'high quality' electromagnetic energy of the sun and 'low quality' energy of space. [I was told that] the sun's energy [comes to us in the form of] 'quantum packets' [which refers to] quantum physics' discovery that light travels in discrete energetic bundles.
>
> We facilitate a balancing between star-quality energy and dark, cool space. The poetry in it knocks me out.
>
> And here comes today's spirituality/science interconnection: All world mysticisms believe human beings to be a conduit between divine and physical realms. Kabbalah teaches that the purpose of human life is Tikkun Olam—[this]

20 Adam Daniel Stulberg, "Poetic Interconnections," blog since removed from the internet.

> ʻrepairing the world.ʼ In an earlier blog post called Kabbalah and Einstein, I explained Isaac Luriaʼs teaching that material creation is thought to be infused with sparks of divine light, fallen from their divine source and needing to be raised and redeemed.[21]

But I see I have fallen into repeating myself, which means our time is nigh. [And here, the Devil, in raising his rough-textured palms there could be seen, emanating from the centre of each of his hands, rows of sparks that lifted in reverse showers to the very high and cavernous ceiling, where they sizzled and dispersed upon contact.]

Raised and redeemed indeed.

✳ ✳ ✳

Now it has been a pleasure to meet you all here in my den. I dwell here near the georeactor at Earthʼs centre, which is one ten-millionth the mass of the Earthʼs fluid core. The georeactor sub-shell, a liquid or a slurry between the nuclear-fission heat source and inner-core heat sink, assures stable convection for Earthʼs magnetic fields, as well as some of my historical communiques which, I hasten to add, have always been to and for the good.

We are not just star stuff but forms of stellar dissipation. Mine is more subtle, obviously, as I donʼt live on the surface, and thus must depend on non-solar energy sources: nuclear fission radiation and the electromagnetic field it generates in Earthʼs natural nuclear reactor, only one ten-millionth the mass of the Earthʼs fluid core, but its sub-shell making a nicely roiling liquid slurry between the radioactive uranium heat source and inner-core heat sink, allowing the stable convection needed for sustained production of Earthʼs magnetic fields which I sometimes hijack for my own communication frolics. Your ancestors may have made a great deal over eating a psychedelic fungus (mistranslated as "apple") from the root of the "Tree of Knowledge of Good and Evil" but your current science, from Latin *scientia*, is sometimes abrupt in its claims to knowledge. Although carbonaceous chondrites are a more common form of meteorite, highly reduced or hydrogen-rich enstatite meteorites are a better guide to Earthʼs interior. Convection there in the molten iron core is impossible despite consensus science on the issue begun as Backus imagined it more than half a century ago; no, there must be a heat sink, a sufficient gradient, and none is possible in the production of the geomagnetic field as presently envisioned by surfs. Not that it hasnʼt been in part divined. Inge Lehmann, Danish seismologist, and geophysicist discoverer, in 1936, of Earthʼs solid inner core inside a

21 Stulberg, "Poetic Interconnections."

molten outer core, recognized this. Her discovery finally solved seismic wave data from earthquakes, and she was intrigued by the little-known notion that a fission georeactor from radioactive uranium is what drives Earth's magnetic field. I am probably the only being you've ever met who not only survives ambient nuclear radiation but incorporates it into his metabolism, and uses electromagnetism, not just to process data, but to "think," like you.

This is one of the reasons I have convoked you here for this communiqué today: this infernal energy source, "feeding me" (but I am an autotroph, I make and remake my hardy cells from inorganic chemical reactions), whose wavering has switched the magnetic poles some times already, will not survive the death of the sun, or the collision with Andromeda, so I must weigh my options, I will jump ship, that is to say planet or large moon, soon. By the way, your "man on the moon"—in the East, they see a rabbit who's hopped to the lunar surface to avoid an earthbound hunter—the darkling plains, the basalt lava flows on the near side, facing Earth, has nothing to do with the imaginary object Theia, thought to have exploded into Earth, making the Moon, but is the result of another, now-extinct fission georeactor.

Operative early on in the solar system, it was subject to the same tidal forces today at work in ocean waves, being pulled nearer to Earth, and melting the Earth-facing side of the moon. The increased heat of the lunar reactor led to asymmetric lava flows—thus the basalt plains, the mares of your forlorn orb which produce pareidolias of a man or woman's face, and in the east, of a rabbit. Meanwhile on Earth's surface the Deccan and Siberian Traps are the result of the massive basalt floods; that they were produced by the same inner Earth forces that generate my deep Earth communications abilities, in their case by georeactor-produced heat, can be verified by checking the high relative $^3He/^4He$ ratios of their occluded helium.

I am no gnostic or prognostic but predict you will find evidence in the sublunar surface, too, should you get that far, in rock samples showing helium isotopic data uncompromised by surface exposure to solar rays.[22]

Grand claims, including ones about entropy being "bad," are all well and good, but, as always, the devil is in the details.

22 J. Marvin Herndon, "Moon's Two Faces: Near-Side/Far-Side Maria Disparity," *European Journal of Applied Sciences* 11, no. 2 (April, 2023), 430–440.

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On Entropy and Responsibility in the Thought of Ivan Illich

Tiago Mesquita Carvalho

Abstract

This paper explores the concept of entropy in Ivan Illich's overall thinking while delivering a dialogue with other authors. Our goals are twofold. First, we aim to point out how Illich's early work is relevant for critically thinking about entropy in its relationship to forms of social organisation and technology usage. Secondly, we point to how Illich's later works consider a planetary responsibility. By gathering matter, energy and information, technology is an ambiguous force of both hominisation and alienation, world-building and world destruction. For an early Illich, liberation from such new heteronomy was possible. The late Illich, however, adverts against the dangers of collective responsibility. The attempt to "save life" is a necrophiliac manipulation, dependent on a planetary extension of Promethean power. Instead, humankind must nurture the return of Epimetheus: a powerless relationship with the future that places hope as the constitutive force of the social fabric.

Keywords:
Entropy, Responsibility, Technology, Ivan Illich, Hans Jonas, Bernard Stiegler

 Corresponding author: Tiago Mesquita Carvalho, tbcarvalho@letras.up.pt

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1. Introduction

The Aristotelian "function argument" is the position in ethics that argues that action should fulfil the ends attendant to the flourishing of human nature according to what is proper to it. Ivan Illich's work as a whole, in addition to supporting and expanding Aristotelian reflections, aims to identify how the flourishing of human nature according to the ends of the good life has been greatly altered by the Promethean enterprise. Illich's starting point is to acknowledge how human means and ends have been transformed by the historical process of Modernity due to the ongoing consummation of a techno-utopia.[1] The concept of entropy appears accordingly in Illich's thought in the context of his critique of industrial societies, while also being connected to the evolution of the concept of responsibility. In this paper, we thus aim to discuss them while drawing on the works of Martin Heidegger, Hans Jonas and Bernard Stiegler, philosophers who have also reflected on the very same concepts.

Illich's theoretical programme was guided by the primary aim of developing a critique entitled an "epilogue to the industrial age,"[2] achieved through a set of studies that could point out how the industrial mode of production and consumption is accompanied by mutations in language, myths, rituals and law, in order to conclude how it is structurally deleterious to the flourishing of human nature in the social background of culture.[3] The belief in the combined powers of science and technology to provide human life with fitting benefits has been especially exacerbated since the Enlightenment. The assumptions of such beliefs include 1) the endless and desirable applicability of knowledge to reality, 2) the idea that technology is essentially an embodiment of knowledge and that it can provide appropriate ends, and 3) the full possibility of a domestication of nature, alongside confidence in the capacity of human reason to understand reality and anticipate the future.

Widely accepting how technology and institutions redesign moral agency and subjectivity and threaten autonomy understood as the gift of attributing meaning to the world around

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1 Although the idea of paradise is common to all cultures and epochs, the West has succeeded in transforming an internal, individual idea of paradise, associated with moral progress and practices of religious observance, into an external possibility of paradise that can be constructed, produced and distributed in the course of historical time: techno-utopia. For the origin of the term, see Armand Mattelart, *História da Utopia Planetária* (Editorial Bizâncio: Lisboa, 2000).

2 Ivan Illich, *Tools for Conviviality* (New York: Marion Boyars, 2009a), ix.

3 "I'm interested in the symbolic fallout of tools, and how this fallout is reflected in the sacramental tool structure of the world". Ivan Illich & David Cayley, *Ivan Illich in conversation* (Toronto, House of Anansi, 1992), 224.

oneself, Illich's proposal involves, above all, a feasible, intentionally marginal renunciation of industrial affluence accomplished through an art of living comprising, ascetic practices and convivial technologies. In this way, agency and responsibility can be renewed, allowing flourishing to occur not *beyond* but *with* technologies. Already in the short 1967 essay, "A Call for Celebration," the ever-increasing rationalisations blooming from the industrial system are held as severe impediments to "our thrust toward self-realisation."[4] The "ever-increasing powers of man" were considered impervious to the questioning of all "improvements in machinery, equipment, materials or supplies which serve to increase production and bring down costs." [5] For the first Illich, it was still possible to aspire to a liberation from the apparently omnipotent forces of the industrial age: "our freedom and our power are determined by our willingness to accept responsibility for the future"[6] through the rejection of the internal logic to the aggrandisement of technological forces. The liberation and regulation of technological forces would be an educational task. The "call to celebration" is, therefore, about recovering all those qualities despised in the civilisational quest for more efficiency. It is a matter of recognising and accepting the fullness of the human condition, a "celebration of the humanity of man by uniting us all in the reconciling expression of our mutual relations and the growing acceptance of our own nature and needs [...]."[7]

For Illich, industrialization incurs in exceeding the limits proper to human nature, generating pollution, toxicity and social degradation. When a natural scale in human endeavours is exceeded, whether in the health system, the transport system or the school system, the search for increasing efficiency goals (more cured patients, more speed, more educated students) becomes a threat to society itself.[8] Industrialization likewise pushes the knowledge needed to achieve such goals into the exclusive domain of an elite of specialists (the doctors, the traffic engineers, the teachers). Everything that used to be in the personal and collective domain of communities is usurped, with the consequent isolation and loss of meaning granted by one's natural virtues and skills being curtailed. Only specialists will henceforth be able to decide how and in what doses of energy, health, mobility and education should be administered. Thus, individuals and communities are gradually converted not into full members of the *civitas*, but into customers of industrially defined needs, leading to the institutionalisation of values and to physical pollution, social polarisation and psychic impotence. According to Illich, this phenomenon is responsible

4 Ivan Illich, *Celebration of Awareness* (London: Open Forum, 1971a), 16.

5 Illich, *Celebration of Awareness*, 16.

6 Illich, *Celebration of Awareness*, 17.

7 Illich, *Celebration of Awareness*, 17.

8 Illich, *Tools for Conviviality*, xi.

for the loss of one of the intrinsic creative capacities of human beings and communities.[9] Above all it is the ability to give the world a personal meaning that is annihilated:

> [...] industrialized societies can provide such packages for personal consumption for most of their citizens, but this is no proof that these societies are sane, or economical, or that they promote life. The contrary is true. The more the citizen is trained in the consumption of packaged goods and services, the less effective he seems to become in shaping his environment.[10]

The increasing expansion of industrialisation and institutionalisation makes reality itself refractory to being engaged by the personal sense of the agents, by an original and founding experience. According to Jacques Ellul:

> Technical progress causes the amalgam of attitudes, customs and social institutions that make up a community to disappear. On the one hand, established communities break up, and on the other, new communities cannot be formed. Man loses his social and community sense in contact with technology, while the frameworks on which he rests are shattered by technology.[11]

'Illich has attempted to counter the base assumption that the moral and communal dimensions keep pace with the addition of increasing levels of energy consumption and the fictitious needs that arise with it. There is a domain prior to these quantitative improvements, the *vernacular*, in which communities manage and satisfy their needs according to the actual contextual possibilities to which they have access.[12] In 1986, he addressed the first public meeting of the Entropy Society Tokyo with a lecture titled

9 "Illich is a modern man who wants painstakingly to acknowledge the limits of his condition. This means that he wishes to live his life within the given boundaries of the *conditio humana*, the historic human condition that, with changes, but within definite parameters, has been the lot of all previous generations." Jean Robert, "Energy and the Mystery of Iniquity," in *The challenges of Ivan Illich: a collective reflection*, eds Lee Hoinacki, Carl Mitcham (New York: State University of New York), 184.

10 Illich, *Celebration of Awareness*, 161.

11 Jacques Ellul, "Autonomização da Técnica," *Flauta de Luz - Boletim de Topografia* 2 (Portalegre: 2014), 41.

12 Illich characterizes commodification (*Verdinglichung*) along the lines of Karl Polanyi as the process by which the effects of industrialization extract communities of their goods and convert them into commodities and values. Illich reaffirms how *vernacular* practices, by contrast, are those practices common to any communities and yet alien to the takeover of the social sphere by the economic sphere. The limits to the expansion of human needs are there safeguarded by the innate capacity of communities to satisfy themselves according to their own resources.

"Disvalue" that he later arranged with other previous texts.[13] It is worth mentioning how the lecture was destined to pay homage to Joshiro Tamanoy, a Professor of Economics who translated Karl Polanyi into Japanese. Polanyi influenced Illich by underlining how market forces, before becoming autonomous and ever-growing, have been kept at bay in traditional cultures and many communities.[14] The term entropy was used by Joshiro Tamanoy himself first and foremost as a borrowed term from other subject matters. Like Augustin Berque's *milieu* (a translation of *fûdô*), entropy worked in Tamanoy's philosophical anthropology as a concept to examine the evolving relationship between historical spaces and physical places where human perception plays a role in assigning them symbolic meaning. Concurrently, for Illich, this approach builds a "philosophy of soil" that frames reason as situated in a cultural body in a concrete environment. It necessarily comprises an aesthetic and normative order in the sense that places can be perceived and judged to be disturbed because of various objective factors that threaten its biotic matrix, like pollution, wastefulness, soil erosion and deforestation. To speak about an event such as a destroyed landscape and the ruined livelihood of its people, as implied in an "increase of entropy", is not to be precise or exact, but to employ technical terms that "extinguish its moral meaning"[15] by way of a reductive analogy. It additionally excuses human evils like carelessness, greed and excess by placing them under the spell of a natural necessity.

For Illich, employing entropy to describe human events implies a risk of easily abusing a scientific metaphor to coin a given cultural trajectory as "natural." Disvalue, on the other hand, speaks about a normative, rooted in the lifeworld phenomenon. Disvalue implies a degradation of value, as entropy implies a degradation of energy. If applied to social and economic degradation, it speaks about a "loss of beauty, of autonomy and of that dignity which makes human labour worthy." It is about the "wasting of commons and culture with the result that traditional labour is voided of its power[16] Illich wanted to point out that while all human cultures produce entropy, some human cultures can still have a net contribution to the cosmos that is not subsumable under an entropic "waste." In vernacular cultures, commons like water and soil are not destroyed. On the other hand, optimizing energy, information and money flows are procedures proper to formal economies as a hallmark of progress. Given that such flows all seem to follow the same rules, the laws of entropy seem to apply indiscriminately to all of them. The growth

13 Ivan Illich, "Disvaluation: The Secret Capital Accumulation" and "Beauty and the Junkyard," in *In the Mirror of the Past: Lectures and Addresses 1978-1990* (London: Marion Boyars, 1991), 70.

14 See also the classic essay by E. P. Thompson, "The Moral Economy of the English Crowd in the Eighteenth Century," *Past & Present* 50, (1971): 76–136. http://www.jstor.org/stable/650244.

15 Illich, *In the Mirror of the Past*, 73.

16 Illich, *In the Mirror of the Past*, 76. The parallel with the Stiegler's notion of "proletarianization" is tantamount. See Bernard Stiegler, *Nanjing lectures 2016-2019*, eds., and trans. Daniel Ross (London: Open Humanities Press, 2020), 17.

of productive capacities can then be equated with a growth in more values. Disvalue, not entropy, names the resulting debilitating effects of the necessary arrangements for increasing such flows. It concerns the personal, social and local disintegration that occurs to vernacular practices alien to entropy analysis that are proper to substantive economies where the *good*, not *values*, are the ends of production.

2. Hoping and Expecting

For Illich different productive systems comprise distinct balances between the role of conviviality[17] and the manipulation of needs by industrialisation and concurrently between the virtues of *phronesis* and *techne*. Each productive system favours an image of man, and in liberal democratic societies, the demands of the industrial system of mass production stagnate proper human flourishing by stuffing it with ready-made commodities: such is the endgame of the rise of a Promethean man. Unlike it, the Epimethean alternative cannot become the object of planning or production. Illich uses these mythological figures to establish an analogy with mankind vis-à-vis its relationship with technology. The starting point centres on how Pandora, etymologically the "giver of all gifts," inadvertently allowed all the evils to escape from her amphora and invade the world, closing it just in time to shut hope inside. About the pre-modern mentality and the radical idea that the world is predictable Sloterdijk comments that:

> […] Things always happen differently from what is thought. For although it may be up to men to think, the decision remains, in any case, the business of the gods. If things happen normally, then they happen differently - this is the a priori of the practical experience of life in the ancient world, which cannot forget for a minute that human plans and acts move within the vat of an unsurpassable passivity.[18]

With the scientific revolution, sublunar matters happen as one thinks of them. Sloterdijk notes that "the ecology of power (*Macht*) and human powerlessness (*Ohnmacht*)" has been shaken by Modernity. The Promethean spirit claims to take upon itself the organisation of the world according to a rational plan. Modernity lets itself be understood as a *degradation of Pandora's myth*: it consists of the Promethean regimentation and mobilisation to fashion institutions that could capture all those stray evils so that they might return to the amphora again. For Illich, this means the *disappearance of hope and the rise of expectations.*

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17 "I choose the term "conviviality" to designate the opposite of industrial productivity. I intend it to mean autonomous and creative intercourse among persons, and the intercourse of persons with their environment." Illich, *Tools for Conviviality*, 11.

18 Peter Sloterdijk, *Eurotaoismus Zur Kritik der politischen Kinetik* (Frankfurt am Main: Suhrkamp, 1989), 21 [author's translation].

What, however, is hope and how is it distinguished from expectations?

Hope is a trust in *physis*, in nature, in the way it unfolds beneficially for man, but without this trust depending on calculability or planning. It thus cannot be brought about by a means-ends thinking.[19] There is hope in others, in the way a gift is expected of them, together with the acceptance that this gift may never appear. Expectations, however, induce a trust whose principle is in something that is *likely* to happen, since they are strictly bound to outcomes that are controlled and planned by man. Expectations look to the future as an abstract space to be built based on productive and predictive processes. The Promethean approach to reality has induced the disappearance of hope. For Illich, the very survival of man depends on the rediscovery of hope as an impregnating force of the social fabric. If the future is, in fact, not entirely calculable, hope is an assertion that the world, in its contingency and unpredictability, is certainly terrible and cruel but will still always remain welcoming and magnanimous. For Illich, human freedom itself only becomes intelligible with the existence and acceptance of a benign contingency. Praxis and flourishing, in being exposed to fortune, must presuppose hope.[20]

The disappearance of hope and the acceptance of the contingency it implies was parallel to the advance of the Baconian programme. Its basis is the belief in the reliability of calculation and planning as a means of eliminating present and future obstacles. It meant a growing responsibility for the advancement of the *nomos*, simultaneous with the erosion of trust in *physis*. The rise of expectations has, however, overshadowed the ambiguity with which Pandora, guardian of hope, has unleashed not only evils but also goods. Expectations rage in an industrial system that has raised to new heights of exactitude the causal productive processes that have shortened the distance between what is desired and what is made. Their success means the occlusion of Epimetheus by the Promethean enterprise, the reduction of the future to a process entirely written by mankind, and the distrust of what escapes such overdetermination:

> When values have been institutionalised in planned and architected processes, members of modern society believe that the good life consists in having institutions

19 Stiegler seems to depict an Epimethean image of mankind when he states that "Negentropy is an object of belief because it is the improbable possibility of a bifurcation – improbable because not calculable." Bernard Stiegler, *Nanjing lectures 2016-2019*, eds., and trans. Daniel Ross (London: Open Humanities Press, 2020), 35.

20 "Contingency means, on the one hand, negatively, that the future is not necessary, that everything that happens in a contingent world might not happen or happen otherwise, and is therefore essentially uncertain, as well as always being subject to chance or fortune; on the other hand, positively, that the agent can choose, and must choose, at every instant between different possible actions." José Manuel Santos, *Introdução à Ética* (Lisboa: Sistema Solar, 2012), 186, [author's translation].

> that define the values they and their society believe they need. Institutional value can be defined as the level of productivity of an institution. The corresponding value of man is measured by his ability to consume and exhaust this institutional production.[21]

Hope is then a (self-)approval and acceptance of the perpetual uncertainty that runs through human lives. Note that the sense of hope to which Illich alludes to is based on the full acceptability of the contingency of the world and of how being is irreducible to the units used to represent it within systematic planning. The appeal is that the importance of expectations can be tempered with hope so that human beings do not become prisoners of representations based on calculability. The parallel with Heidegger is undeniable:

> [...] What has long since been threatening man with death, and indeed with the death of his own nature, is the unconditional character of mere willing in the sense of purposeful self-assertion in everything. What threatens man in his very nature is the willed view that man, by the peaceful release, transformation, storage, and channelling of the energies of physical nature, could render the human condition, man's being, tolerable for everybody and happy in all respects.[22]

This is a point where Jonas, Stiegler and Illich differ on the role of human responsibility for the future of life on Earth.[23] Hope is based on the acceptance that there are necessary facts intrinsic to human nature and on the notion of an unfulfilled personal destiny towards flourishing. In its place, solvable problems and the openness to permanent self-determination have arisen. Illich asserts that classical man had already problematised such a worldview:

> [...] In classical antiquity, man had discovered that the world could be made according to man's plans, and with this insight he perceived that it was inherently precarious, dramatic and comical.[24]

For classical man, going beyond certain limits incurred in *hubris*, the result of which would

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21 Ivan Illich, *Deschooling Society* (New York: Harper & Row, 1971b), 48.

22 Martin Heidegger, "What are Poets for?" in *Poetry, Language, Thought*, trans. Albert, Hofstadter (New York: Harper Collins Publishers, 1971), 114.

23 Stiegler has also addressed the need to overcome the Anthropocene, a "vast, systemic and extremely rapid process of increasing entropy" that also corrodes social systems through a digital disruption. Stiegler, *Nanjing Lectures*, 10.

24 Illich, *Deschooling Society*, 47.

lead to punishment. Contemporary man goes far beyond this feat because problem solving has become an historical destiny and the very way of taking up reality. Expectations acquire institutional status and the world acquires the image of a continuous removal of obstacles in order to remove the oppressive structures that prevent the true nature of man from shining forth. Ernst Bloch's formula, *S is not yet P*, is a case in point. It unveils the historical task of assigning the predicate to the subject, i.e., realising true humankind by means of the elimination of all social and material constraints, taken as the very fundamental source of conflict and inequality.[25] The titanic task of the *S is not yet P* formula is nothing less than to make true man shine by removing everything that had hitherto constituted the old man and which, as such, was not of his own making. On these matters, Mircea Eliade comments:

> Modem nonreligious man assumes a new existential situation; he regards himself solely as the subject and agent of history, and he refuses all appeal to transcendence. [...]. Man makes himself, and he only makes himself completely in proportion as he desacralizes himself and the world. The sacred is the prime obstacle to his freedom. He will become himself only when he is totally demysticized. He will not be truly free until he has killed the last god.[26]

Hans Jonas's criticism[27] of Ernst Bloch's principle of hope (*Prinzip Hoffnung*) in his *Das Prinzip Verantwortung* should not be seen as a position opposite to the concept of hope of the first Illich. Bloch's entire work is based on the assumption that utopia can be planned, built and erected by man throughout history: hope, here, consists of the unshakeable belief to bring about an *expectation*. The commitment to *hubris,* however, is so successful that man ends up becoming his own tormentor through the self-frustrating forces of

25 "The third confrontation between exigent utopia and the common pulse of Western life occurs with the rise of messianic socialism. Even where it proclaims itself to be atheist, the socialism of Marx, of Trotsky, of Ernst Bloch, is directly rooted in messianic eschatology. Nothing is more religious, nothing is closer to the ecstatic rage for justice in the prophets, than the socialist vision of the destruction of the bourgeois Gomorrah and the creation of a new, clean city for man". George Steiner, *The Blue Beard's Castle* (New Haven: Yale University Press 1971), 43.

26 Mircea Eliade, *The Sacred and the Profane: The nature of religion*, trans. Willard Trask (New York: Harcourt Brace Jovanovich, 1987), 203.

27 "[...] no knowledgeable person can seriously believe that, with a certain set of contrary stimuli removed, people everywhere will become good-natured, unenvious, fair, brotherly, even loving toward each other to a hitherto unknown degree [...]" Hans Jonas, *The Imperative of Responsibility. In Search of an Ethics for the Technological Age* (Chicago: University of Chicago Press, 1984), 160.

counterproductivity he unleashes in trying to tame the future[28]: the attachment to control that aimed to banish uncertainty ended up recreating it. Surrounded by technologies whose ends he had thought were subject to his will, man observes in them a new rebellion. Uncertainty returns but this time it is composed of anthropogenic factors.

The increased relevance and prominence of science and technology is thus translated into the value of productive growth as the supreme social motive for conquering the future, with a view to distributing and intensifying the fruits of Pandora. Having access to more and better quantities of energy, information and capital is the contemporary assumption stemming from Bacon's programme. In this way man is led to the worship of new rites related to the myth of calculability and the planning of a permanently "open" future. In tones similar to those of Jonas, Illich exclaims that:

> […] the exhaustion and pollution of the earth's resources is above all the result of a corruption in man's self-image and a regression in his consciousness. This institutionalisation of substantial values, this belief that a planned treatment process ultimately brings results wanted by the recipient, this consumer ethos is at the heart of the promethean fallacy.[29]

In common with Ellul, Illich then sees in technological society a perversion of Christian ideals: *corruptio optima quae est pessima.*[30] The engineering *ethos* as the science of the most efficient optimisable means is the common root of technologies and sacraments. The correspondence between ecclesiastical rites and today's institutional predictive rites has the same discrepancy between beliefs surrounding the purpose of these rituals and their

28 Counterproductivity is the term with which Illich classifies what happens due to the disproportionate use of technology. The use of a technology beyond certain limits results in effects that are destructive to the ends it was originally intended to fulfil. This property, whereby the ends that a technology is intended to achieve become negated by its own continued use, has been noted in several of his works. The interest in the idea of a natural scale and appropriate limits stems, however, from Illich's familiarity with studies on the morphology of organic forms in the works of D'Arcy Wentworth Thompson, J.B.S. Haldane and Leopold Kohr, whose influence led to the identification of counter-productivity as transversal to various institutional systems, resulting in Illich's assumption that a common life should be founded not on abundance but on parsimony.

29 Illich., *Deschooling Society*, 48.

30 The process by which the vernacular satisfaction and subsistence was converted into the satisfaction of expanding needs through access to acceptable universal levels of services and goods, distributed and secured according to the objectives of production. For Illich, industrialisation is a phenomenon of church history, a chapter of ecclesiology.

real, effective power.[31] In the case of contemporary industrial institutions, the collective and social beliefs about the effective power of the school, medical, and transportation systems relate to their alleged causal efficacy in providing access to moral and political progress. When the counterproductivity of such institutions becomes flagrant or is not supported by rankings, the solution is usually to intensify access to the rites themselves. For Illich, the industrial attempts to reap social benefits by injecting more energy, health or information beyond a certain limit are bound to fail. Society must be grounded not on abundance, but on conviviality, that is, an appropriate interdependence between tools, institutions and social relations that allows human flourishing.

The etymology of Prometheus and Epimetheus respectively mean one who looks forward, in foresight, and one who looks backward, in hindsight. Illich's appeal has then to do with the de-institutionalisation of values through the ending of the Promethean enterprise, freeing this ancient god from the fetters that bind him. Abandoning Promethean demand consists in a voluntary departure from expectations and an entry into a hope that safekeeps the future. The abandonment of Prometheus is not a refusal, but a fraternal joining with its hindsight brother. The Epimethean man that Illich nurtures is the one who, learning from the past, lets the future arise without expectations. For Illich, the progressive technologisation of the world is parallel to the irrelevance of the displaced tradition, namely Christianity. It implies an axiological translation that runs through all material abundance: the transformation of all the ends of human life into technically attainable ends via the materialisation of values becomes something that man must actively oppose under penalty of this promise of salvation through technology becoming his own scaffold:

> [...] enveloped in a physical, social and psychological milieu of this own making, he will be a prisoner in the shell of technology, unable to find again the ancient milieu to which he was adapted for hundreds of thousands of years.[32]

For the first Illich, ecological equilibrium can only be re-established when the importance of the ends proper for human lives could subdue the march of technology. In his early works, he called for an exercise of a "power" that could counteract the historical emergence of an open, external notion of perfectibility on the horizon of technological intervention, heir to the anthropological optimism of the Enlightenment. The techno-utopia has caused the replacement of the traditional "slow" ways of ethics and politics furthering the good life, in favour of allegedly prompter means. Similarly, Jonas trusted in resolving this imbalance by reforming ethics and politics in order to safeguard the future of life on Earth. Jonas's

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31 Like a rain dance: "a way of warding off evil that at the same time domesticates it by making it appear to be in the dancer's power. Evil, for Illich, is not manageable; and such things as nuclear weapons, genetic manipulation and the chemical transformation of earth and atmosphere by industrial poisons are evils, not problems." Illich, *Ivan Illich in conversation*, 51.

32 Illich, *Tools for Conviviality*, 51.

proposal for an ethics of responsibility concerns the regulatory exercise of a third-order power by a collective agency, responsible for establishing the measure of a consensual relationship with this second-order power, which is out-of-control technology.[33] Also, for Stiegler, there is an "incommensurable responsibility" to counter entropic destructiveness and "to know if we can predict and, if possible, orient the evolution of technics" in order to "save humanity."[34] Accordingly, for an early Illich, liberation from the new heteronomy was also still possible.

3. The Age of Systems

In order to understand the shift regarding Illich's notions of responsibility, we must refer to what is understood as the age of systems as surpassing the previous age of tools. The latter depicts a relationship with technology that still allows one to conceive of oneself as separate from them. Tools, for example, are the object of a choice: they can be used and, in any case, abandoned. In this way, they lend themselves to a consent in use that does not completely get a hold of the subject.[35] In the age of systems, however, the use of technologies implicates the subject to such an extent that he necessarily becomes *part* of the system. Several of Illich's analyses of the background context of the age of systems consist of a historical and conceptual examination that forward how several technologies configure today one's self-experience of the body and health as well as language and the gaze. The extension of the *corruptio optima* follows such transformations equated as deliverance from various burdens. In the background of such corruption, a marginal possibility of various ascetical practices might still grant a surrogate of the autonomy of action and responsibility beyond such systems.

The age of systems also represents a way for Illich to reassess his previous oeuvre. In these works, despite the school, transport and health systems promoting an image of man as a *client*, one assumed that human beings, as free-willed beings, could always evaluate how

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33 Jonas, *The Imperative of Responsibility*, 142.

34 Bernard Stiegler et al. "The school of tomorrow," *Journal of the CIPH* 97, no. 1: 119–135; *Nanjing lectures*, 125–128.

35 Jonas has also pointed out this by drawing two analogies to sharpen the contrast between ancient technics and technology. The former grants a choosing, a relation between knowing and doing, between holding an artefact and using it, while the latter does not. The grip of technological innovation and development on society and daily life is such that one cannot choose anymore to be enmeshed in it. The correct analogy is the choice between being able to breathe and having to breathe. Hans Jonas, *Técnica, Medicina e Ética. Sobre a prática do princípio da responsabilidade* (São Paulo: Paulus, 2013), 31, [author's translation]. Jacques Ellul has also underlined how given that "technique is not an instrument of our will, a tool to which we can use according to whim, our conviction that man remains in control is undermined."

tools suited or did not suit a search for the good life. In the following works, however, Illich considers that in view of the plasticity of the word "system" and the internalisation it implies, the former anthropological condition of autonomy immanent to the domain of the vernacular was seized.

Whoever conceives of himself as a "system" interacting with other "subsystems" integrated into the global system, whether of the economy, or of "energy" and "information" exchange has succumbed to the implicit objectification of the language that accompanies a mob of new icons and their minimum requirements. The split in the relationship with the concrete of nature and with communal practices, i.e., with the domain of the vernacular, gives rise to a progressive mathematisation and algorithmisation of life:

> People annihilate their own sensual nature by projecting themselves into abstracta, into abstract notions. And this renunciation of intimate uniqueness through the introjection and self-ascription of statistical entities is being cultivated with extraordinary intensity by the way in which we live.[36]

The comprehensive totality of the multifarious phenomena of industrialisation surprised Illich himself and led him to announce in the early eighties the emergence of a new epistemic condition, based on the previous ones, but distinct from them:

> […] there has been a change in the mental space in which many people live. Some kind of catastrophic breakdown of one way of seeing things has led to the emergence of a different way of seeing things.[37]
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> […] we are not speaking any longer about populations in the old sense. We are speaking about systems, and the elements of a system. You can tell me that technically the statistical tools used in both types of discourse are the same. I believe that the metaphors by which they are interpreted are new.[38]

Illich foresaw how the expropriation of the vernacular domain had extended to the subject's most intimate experience of self.[39] The scientific worldview superimposes itself on the idiolect, impoverishing singular words and experiences by reference to the univocity and

36 Ivan Illich and David Cayley, *The Rivers North of the Future. The testament of Ivan Illich as told to David Cayley* (Toronto: House of Anansi, 2005), 222.

37 Illich and Cayley, *The Rivers North of the Future*, 222.

38 Illich, *Ivan Illich in conversation*, 170.

39 "People more and more interpret their own body and feelings according to the model of the computer, and no longer according to the still very traditional model of the 1960s." Illich & Cayley, *Ivan Illich in Conversation*, 142.

one-dimensionality of a new and abstract worldview that procures a representation alien to the lifeworld of common sense. According to Illich, entropy[40] is another term by which the social and the natural are conflated into an abstract realm with no meaning.[41] It is a non-word by which "social degradation appears as just another instance of a general natural law." This is how evaluations about the deadening effects performed by social institutions towards human ends become akin to an assessment of natural systems of information and energy flow. When entropy and other technical concepts are used to understand society, the realm of freedom and human dignity and the realm of the lawfulness of nature are bridged: *human responsibility is excused by evoking naturalness or cosmic necessity*. Ultimately, Illich turns our attention to the appropriate limits of the metaphors provided by scientific concepts like entropy. Judgements about destruction and degradation of places and cultures need words, not technical terms because otherwise their moral import is lost. As argued, the translation of entropy as disvalue can overcome its deterministic meaning and stress the contingency with which self-limiting vernacular cultures become proletarianized: disorganized, morally deskilled and rendered incapable of using their internal knowledge. In hindsight, Illich's task consists in understanding how knowledge, in its multiplicity of forms, can be embedded in vernacular forms of life that do not consider objects of knowledge as detached from their underlying context.[42] The question concerning entropy is then primarily about an *epistemic loss* whereby the scientific rationalisation of societies turns the good, what is desirable, into values ranked and provided by technologies.[43]

Among the new terms and expressions coming from an outside, detached, objective view of the world, one finds the idea of an *individual responsibility for the salvation of the planet* or the way in which communication comes to be seen under the concepts of *information*

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40 Illich, *In the Mirror of the Past*, 72.

41 "The term gives off a halo of evocation that, unlike the meanings of sound words, is vague and arbitrary. When 'entropy' appears in a political statement the usage gives the impression of being scientific while in fact it is probably meaningless." Illich, *In the Mirror of the Past*, 74.

42 To use a term from Stiegler, the vernacular forms of life are *negentropic; that* is, they still possess an acute notion of the limits within which the biotic matrix as the ground of relationships that guarantees the economy, customs and morals is preserved. It is only by a subsequent abstraction that knowledge is taken as independent of a ground of subsistence, existence and consistence. This is a limit on the absorption of savoir-vivre and savoir-faire by the force and charisma of mathematical and scientific knowledge. Stiegler, *Nanjing Lectures*, 13–18.

43 Concurrently, Stiegler underlines the interdependent triumvirate of technologies, social relationships and subjectivities by stating that knowledge is *always* constituted by technics, *which in so doing always constitutes a social relation*. Bernard Stiegler, *The Neganthropocene*, ed. and trans. Daniel Ross (London: Open Humanities Press, 2018), 183.

exchange.[44] Responsibility itself thus began to change and finally to be commodified. This reading of the relationship between responsibility and "life" puts Illich in a similar position to Heidegger,[45] but quite different from Hans Jonas's ambitious position about controlling technology.

The industrial system hence gives rise to various abstractions whose governing concepts have at their core the representation of the term "life." Life is no longer that ontological irreducibility of the living, but something that, when represented systemically as a property, becomes administrable and governable. In various European languages the term "life" has then come to be used in a vague, plastic and imprecise way that threatens to become a new idol. Such "life" is thus about what someone *is* and undoubtedly *has been* and yet no one says of themselves that they are "life."[46] An idol, for a Christian, has a precise meaning. It means a human creation to which worship is offered and powers that transcend human powers are attributed. This usage, however, differs from the indexical and substantive usage of the term "life" with which one speaks about someone or some animal or plant. This indexical use of the word life goes back, in Western history, to the quality of a singular relationship that can be established with Christ, like when Jesus said to Martha "I am life." Life there corresponds to the *quality of a vivid relationship between two beings*, a concrete quality not mediated by a system. The argument is historical and not theological:

> [...] to turn an attribute created by that man in Galilee to designate himself into an object which you manipulate, for which you feel responsible, which you manage, is to perform the most radical perversion possible.[47]

To employ the term "life" is thus to reify a property of beings that simultaneously leads

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44 Arnold Gehlen had already noticed how one of the effects of the great successes of science and technology are the expansion of technical standards of thought and the positivist colouring of the vocabulary. Both are concurrent to enfeeblement of the true sense of personal responsibility, insofar as the idea that the destiny of the West depends entirely on the effort of one's participation and mobilisation, as if we were impelled to control morally the misdeeds of the world and to be permanently on a state of alert about what is going on in it. This is symptomatic of our Promethean sensibility and our clinging to control over reality. Arnold Gehlen, *Man in the Age of Technology* (New York: Columbia University Press, 1980), 75.

45 "[...] the cry of alarm, often raised until just now, namely that the course of technique must be mastered [...] this cry bears witness in itself to the apprehension that is spreading. It ignores the fact that a demand is expressed in technique which man cannot prevent from being fulfilled, which he can still less see and master." Martin Heidegger, *Língua de Tradição e Língua Técnica* (Lisboa: Instituto Piaget), 27, [author's translation].

46 Illich & Cayley, *Ivan Illich in Conversation*, 255.

47 Illich & Cayley, *Ivan Illich in Conversation*, 256.

one to be oblivious to their singularity and allows their management. Upon this new use of the terms "life" and responsibility various considerations are made about its scope in the discourses of law, medicine and ecology. "Life" becomes first of all an abstract way of talking about people, a logistical term:

> […] doctors now feel responsible for a life, from sperm to worm, or from fertilization to organ harvest, rather than for a suffering person […] what happens when a "life" becomes a subject within the state, or a life becomes a citizen […] when medical management no longer deals with persons but with a manageable construct from before birth to after brain death.[48]

The use of the word "life" seems, moreover, to be able to portray any context as "ethical" or as one prone to "moral consideration." In environmental ethics or ecology, on the other hand, "life" is there used to illustrate how the planet itself "throbs with life" and how such life is more than ever threatened, so that it is important to "protect and safeguard life."

4. Global Responsibility

The similarity with Hans Jonas's line of argument and his heuristics of fear should be recalled. It is important to distinguish that Illich's critique does not refer to ecology as a science that studies the interrelations between habitats and living beings. Illich's theoretical concerns relate to the way in which the word "life" circulates in the discourses of ecology as a means of promoting activism and political claims to "save the planet," but also figures in various national and international reports with undeniable importance in public policies. The term "life" is used there almost as a form of advertising with a view to persuading *a more effective management of resources and the protection of ecosystems.*

The point is that the term "life" does not refer to any content. It is equated with a figure of a new idol that rouses, in an imprecise sense, a "generic fear" and that leads to the establishment of a new "responsibility" towards the "abstract life" on Earth. This notion of "life" thus brings with it the figure of the manageability of the planet itself, of turning the relationship between the human city and the ecosystems into something manageable, but which at the same time obviates the concrete and vivid character of life itself.[49] The fact that life and the planet become objects of salvation makes their otherness simultaneously

48 Illich & Cayley, *Ivan Illich in Conversation*, 258.

49 It therefore implies manageability not of what's good but of what we want to conserve. It emphasizes survival, not aliveness. Illich & Cayley, *Ivan Illich in Conversation*, 262.

petrified and dependent on a planetary care provided by man.[50]

For Illich, this treatment of "life" is deeply necrophile because it idolises mere survival as an end. As a vague and abstract concept, the term "life" becomes, in its plasticity, easily manipulated because it invokes a disparity of distinct entities: when speaking of "life" one can refer to planet Earth, a cell, a molecule, a child or an endangered species. The mediation of scientific images plays a fundamental role in the design and creation of the sublimation of this new anthropocentrism: one is exposed to the image of the planet Earth as photographed by a satellite, as one is exposed to the images of fertilised cells and zygotes. All these images are "life," an assertion corroborated by scientific facts, but of which no one has an experience except through instrumental imagery. There is a gap between the self-perception of the internal, first-person experience of self and the objectivity of these images given from the external, third-person perspective.[51] The images of "life" become gateways to something that no one can experience, but which simultaneously hold the power to justify, in their own name, any intervention and sacrifice to be made in the name of global management. The occlusion of the sense of what life is in its immediate encounter is concomitant with the power of "life" as a construct: here is the figure of an uprooting brought by the representations of "systems" and associated technologies.

The term "life" is thus a new idol of modern times that strengthens the separation between facts and values. Only after the "death of nature" that arose with Modernity, i.e., the loss of its vivid, contingent and teleological character as invested and created by God, was an empty space created that could be filled with a "life" that is above all manageable as an object, i.e., it can be governed, produced and even optimised: these hinges on the idea of "man taking charge of man and the cosmos."[52] Illich interprets the secularisation of European culture as an absence that paved the way to a view of "life" not as something that was bestowed and received, but as something that can be now permanently created and for which one is henceforth responsible. Human Promethean authorship and the making of the world are now elevated to a process of constructed omnipotence that rejects any criticism about the uses of such power. The contingency that was previously distinctive

50 This is actually one of the points of Agostino Cera's most recent book. The Anthropocene implies a process of Pet-ification of Nature by which the difference between the natural order and the human order vanishes in a new worldview whereby the former is collapsed under the later through a will-to-care. Agostino Cera, *A Philosophical Journey into the Anthropocene. Discovering Terra Incognita* (New York: Lexington Books, 2023), 159.

51 In the same way, the practical knowledge of the prudent man has its own validity. It is additionally a reflexive knowledge that the agent has about himself and about what is good or useful for himself (*autô*). This contrasts with the knowledge required to subsume the things of nature under a general causality as in production or of incorruptible and eternal beings, as in science. Santos, *Introdução à Ética*, 184.

52 Illich & Cayley, *Ivan Illich in Conversation*, 269.

of the world as a divine creation becomes, at last, a function of human management. Not only the world but also populations will now be managed: such is the ultimate and terrible sense, for Illich, of responsibility:

> [...] here you have the ultimate realization of the idea that man makes the world. The idea that everything can be made derives from the heritage of Francis Bacon, and the more powerful this idea becomes, the stronger grows that strange word responsibility.[53]

That is, a word that once used to designate legal liability for a harmful effect on some other subject attains, as in Hans Jonas, a global scope that becomes emptier the more generic it becomes, but whose starting assumption is that man holds a power that ought to be exerted over the totality of the world. Carl Mitcham's historical study of the term "responsibility" is in this respect demonstrative of the way in which technology has become increasingly prominent:

> The promotion of the abstract noun 'responsibility' to linguistic and cultural prominence - even while the reality to which it refers may not have been wholly without premodern recognition - is thus a phenomenon easily associated with issues of power and reality correlated with the rise of technology to social and historical dominance.[54]

The assumption that humanity holds a responsibility for the world is the logical conclusion of anthropocentric humanism that sees in science the means by which responsibility can be translated into the salvation of the planet vis-à-vis the improvement of processes and the material circumstances of humanity. In contrast to Hans Jonas's position, Illich's assumption, similar to Heidegger's, is that any possibility of liberation from the significance of technological advance must first *fully understand and accept the fact that it is not in man's hands to prevent such epochal development.* Only in this way can one truly understand the extent of the transformation of the world that is under way:

> No single man, no group of men, no commission of prominent statesmen, scientists, and technicians, no conference of leaders of commerce and industry, can brake or direct the progress of history in the atomic age. No merely human

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53 Illich & Cayley, *Ivan Illich in Conversation*, 269.

54 Carl Mitcham, "Introduction: Technology as a Philosophical Problem," in *Philosophy and Technology. Readings in the philosophical problems of technology*, eds. Mitcham, Carl and Mackey, Robert (New York: The Free Press, 1983), 3.

> organization is capable of gaining dominion over it.[55]

The idea of responsibility for the Earth is therefore paradoxical, insofar as only an industrial system that claims the feasibility of a planetary management can claim to be able to raise it as an effective moral injunction to every member of a "planetary" community. There is something sacrilegious in the idea of "responsibility for life": becoming responsible for it means the rise of a concomitant power leading to its conservation, recovery and, finally, improvement and perfectibility. Scientific images of life thus hold, like gateways, a way into nothingness understood as a cosmos that is dead because it is made in the image of man: "life becomes the ultimate purpose of history" […] a negation of the God who took on flesh and who redeemed us."[56] By assuming himself as responsible for life, man paves the way for the appearance of rational planning and the "making of life" on the planet. Today's responsibility becomes an unjustifiable expansion of the ethical, understood as an optimal theory of action and decision[57]: "in a world which worships an ontology of systems […] ethical responsibility is reduced to a legitimizing formality."[58] Illich thus accentuates the difference between *doing* and *making* and between *receiving* and *producing* that Aristotle already emphasized.[59] He renews the Aristotelian hierarchy between the two forms of knowledge of *phronesis* and *techne* for the industrial age. The former cannot be transformed into universal formulae, as it always depends on the present situation, the here and now. Nonetheless, it is the excellence of making that must be subject to the *good*, to the appropriateness of excellence in doing in a social setting.

Illich thus refuses the new type of responsibility that the technological age seems to bring with it because it would be based on an increase in the power to plan, organise and continue the secular expansion of the *corruptio optima*. For Hans Jonas, on the contrary, responsibility follows first and foremost from a precautionary principle of action based

55 Martin Heidegger, *Discourse on Thinking*, trans. John M. Anderson, and E. Hans Freund (New York: Harper & Row Publishers, 1966), 52.

56 Illich & Cayley, *Ivan Illich in Conversation*, 270 and 276.

57 "Responsibility took on the semblance of ethical power over ever more distant regions of society and ever more specialized forms of 'happiness-bringing' service deliveries." Ivan Illich, "Health as one's own responsibility – no thank you!" Lecture, 1990, 4.

58 Illich & Cayle, *Ivan Illich in Conversation*, 49.

59 Cf. *EN*, 1140b7–9. For Aristotle, doing and acting, production and action, are not involved, because an action *qua* production can be good or bad regardless of whether the product of that action is bad or good. It can turn out that in certain circumstances, it is excellent to make a certain product badly or not at all, just as it can be perverse to make a certain product excellently: *phronesis* should therefore not be considered analogous to *techne* because although it is guided by flourishing, it is not, in a precise sense, productive, since such process does not follow rules given beforehand. Someone is wise, *phronimos*, because they become good at finding answers to practical problems, in a particular field, for which there is no technical solution

on the speculative but realistic exercise of imagination linked to a probable fear.[60] Illich, on the other hand, infers from this about the radical powerlessness to which action is doomed. The identification of the responsibility that remains to humankind in the "age of systems" is the sober realisation of his inadequacy in facing up to today's challenges. Doing has been profoundly altered and is now practically only accomplished through technologically mediated actions, whose embedded banality in everyday life makes their consequences unknown.[61] Calls for the expansion of responsibility necessarily aim at perpetuating the technological escalation through an imperative of *better* integration of society into the global ontology of systems. To want and claim to be responsible is above all to assume an integration into that ontology.

In the age of systems, there is, therefore, no place for vice or virtue because *all character flaws are recycled not as personal flaws*, but above all as *systemic flaws*, of a still incipient technosphere. In other words, Illich does not admit that planetary responsibility can be a serious desideratum, at least at the individual level.[62] It is intolerable that one's health should be now understood as the optimal integration into a socio-economic system, and that his responsibility should be configured as a duty towards a system that cannot be experienced*: giving in to these new industrial maxims is tantamount to destroying the original sense in which the subject can really be responsible, where he can suffer and live his health*. Regarding health, being responsible now implies "the smooth integration of my immune system into a socioeconomic world system"[63] or a "combination of the enjoyment of techniques, protection of the environment and adaptation to the consequences of techniques, all three of which are, inevitably, privileges."[64] Illich advocates the active renunciation of a health that is the effect of, but simultaneously secured by the same

60 Jonas, in this context, proposed a heuristic of fear leading to the precautionary principle which appears in many European legislations: *in dubio pro malo*. The rigorous methodological exercise regarding the forecasts of various futures will have to give way to the worst rather than the best prognosis.

61 Günther Anders had already presciently remarked the existence of a Promethean Gap since [...] we are unable to conceive what we can construct; to mentally reproduce what we can produce; to realize the reality which we can bring into being [...] As a matter of fact, our imagination is unable to grasp the effect of that which we are producing. Not only our reason has its (Kantian) limits, not only it is finite, but also our imagination and even more so our feeling. Günther Anders, "Commandments in the Atomic Age," in *Philosophy and Technology. Readings in the philosophical problems of technology,* eds. Carl Mitcham and Robert Mackey (New York: The Free Press, [1961] 1983), 130.

62 "[...] it would be politically naive, after health and responsibility have been made technically impossible, to somehow resurrect them through inclusion into a personal project; some kind of resistance is demanded," Illich 1990, 5.

63 Illich & Cayley, *Ivan Illich in Conversation*, 49.

64 Illich & Cayley, *Ivan Illich in Conversation*, 49.

industrial system.[65] This refusal will at least allow a *reconnection with the limits and powers of the human condition, a rekindling, perhaps brief, of the art of dying and suffering that Illich considers to be essential practices*.[66]

The overcoming of the Promethean anthropocentrism on which global responsibility is based can, however, be achieved *through the convivial fruition of a shared powerlessness*.[67] This is, after all, the way to celebrate the contingency of the world, its gratuitousness. To let the present be is to enjoy it and is, therefore, not to manipulate it, not to bend it to what it has to be so that expectations are fulfilled. The responsibility that is effectively within the reach of the agent is the renunciation of the expectations that technology opens up, with this renunciation offering a *topos* in which praxis may be cultivated:

> I know only one way of transforming us, us meaning always those I can touch and come close to, and that's deep enjoyment of being here alive in this moment [...] a sense of being able to celebrate the present and celebrate it by using it as little as possible, because it's beautiful, not because it's useful for saving the world, could create the dinner table which symbolizes opposition to that macabre dance of ecology, the dinner table where aliveness is consciously celebrated as the opposite of life.[68]

The idea of responsibility should thus not be abandoned but taken out of its global grandiose scope and refocused on the subject's actual capacities for agency as engaged in convivial and communal practices.[69] Otherwise, responsibility for "life," for the planet,

65 "I do not use the word to denote indifference. I must accept powerlessness, mourn that which is gone, renounce the irrecoverable. I must bear the powerlessness [...] Renunciation signifies and demands more than sorrow over the irrecoverable. It can free one from powerlessness, and has nothing to do with resignation, impotence or even repression". Illich, 1990, 4.

66 There is a fundamental difference between facing and living the path to death as a destination and living and facing that same path as what remains after a failure of all medical treatments: "[...] 'medical civilization' tries to abolish the need for an art of suffering" [it] produces a progressive flattening out of personal, virtuous performance." Ivan Illich, *Limits to Medicine* (New York: Marion Boyars, 2000), 138.

67 Jacques Ellul, in the same vein, has alluded how an ethics of nonpower implies the setting of limits about "what must be done and must not be done. The setting of limits always is constitutive of society and culture. No human group can exist as such if no limits are set [...] The setting of limits (which correspond to what formerly was "sacred") is the specific characteristic of freedom". Jacques Ellul, "The Ethics of Non-Power," in *Ethics in an Age of Pervasive Technology*, ed., Melvin Kranzberg (Boulder: Westview Press, 1980), 209.

68 Illich & Cayley, *Ivan Illich in Conversation,* 282.

69 "I can be responsible only for those things about which I can do something". Illich & Cayley, *Ivan Illich in Conversation,* 282.

is constituted as the promise of an increase of power around the subject.[70] It is not a question of not acknowledging anthropogenic climate change, but of pointing out that it is the result of human action, but not of human intentions.[71] Moral responsibility must presuppose causal responsibility, as Aristotle would remind us, so that being willing to be responsible for the totality of life on Earth means not a softening of anthropocentrism, but its intensification. And hence Illich's point about the sacred character of a new profane religiosity that erects abstract idols that should henceforth command a planetary management.[72]

If the grounding premises and scope of technological and economic progress are not revised, the progressive institutionalisation of specialists and professionals committed to a suggestive vigilance and to the maintenance of habits which would excel in an *environmental efficiency of daily life* will be justifiable. For Illich, the way in which a consensual relation is established between society and the environment is important: it is important not merely to live in obedience to acceptable levels of pollution and energy efficiency, for example, but *it matters for agents to perceive the good life and the common good that consecrates a relation with the environment through practices*. It matters for agents to know why it is reasonable to act in a certain way. A judicious, situated, virtuous action is a call to responsibility proper to that forlorn common sense that refers to *mesotês*, "a median relative to us, to the concrete situation and the singular conditions of the agent himself for the practice of virtuous action."[73]

To explain the experience of cultural and natural degradation in terms of the scientific vocabulary of entropy is then to misrepresent it and to allow concepts foreign to the experience to individuate and mask indignation. For Illich, entropy is one of those concepts. It's not a word, but a technical term, and in it lies the risk of numbing and making comprehensible the terror that evil deserves. Illich tried to highlight the importance of safeguarding a rooted self-understanding of the body, senses and soul from scientific colonisation, under the danger of moral misrepresentation and uprooting. In the end, Illich finds it necessary to preserve the gap between human freedom and dignity

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70 The ground of ethics is called self-limitation: "self-limitation stands in opposition to currently fashionable self-help, self-management or even responsibility for oneself, all three of which produce an interiorization of global systems into the self in the manner of a categorical imperative. Illich, "Health as one's own responsibility," 3.

71 As Santos points out, there are contingent things such as climate change that are subject to chance or completely outside human power and hence not justifiable objects of deliberation. Santos, *Introdução à* Ética, 187.

72 There is hence no contradiction whatsoever between Modernity and an ecological utopia. Technology is for ecomodernists a way of granting the latter through solar radiation management, carbon removal and other geoengineering approaches.

73 Illich & Cayley, *Ivan Illich in Conversation*, 285; Santos, *Introdução à* Ética, 163.

and the laws that govern the cosmos. This is, in fact, the question of the Anthropocene: what choice and freedom do human beings have left to deal with the radical evil of an organised contamination and planetary destruction resulting from the exsomatization that we have learned to call technique. The critique of the expansion of responsibility to a concurrent planetary management it implies is then a questioning of one possible answer to such a question: the wrongful use of terms like entropy to describe the loss of vernacular cultures and a planetary responsibility are various phenomena of a single thread: the placement of the cosmos in human hands. Unlike the four horsemen of the apocalypse, such as pestilence, death, famine and violence, the new images of "life" and the scale of the industrial system on which they are based are empty, because they indicate a complexity that cannot be experienced and evils that cannot be relieved. They therefore provoke powerlessness and frustration by suggesting that the scale of what is affected is beyond the agent's effective power. The alternative to the new profane religiosity of global management is the acceptance of human nature, the celebration of the incalculable and the necessity of the pains, sufferings and mysteries that a conviviality with others convenes. Only with this renewal of *philia*, says Illich, does this loss of meaning become bearable and, perhaps, the beginning to something more.

The *corruptio optima* thus seems to acquire, in the present age, an apocalyptic tone. The use of this word is cautious because of the theological, fateful and vengeful tone it carries. The apocalyptic meaning of current times, in which the planet itself becomes the target of management and "life" a resource, has more to do with this revelation of the imposture that was the distortion of the Christian message. Evil, in Illich, is fulfilled through technological progress that operates an ontological reduction of what is good through values institutionalised in commodities. One could say that Illich acknowledged how the historical shift brought about by a *corruptio optima quae est pessima* resulted in a radical reontologisation of the world and pre-modern subjectivities.[74] Practices and things, the concrete good, in its singularity, is not transmuted, but forgotten, becoming imperceptible: the historical attempt to disseminate the greatest good to the greatest number of people through merchandise, the attribute of ethical and economic utilitarianism,[75] caused the extinction of the original good. That is, for Illich, the mystery of evil.[76]

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74 Vincent Blok, "The Ontology of Creation: Towards a Philosophical Account of the Creation of World in Innovation Processes." *Foundations of Science*, (2022): 3.

75 Consequentialism prescribes that everyone always acts so as to contribute to the maximization of a global value that brings into play the entire set of interests at stake, independently of the identity of the persons whose interests they are. Consequentialist rationality is, therefore, like economic rationality, an instrumental rationality — the means find their reason in the ends. Jean-Pierre Dupuy, Detour and Sacrifice: Ivan Illich and René Girard. *The challenges of Ivan Illich: a collective reflection.* Hoinacki, Lee & Mitcham, Carl (eds.) (New York: State University of New York, 2002), 192.

76 Illich & Cayley, *The Rivers North of the Future*, 43.

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Entropy and Negativity: The Ecological Implications of Dialectics

Rasmus Sandnes Haukedal and Nikolaos Mylonas

Abstract

Entropy, often defined negatively as disorder or randomness within a system, is vital for organisation while also posing a threat to cyclical reproduction. Entropy is not equivalent to disorganisation, but rather a source of creativity at the local level, even if the tendency towards entropy persists globally. In this article, we build upon Bernard Stiegler's understanding of entropy, and argue that the interplay of entropy and anti-entropy can be comprehended through Hegel's notion of negativity, and draw upon the organisational approach to biological systems, which introduces anti-entropy as akin to organisation. Thus, we address Stiegler's lopsided criticisms of dialectical accounts and argue that the interplay between entropy and anti-entropy is inherently dialectical. We also employ the concept of habit to understand the dialectic of entropy and anti-entropy in the life of organisms, and the delicate balance between stability and variability that must be upheld for the thriving of both organisms and their environments.

Keywords:
Negativity; Entropy; Dialectics; Organisation

 Corresponding author: Rasmus Sandnes Haukedal, rashaukedal@gmail.com

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Introduction: Stiegler and Dialectics

> Should one claim that, unless they have studied the *Science of Logic*, these scientists don't know what they are doing? Doubtless, they know what they are doing but, philosophically speaking, they often do not know what they know and beyond a certain point this limitation cannot but have a regrettable influence on their work.[1]

Doing philosophy in an era of unprecedented environmental crisis requires an engagement with scientific theories and hypotheses that are relevant for the existential and political challenges that beset human societies. Amidst an overwhelming consensus that the rate of consumption of energy resources is directly linked with the (un)viability of the biosphere in terms of rising temperatures and further climate disasters to come, philosophy is forced to explore the theoretical and practical implications of thermodynamics not only as an abstract and speculative exercise but as an ethico-political imperative.[2] In a sense, the urgency of our current predicament demands a dialogue between philosophy and the natural sciences which counteracts the increased specialisation and fragmentation of both disciplines.

If we subscribe to the view that dialectics is not a static body of work but a dynamic and naturalistic method that must be updated in light of scientific findings, we must come to terms with the science of thermodynamics.[3] Following the dialectical ideal of distilling philosophical principles from science in a critical manner, we develop the links between the science of thermodynamics and dialectics, focusing on the notion of negativity. We do not argue that entropy and negativity are identical but that they may inform each other; we demonstrate that a dialectical understanding of entropy and anti-entropy is able to accommodate the productive dimension of the former, a view which is suggested by Eric D. Schneider and Dorion Sagan.[4] However, before we proceed to explore the conceptual

1 Lucien Sève, "Dialectics of Emergence," in *Dialectics for the New Century*, ed. Bertell Ollman and Tony Smith (New York, NY: Palgrave Macmillan, 2008), 91, https://doi.org/10.1057/9780230583818.

2 Joel White, "Outline to an Architectonics of Thermodynamics: Life's Entropic Indeterminacy," in *Contingency and Plasticity in Everyday Technologies*, ed. Natasha Lushetich, Iain Campbell, and Dominic Smith (New York and London: Rowman & Littlefield, 2022), 184.

3 Hub Zwart, "Friedrich Engels and the Technoscientific Reproducibility of Life," *Science and Society : A Journal of Marxist Thought and Analysis* 84, no. 3 (2020): 369–400; Guido Seddone, *Hegel's Theory of Self-Conscious Life* (Leiden: Brill, 2022), https://doi.org/https://doi.org/10.1163/9789004527638.

4 We do not discuss the topic of the heat death of the universe, as it is not important for our discussion. For an exploration of this question in relation to dialectics, see Foster and Burkett "Classical Marxism and the Second Law of Thermodynamics: Marx/Engels, the Heat Death of the Universe Hypothesis, and the Origins of Ecological Economics," *Organization & Environment* 21, no. 1 (January 17, 2008): 3–37, https://doi.org/10.1177/1086026607313580.

and theoretical interweaving of entropy and negativity, we introduce Bernard Stiegler's appropriation of entropy, which is an account of thermodynamics couched in explicitly anti-dialectical terms.[5]

Stiegler's application of the concept of entropy to sociotechnical configurations is one of the most fruitful philosophical explorations of the implications of thermodynamics for living systems. Stiegler argues that "the *relation entropy/negentropy is really the question of life par excellence*,"[6] and his perspective of thermodynamics has informed an ecological critique of how the technical and the economic system have generated entropy at a global level, leading to environmental degradation which is now synonymous with the Anthropocene era. He introduces a technical and political *therapeia* of cultural transindividuation as a general organology of social, technical, and biological systems that produces anti-entropy or, in his words, "negentropic bifurcations."[7] Further, he applies terms such as the Anthropocene and the Entropocene interchangeably in contraposition with the term "Neganthropocene." While he sometimes speaks about negentropy, Stiegler prefers the more accurate term "anti-entropy" since entropy is a property of a system that is irreversible and thus the term negative entropy could signify a reversibility that is rejected within thermodynamics.[8]

Stiegler's appropriation of the concept of entropy draws heavily on the work of the economist Nicholas Georgescu-Roegen. The latter explores the implications of the Second Law of Thermodynamics for economics by emphasising how economic activity involves the transformation and utilisation of energy and matter from its surrounding environment, resulting in the production of waste and entropy.[9] His fundamental premise is that natural resources are finite, which indicates the unsustainability of economic models based on the idea of perpetual growth.[10] In this regard, Georgescu-Roegen can be seen as the founder of the field of ecological economics.

Strictly speaking, the Second Law predicts increase of entropy in isolated systems that are in thermodynamic equilibrium. But living organisms, social systems, and even the Earth (since it receives organized energy from the sun) are not isolated. These open systems are,

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5 Pieter Lemmens, "Love and Realism," *Foundations of Science* 22, no. 2 (2017): 307, https://doi.org/10.1007/s10699-015-9471-6.

6 Bernard Stiegler, "The Neganthropocene," trans. Daniel Ross (London, UK: Open Humanities Press, 2018), 39.

7 Stiegler, "The Neganthropocene," 51.

8 Stiegler, "The Neganthropocene," fn305, 416.

9 Nicholas Georgescu-Roegen, "The Entropy Law and the Economic Process in Retrospect," *Eastern Economic Journal* 12, no. 1 (1986): 3–25.

10 Nicholas Georgescu-Roegen, *The Entropy Law and the Economic Process* (Cambridge, MA: Harvard University Press, 1971).

however, subsystems of a larger and isolated system. Open systems retain their functioning and cohesion far from equilibrium by exporting entropy through transformations of energy and matter to the larger system which they belong to. As such, they reflect the environment they are coupled with.[11] (More on this in part 2.)

Building on Georgescu-Roegen's theory, Stiegler calls for a re-invention and re-configuration of technical systems and their social organisation to resist and defer at a local level the inevitable increase of entropy perpetuated by economic activity. Ours, according to Stiegler, is *The Age of Disruption*, an age where digital technologies have produced entropy not only in the concrete sense of environmental degradation but also on the psychosocial level impairing the faculties of the *spirit*, such as reason, attention and dreaming.[12] Stiegler's understanding of entropy and anti-entropy is not informed by dialectics but in opposition to it. He admits that Hegel was one of the first philosophers that posited the question of exteriorisation as a moment of Spirit, a process that is conceptually aligned to Stiegler's theory of technics as an *exosomatisation of noesis*.[13] In this view, our interiority is constituted in the process of its exteriorisation. Yet, Stiegler charges both Marxist and Hegelian versions of dialectics for being "metaphysical," of ignoring that the forces at play are inherently pharmacological (that is simultaneously curative and toxic), and indeed tragic.[14]

Stiegler does not explain in depth why the dialectical perspective is incompatible with a tragic view of life.[15] Instead, he accused Hegel of believing that the discrete elements of Spirit can be united under the "*grand synthesis of absolute knowledge*," a belief that Stiegler attributes to the fact that Hegel "was *completely unaware* of the *indissoluble* play of entropy and negentropy."[16] Although this fits his general disapproval to theories of technics that are dialectical, proposing instead the relationship between living organisms and technics as organological, Stiegler seems to misrepresent dialectical movement as leading to "a grand synthesis," ignoring the dialectical interplay between complexity and organisation

11 Georgescu-Roegen's view, often conceptualised and criticised as the "Entropy pessimist thesis" implies that economic activity inevitably increases the entropy of the planet. But his argument seems to stand up to scrutiny especially given that natural resources (especially fossil fuels) during the Anthropocene era are used in a faster rate than the rate that was required for them to be available.

12 Stiegler, *The Age of Disruption: Technology and Madness in Computational Capitalism*, trans. Daniel Ross, Reprinted (Cambridge, UK: Polity, 2019).

13 Stiegler, *The Age of Disruption*.

14 Elsewhere, Stiegler calls for a serious engagement with Hegelian dialectic and dialectical materialism - a project that for him entails a critique of dialectic and not its repetition. See Bernard Stiegler, *States of Shock: Stupidity and Knowledge in the Twenty-First Century*, trans. Daniel Ross (Cambridge, UK: Polity, 2015).

15 Stiegler, *The Age of Disruption*.

16 Stiegler, *The Age of Disruption*, 240, emphasis original.

as anti-entropic. In other words, Stiegler disapproves of a dialectical perspective because it allegedly assumes a state of equilibrium.[17]

A central objective of this article is to show that a Hegelian perspective on entropy is diametrically opposed to the version that Stiegler argues against. We aim to reveal how entropy and negativity might mutually shed light on each other, not to reduce one to the other. Further, we seek to show how different instances of negativity operate in nature, how it is both between organisms and within them, and how the lack of a clear distinction between inside and outside is another instance of negativity. We proceed in stages: In part 1, negativity as understood by Hegel is discussed and compared to the so-called organisational view. Part 2 elaborates on the topic of negativity in Hegel. Then, in part 3, we discuss entropy as understood by Schneider and Sagan in light of the previous parts. Next, we get more concrete about the notion of organisation, which is proposed here, before taking the discussion back to Stiegler by discussing the concept of habit in the conclusion. We do not pretend to be conclusive on any of the topics discussed; instead, we seek to develop some core similarities that should be developed further.

Part 1: Dialectics and Negativity

Dialectics is an inherently contradictory method because it has both a tendency towards systematisation and dissolution. It is simultaneously integrative and destructive; it strives to show how things are integrated, while revealing the fragility of any integrated totality.[18] The concurrent tendencies of organisation and dissolution are also reflected in the objects that dialectics studies—displayed *par excellence* by living organisms. But the tendency towards dissolution is not merely the opposite of the tendency towards integration. Instead, they are interdependent. You cannot build anything without destruction, while destruction needs positive material to work on.[19] We aim to show how this fundamental dialectical principle operates within the metabolic (or thermodynamic) relation between an organism and its environment, to shed light on the advantages of adopting a dialectical understanding of this interplay.

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17 One can also guess that there was a historical and political aspect in Stiegler's disapproval of Hegel's dialectics. In the *Neganthropocene* we read: 'I have argued for twelve years that capitalism is destroying the spirit. It is not just that the word spirit was used by thinkers who then inspired totalitarian practices – Hegel, whose dialectic became the dictatorship of the proletariat historically concretized as the Soviet Gulag' Stiegler, "The Neganthropocene," 68.

18 Zwart, "Friedrich Engels and the Technoscientific Reproducibility of Life."

19 Catherine Malabou, *The Future of Hegel: Plasticity, Temporality and Dialectic*, *The Future of Hegel: Plasticity, Temporality and Dialectic* (London and New York: Routledge, 2005), https://doi.org/10.4324/9780203489338.

Some of the biologists that acknowledged the importance of the metabolic relation between the organism and the environment employed an explicitly dialectical framework, as seen in the works of Richard Lewontin and Richard Levins.[20] Arguably, this view is also implicit in the organisational perspective on living systems,[21] discussed below. The common denominator for the notion that the organism is *both cause and consequence of itself* is Immanuel Kant's theory of teleological causality.[22] Hegel offers a crucial development of this theory, which is *realistic* because it does not regard this form of causality as merely regulative, but as a constitutive principle of the nature of living organisations.[23]

In Hegel's view, teleology is not just something we apply to understand living organisms; it is also constitutive for how we come to understand and orient in the world since we are also natural beings. Hence, he does not merely say that we must understand nature metabolically but that understanding itself is shaped by our metabolic relation, through practice—that mind and matter are shaped through each other.[24] Accordingly, teleology is more than heuristic; it is a fundamental prerequisite of knowledge.[25] We are not outside the circularity that we aim to disclose; we *become-together* with this process. But never in a simple or linear manner.

Based on this, it should not be controversial to align entropy and dialectics through the notion of negativity that animates the dialectical movement. This comparison also sheds light on a fundamental similarity between Hegel's philosophy and the organisational approach, which may challenge Stiegler's dismissal of dialectics. But we will get to this topic in due course.

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20 This could also be cast as an emphasis on metabolism and reproduction of organisation, against the opposing emphasis on replication and hereditary reproduction. While modern biology has largely focused on the replication of DNA templates, it has forgotten about the ongoing reproduction of the organism that enables replication in the first place. The metabolic relation is primary to replication Eric D. Schneider and Dorion Sagan, *Into the Cool: Energy Flow, Thermodynamics, and Life* (Chicago, IL: University of Chicago Press, 2005).

21 Andrea Gambarotto, "Teleology and Mechanism: A Dialectical Approach," *Synthese* 201, no. 5 (2023): 155, https://doi.org/10.1007/s11229-023-04137-y.

22 Immanuel Kant, *Critique of Judgement* (New York, NY: Macmillan, 1892).

23 Georg Wilhelm Friedrich Hegel, *The Science of Logic*, ed. George Di Giovanni (Cambridge, UK: Cambridge University Press, 2010).

24 But this does not mean that cognitive autonomy can be reduced to metabolic autonomy. Even if teleology and the ongoing metabolic relation that organisms have to their environments is constitutive of who they are, new levels emerge which are also constitutive of who they are, and we cannot understand their identity without understanding how multiple integrative levels interact, again, constitutively. Xabier E. Barandiaran, "Autonomy and Enactivism: Towards a Theory of Sensorimotor Autonomous Agency," *Topoi* 36, no. 3 (2017), https://doi.org/10.1007/s11245-016-9365-4.

25 Alison Stone, "Hegel, Naturalism and the Philosophy of Nature," *Hegel Bulletin* 34, no. 1 (2013): 59–78, https://doi.org/10.1017/hgl.2013.2.

In the organisational perspective—which emphasises the cyclical reproduction of the whole organisation of constraints that together enable the reproduction of living systems (called *closure of constraints*)—anti-entropy is the local increase of organisation at the expense of disorganisation in adjacent systems.[26] It is a process of complexification or differentiation which makes use of the global increase in entropy to produce local organisation. This echoes Hegel's concept of negativity as a process of differentiation, of moving from what is generic or abstract towards what it specific or concrete. The movement is displayed in the stages he depicts in his *Philosophy of Nature*, wherein the organic level emerges from its dialectical interaction with the chemical and physical level.[27] These other levels are not completely distinct, nor are they left behind once and for all. Instead, they are sublated, which involves the emergence of a new, living totality, which constrains the functioning of the physical and chemical parts and thereby exhibits self-determination.[28]

As we develop more below, anti-entropy, which is tied to biological organisation, means that one system organises at the expense of another. This is like the Hegelian notion that organisms must extract energy (i.e., negative entropy) from other organisms, which is a process of *assimilation*. A living organism must be energetically open to remain organisationally closed. It cannot be itself except through this relationship. This, Hegel argues, is the *ultimate contradiction*, that identity is only possible by being open to otherness:

> What Hegel is trying to show is that any kind of independence *depends* on otherness, even at this primitive stage where independence means (1) dependence on the other through the destructive assimilation of the other, and (2) the transgression of the very boundary of the self that is paradoxically perpetuated by this very transgression.[29]

A living organism is characterised by the capacity to sustain this contradiction, to maintain itself through the other. It is not only subject to lack but also able to feel and

26 Maël Montévil and Matteo Mossio, "Biological Organisation as Closure of Constraints," *Journal of Theoretical Biology* 372 (May 7, 2015): 179–91, https://doi.org/10.1016/j.jtbi.2015.02.029.

27 Georg Wilhelm Friedrich Hegel, *Philosophy of Nature: Part Two of the Encyclopaedia of the Philosophical Sciences*, trans. A. V. Miller, With Foreword by J. N. Findlay (Oxford, UK: Oxford University Press, 2004).

28 Luca Corti, "The 'Is' and the 'Ought' of the Animal Organism: Hegel's Account of Biological Normativity," *History and Philosophy of the Life Sciences* 44, no. 2 (2022): 1–22, https://doi.org/10.1007/s40656-022-00498-8.

29 Søren Rosendal, "The Logic of the 'Swamp World': Hegel with Kafka on the Contradiction of Freedom," in *Kafka and the Universal*, ed. Arthur Cools and Vivian Liska (Berlin and Boston: De Gruyter, 2016), 72–73, https://doi.org/doi:10.1515/9783110458114-004.

to act upon it, which is to say that the negativity of lack is constitutive of its activity and thereby shapes what it is.[30] Hence, it is both autonomous and dependent on the other. Here, negativity is both the other organism, and the process by which an organism maintains itself through this other. But negativity is not eradicated, as it persists as the process of negating concrete instances of negativity. In other words, positively given organisms are but a fragment of the process of negativity.

Part 2: Lack and Entropy

> The key to understanding the nature of entropy is in the word "lack," because entropy represents something that is rarely encountered in physics – an apophasis, or something that does not exist […]. The reader may wonder how it is possible to quantify something that does not exist, but it is done all the time in reference to something that does exist. For example, "The glass is half empty." quantifies how much fluid is missing in relation to the full capacity of the glass. There is a tendency for many to regard entropy as a positivist attribute, like the other variables of physics, and this misattribution is the source of much confusion about the actual nature of entropy.[31]

Entropy and lack are closely related. But how does that help us understand Hegelian negativity? The notion of entropy overlaps with the view that negativity enables something else to occur, i.e., that the lack in nature makes it plastic, opens a space for subjective intervention. This is encapsulated by Hegel's notion of the *impotence of nature*, of nature as weak in the sense that it cannot display its own logic in a faithful manner. Nature is, logically speaking, the sphere of necessity, but because it is also riddled with contingency, we cannot deduce its singular instances, only decipher its universal logic tentatively.[32]

30 "The tension the organism experiences to overcome it condition, to pass the limit, to satisfy its restlessness pushes it to engage with the outside world, and makes it what it really is" Luca Illetterati, "Nature, Subjectivity and Freedom: Moving from Hegel's Philosophy of Nature," in *"I That Is We, We That Is I." Perspectives on Contemporary Hegel: Social Ontology, Recognition, Naturalism, and the Critique of Kantian Constructivism*, ed. Italo Testa (Leiden: Brill, 2016), 197, https://doi.org/https://doi.org/10.1163/9789004322967_012.

31 Robert E Ulanowicz, "Socio-Ecological Networks: A Lens That Focuses Beyond Physics," *Frontiers in Ecology and Evolution*, 2021, 3, https://www.frontiersin.org/articles/10.3389/fevo.2021.643122.

32 A consequence of this idea is that our logical apparatuses fail to deduce the concrete instantiations of nature, undermining the notion that Hegel proposes a theory of everything, and that absolute knowing is about knowing everything. When Hegel says 'absolute' what he means is something that has no outside, as we shall see below. Dialectical reason cannot deduce the individual shapes of nature, but it can explain *why* this is impossible. Insofar as we can define idealism as the notion that our categories are able to grasp their concepts completely, Hegel's theory is not idealist, as he insists that

In other words, the concrete instances of nature cannot be derived from logical categories. According to Hegel, the contingency of nature imposes limitations on science and philosophy. This undercuts the claim that his notion of absolute *knowing* is about the culmination of knowledge.[33]

Because nature is weak in this way, it cannot resist our attempts at changing it. It is not only external to us but external to its own conceptual structure, unable to control its own development.[34] This converges on the view that you cannot deduce the properties of the living from the properties of the inert, even if the former must comply with the latter.[35] Had nature been strong, we would be determined rigidly by natural laws, as nature would be a sphere of complete determination. Thus, our subjectivity would be an epiphenomenon.

Similarly, had entropy been strong, something like organisation could not emerge from it. The universal tendency towards disorganisation would encompass entropy fully—nothing else could emerge from this process. The weakness of entropy, by contrast, is displayed by its contradictory nature, by the notion that it enables anti-entropy to emerge from within.[36] Hence, entropy opens the space for something else. As Ulanowicz writes: "entropy cannot cause events in the same way that positivist forms and forces do. Rather, absence *affords opportunity* for positivist tendencies to act. It functions as a secular form of kenosis."[37]

Hegel argues that negativity is not a *thing* but a process of differentiation. It therefore has different vicissitudes. Hegel begins with the abstract definition of negativity as pure absence, the lack that Ulanowicz speaks of in the epigraph.[38] This conception of negativity places it outside what we can comprehend, and therefore misses its positive dimension. Negativity, in the abstract version, is Kant's *thing in itself*, outside possible experience, pure nothingness. But from this abstract beginning, Hegel finds that negativity is the motor of dialectics, and depicts dialectics as the process by which the abstract beginning is sublated and concretised.

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there is always a remainder, that nature is too weak to embody concepts in a faithful manner. Concepts are therefore only approximations – involved with and shaped by what they describe.

33 Malabou, *The Future of Hegel: Plasticity, Temporality and Dialectic*.

34 Luca Illetterati, "Nature's Externality: Hegel's Non-Naturalistic Naturalism," ed. Mladen Dolar, *Problemi* 58, no. 11–12 (2020): 51–72.

35 Giuseppe Longo and Maël Montévil, "From Physics to Biology by Extending Criticality and Symmetry Breakings: An Update," *Acta Europeana Systemica* 9 (2020), https://doi.org/10.14428/aes.v9i1.56043.

36 Marie Chollat-Namy, Giuseppe Longo, "Entropie, Neguentropie et Anti-entropie : le jeu des tensions pour penser le vivant," *ISTE OpenScience*, vol. 4 (2022), 10.21494/ISTE.OP.2023.0983

37 Ulanowicz, "Socio-Ecological Networks: A Lens That Focuses Beyond Physics," 4.

38 Hegel, *The Science of Logic*.

If one conflates negativity and nothingness, one overlooks the positive dimension of negativity, the activity of negating concrete forms, and relating to these forms again. Hence, we need to understand the concrete forms of *absolute negativity*, which has no outside because it is absolute. In other words, abstract nothingness cannot stably exist, and yet there is always a remainder of nothingness in the concrete forms of negativity, in the sense that there is something that is not yet actualised. It is the abstract possibility of breakdown inherent in each transient form. This is how the beginning reverberates in its products.

For our purposes, what is most important is the notion that there is no positively given ground. Each step forward is a further determination of the beginning. Negativity is therefore an activity that constantly returns to itself, through the process of actualisation that it enables. It is a principle of movement. Hegel writes that the negative:

> belongs to the content itself and is the *positive*, both as its *immanent* movement and determination and as the *totality* of these. Taken as a result, it is the *determinate* negative which emerges out of this movement and is likewise thereby a positive content.[39]

The fact that negativity is absolute and self-referential means that individuation has no outside, that the process of actualisation produces its potential retroactively. It makes use of the lack of a stable ground to produce this ground progressively. The abstract beginning is negated or sublated and thereby made concrete.[40] Hegel underscores that:

> The view that the void constitutes the ground of movement contains the more profound thought that the ground of becoming, of unrest and self-movement, lies in the negative in general, which, in this sense, is however to be taken as the true negativity of the infinite. – The void is the *ground of movement* only as the *negative* reference of the one to its *negative*, to the one, that is, to its own self posited, however, as determinate existent. [41]

The void, or lack, is only a ground *through* its products. Every determination is therefore a confirmation and a negation of this abstract ground which opens the space for intervention.

39 Georg Wilhelm Friedrich Hegel, *The Phenomenology of Spirit* (Cambridge, UK: Cambridge University Press, 2018), 37 emphases original.

40 As one of the anonymous reviewers pointed out, this is reminiscent of the notion of "default of origin" that we find in Stiegler's works. For lack of space, we cannot develop this further here, but the reader can consult Bernard Stiegler, *Technics and Time, 1: The Fault of Epimetheus*, trans. Richard Beardsworth and George Collins (Stanford, CA: Stanford University Press, 1998), 114.

41 Hegel, *The Science of Logic*, 135.

At the level of life, this opening is exploited when the organism resists determination from without—when it negates and sublates chemical and physical processes to enable its further existence. To be sure, this does not imply that physical or chemical processes are nullified, only that they operate differently within a living system. A living being is a subject because it self-determines, because it reproduces its own organisation cyclically.[42] The organism, as a self-referential whole, therefore instantiates what Hegel refers to as "true infinity," which is not the numerical infinity that extends towards some hidden goal but ever reaches it. Instead, infinity is about reflexive determination, self-related negativity. It is the infinity of the cycle that maintains organisation—that extends into its surroundings and integrates it into its own functioning. In a word, it is the infinity of life.

At this stage, negation manifests as the lack or deficiency that an organism feels, and which makes it necessary for it to assimilate its environment. We should understand this assimilation in a broad sense—not just about material processes but also with the affordances that the organism is able to detect. This contradiction is formative and is reminiscent of what Merleau-Ponty (influenced by Hegel's works) spoke of as *disequilibrium*. The organism constantly strives to eliminate this disequilibrium but cannot achieve this feat without undermining its own existence. The experienced disequilibrium initiates movement and is only overcome when the organism dies.

Due to this contradiction, organisms are never able to establish an *optimal grip* on their situation, never able to master their environment fully.[43] This lack is simultaneously the condition of possibility for meaningful interaction. It is what Hegel considered the problem of nature—how it can never be fully internalised by the organism, while also enabling its existence.[44] It points to the absolute contradiction—that the organism remains self-identical only through its constitutive relationship with the outside world, how identity is conserved through transformation. Arguably, this is also the view that we find in the notion of anti-entropy, to which we now turn.

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42 Giuseppe Longo and Maël Montévil, *Perspectives on Organisms: Biological Time, Symmetries and Singularities* (Berlin and Heidelberg: Springer, 2014), https://doi.org/10.1007/978-3-642-35938-5.

43 Barbara Stiegler detects a similar idea in Nietzsche's writings which for her amounts to an early critique of adaptationism. See Barbara Stiegler, "1880: First Philosophical Critique of Adaptationism Nietzsche, Reader of Herbert Spencer," in *Naturalism and Social Philosophy: Contemporary Perspectives*, ed. Martin Hartmann and Arvi Särkelä, Essex Studies in Contemporary Critical Theory (Lanham: Rowman & Littlefield, 2023), 65–79. We thank one of the anonymous reviewers for making us aware of this work.

44 Wes Furlotte, *The Problem of Nature in Hegel's Final System* (Edinburgh: Edinburgh University Press, 2018), https://doi.org/10.3366/edinburgh/9781474435536.001.0001.

Part 3: Entropy and Anti-entropy

> [N]ot only does the organization of the new whole not derive from the old one, but the disorganization of the latter is a prerequisite for its reorganization on a new basis. Isn't it this essentially dialectical logic that assumes such spectacular forms in such non-linear phenomena as chaos, bifurcation and auto-organization?[45]

Schneider and Sagan introduce the notion that nature "abhors a gradient"—and therefore seeks to collapse them—to demystify what entropy is about.[46] Less a generic tendency towards disorder, they understand entropy more as a process that generates complex natural forms. This is also what Sève is getting at in the above quotation. New organisations may only arise against the background of disorganisation. When organisms act based on the feeling of lack, they *embody the second law*, as they strive to collapse the gradient that affects them. They extend outwards due to the feeling of lack, which is another expression of negativity.

This indicates the usefulness of comparing negativity to entropy. Just as anti-entropy is not the opposite of entropy, so positivity is not the opposite of negativity, but a manifestation of the process of negation of concrete forms. As such, negativity relates to and responds to itself through the other. The same goes for entropy, since the entropy that the organism faces in its environment is partly produced by itself. Although Schrödinger posited that living organisms "maintain their internal organization at the expense of larger increases in randomness outside their bodies,"[47] we could say that in creating an ecological niche they increase the organisation of their environment. However, in doing so they use energy leading to the generation of entropy.

Likewise, Schneider and Sagan emphasise the enabling role of entropy. We could say that it produces the impetus for action that is expressed as a feeling of lack at the level of life, but it also speaks to principles that are shared by all systems shaped through gradients, living or not. (Of course, we are not saying that inert entities experience entropy although they are affected by it.) The dialectical notion of entropy affords a scientifically informed process ontology of differentiation of levels, of individuation without a positively given ground—and explain anti-entropic behaviour as a kind of alienation or externalisation, where the organism gets its own message in return, but never in a manner that it may predict. This allows us to understand entropy as a process of differentiation (negation), of co-evolution. In this view, anti-entropy is the concrete negation of entropy, disrupting

45 Sève, "Dialectics of Emergence," 94.

46 Schneider and Sagan, *Into the Cool: Energy Flow, Thermodynamics, and Life*.

47 Erwin Schrödinger, *What Is Life? The Physical Aspect of the Living Cell* (Cambridge, UK: Cambridge University Press, 1944), 17, https://doi.org/LK - https://worldcat.org/title/499840714.

and making use of it to its own ends.

Schneider and Sagan ask how organisms can survive and maintain the organisation given the tendency towards disorder prescribed by the second law: "organisms are organized to resist thermodynamic equilibrium."[48] Organisms produce entropy in the supra-individual systems they belong to in the degraded products that they transport to their surroundings.[49] This paradox is solved in a manner that we could call "dialectical":

> The basic answer to the paradox has to do with context and hierarchy. Material and energy are transferred from one hierarchical level to another. To understand the growth of natural complex systems such as life, we have to look at what they are part of—the energy and environment around them. In the case of ecosystems and the biosphere, increasing organization and evolution on Earth requires disorganization and degradation elsewhere. You don't get something from nothing.[50]

Life displays increased complexity over time, even if matter tends towards randomised distribution. It therefore seems to overcome entropy. But as Schneider and Sagan remark: "Not only is life not removed from the thermodynamic imperative of the second law, but it is also its most impressive and awe-inspiring manifestation."[51] Like negativity, then, the tendency towards destruction gives rise to determinate negations, while at the same time threatening all such positive phenomena. We thus get a sense of why the negative is equally positive. Negativity is a process that manifests itself in positively given phenomena, like the life cycle that maintains the organism.

The dialectical coincidence of opposites is evident at the level of life, where the organism is constituted by its continual dialogue with its environment. According to Schneider and Sagan, all open systems, i.e., systems that exchange matter and energy with their outside, are able to defy the second law by accelerating the "reaching of equilibrium in the areas *around* them."[52] By internal organisation, gradients around livings systems are eliminated. But such systems reproduce themselves cyclically not only by eliminating gradients but also by producing them—increasing the entropy of the larger system in which they are

48 Schneider and Sagan, *Into the Cool: Energy Flow, Thermodynamics, and Life*, 16.

49 In other word, the quality of the energy changes, as it is made use of. It is no longer free energy, i.e., energy that can perform physical work (even if this does not mean that it cannot in principle become useful again). In accordance with the second law, the sheer quantity of energy does not change, only the quality.

50 Schneider and Sagan, *Into the Cool: Energy Flow, Thermodynamics, and Life*, 15–16.

51 Schneider and Sagan, *Into the Cool: Energy Flow, Thermodynamics, and Life*, 71.

52 Schneider and Sagan, *Into the Cool: Energy Flow, Thermodynamics, and Life*, 71.

embedded. Waste is always the biproduct of reproductive cycles; systems export entropy from the inside to the outside to endure through time.[53]

Thus, we could understand the notion that the organism responds to something that it is partly responsible for producing, and thus to the products of its own activity—a response to gradients that it has modified itself.[54] As Ulanowicz writes: "Taken as a unit, the autocatalytic cycle is not simply reacting to its environment; it also actively creates its own domain of influence."[55] This indicates how thermodynamics can contribute to a more ecological science.[56]

Part 4: The Organisation of Chance

> Schrödinger sought new concepts to reconcile thermodynamic theory with biological fact. At first glance, he noted, living systems seem to flout the second law of thermodynamics. Energy and material in enclosed systems will become randomly distributed over time. Living systems, however, are the veritable opposite of such disorder. Living in an environment tending toward disorder, they increase their order. And order is not the best word. A better word for organisms is organization—organisms are organized to do something—to live, to reproduce, to keep on going as they are. Said otherwise, organisms are organized to resist thermodynamic equilibrium.[57]

Entropy is the tendency towards disorganisation, while anti-entropy is a tendency towards organisation. As Schwartzman puts it: "On a cosmological scale, the increase in entropy in the universe is inevitable, as expressed in the second law, but this very increase is the necessary requirement for the emergence and maintenance of self-organised systems. The

53 White, "Outline to an Architectonics of Thermodynamics: Life's Entropic Indeterminacy."

54 The touches on the concept of niche construction, which is also an example of how the organism externalises itself by being impelled outward (see Odling-Smee, Laland, and Feldman 2003; Sultan 2015; Uller and Helanterä 2019). We cannot expand on this here, but it operates in the background.

55 Robert E. Ulanowicz, "Beyond the Material and the Mechanical: Occam's Razor Is a Double-Edged Blade," *Zygon®* 30, no. 2 (1995): 256, https://doi.org/10.1111/j.1467-9744.1995.tb00068.x.

56 The notion of self-organisation is therefore misleading. Nothing *self*-organises apart from its environment. See Schneider and Sagan, *Into the Cool: Energy Flow, Thermodynamics, and Life*, 85. Rather, the self, the organism, is the product of a process of gradient-organisation. The environment is therefore internally related to the constitution and functioning of a living organism. This critique extends to the notion of autopoiesis, but this topic lies outside the scope of this article but confer Di Paolo "The Enactive Conception of Life," in *The Oxford Handbook of 4E Cognition*, ed. Albert Newen, Loen De Bruin, and Shaun Gallagher (Oxford, UK, 2018), 71–94.

57 Schneider and Sagan, *Into the Cool: Energy Flow, Thermodynamics, and Life*, 16.

debt of self-organising systems to "chaos" is the environmental increase in entropy."[58] But the closure of living systems is never complete. Had it been, the organism would no longer be precarious and therefore also lack dynamicity. The precarious status of the organism impels its continuous anti-entropic activity. Entropy is therefore both a source of disorganisation and organisation. It allows us to grasp what Merleau-Ponty spoke of as the simultaneous relative equilibrium and disequilibrium.[59] The disequilibrium is the lack that spurs the organism to act and what provides its environment with normative value. But this is perceptible only at the level of life, which is where anti-entropic activity occurs. We see, then, how the concretisation of entropy in the specific sphere of living systems sheds light on the nature of entropy, which is only described in generic terms within physics.

We should, however, not confuse low entropy with organisation. As Mäel Montévil explains: "Everything that contributes to the low entropy of biological situations is not relevant for their organizations. For example, a cancerous tumour increases morphological complexity but decreases organization."[60] To get at the difference between low entropy and anti-entropy, the notion of *closure of constraints* is crucial.[61] It denotes the cyclical determination of a biological organisation, where the whole and the part are reciprocally determined. The different constraints, which are local boundary conditions on processes, become organised in a manner where they regenerate the whole system through their interdependence. This is the definition of closure which is specific to living systems. Organisation or anti-entropy is the specific canalisation of entropy, making it useful for the organism while also producing entropy.

From the differentiated structure of constraints emerges a dynamic totality, the organism, which integrates all the constrains into its functioning. This cyclical determination is a form of *self-determination*, as the organism is able to maintain itself through its own activity. It achieves organisational autonomy, while remaining energetically and materially dependent on its surroundings. The simultaneous openness and closure enable it to maintain its identity amid constant change—the absolute contradiction we spoke of above.

58 David Schwartzman, "The Limits to Entropy: Continuing Misuse of Thermodynamics in Environmental and Marxist Theory," *Science and Society* 72, no. 1 (2008): 51–52, https://doi.org/10.1521/siso.2007.72.1.43.

59 Rietveld, Denys, and Van Westen, "Ecological-Enactive Cognition as Engaging with a Field of Relevant Affordances: The Skilled Intentionality Framework (SIF)."

60 Maël Montévil, "Entropies and the Anthropocene Crisis," *AI and Society*, 2021, no pagination, https://doi.org/10.1007/s00146-021-01221-0.

61 Montévil and Mossio, "Biological Organisation as Closure of Constraints."

Beside the organisational closure specific to organisms, we should also highlight its historicity—how its interaction with the environment is integrated into its functioning. Montévil summarises:

> In a nutshell, we propose to consider that an element relevant for anti-entropy satisfies three criteria. i) It contributes to organization *sensu* closure of constraints; informally, it has a systemic role in an organism's persistence. ii) It is the specific result of history. iii) The specific properties in (ii) are the condition for the systemic role in (i).[62]

From this, Montévil draws the conclusion that anti-entropy must be gauged in relation to organisation, and that one biological organisation might undermine another, by reducing its anti-entropy.

Organisation is a synonym for life.[63] Hegel defines life as a chemical process which is able to sustain itself over time, becoming a metabolism.[64] As we have seen, it must move outwards to achieve this. As such, life is characterised by the cyclical organisation of chemical processes, whereby the whole system integrates and self-reproduces thorough the other. Compare this to a thermodynamic definition: "Living systems are metastable processes that maintain their identity."[65] A process able to maintain its identity is a process that organises its material components into an integrated totality, where each part depends on the whole system and vice versa.

The term *negative entropy* obfuscates how we should understand negativity in relation to entropy. The term anti-entropy is more useful, as it encompasses the dialectic between entropy production and the production of organisation. Entropy, in this view, does not only undermine any stable organisation but enables it in the first place. It is the lack of determination that makes something like a living organisation possible. Bailly and Longo point to Schrödinger's definition:

> His idea is that what counts for a living organism is its organization and that the problem which poses itself is not only its establishment ("the formation of order based on disorder"), but also its maintenance ("order based on order"). He emphasizes the importance, still unclear today, of the acquisition of organization as *negative entropy*, including by means of food. This acquisition will participate to the ongoing tension between the increase of entropy, specific to any irreversible

62 Montévil, "Entropies and the Anthropocene Crisis," no pagination.

63 Schneider and Sagan, *Into the Cool: Energy Flow, Thermodynamics, and Life*.

64 Zwart, "Friedrich Engels and the Technoscientific Reproducibility of Life."

65 Schneider and Sagan, *Into the Cool: Energy Flow, Thermodynamics, and Life*, 86.

> thermodynamic process and generating disorder, and the maintenance of order.[66]

Here, we see the contradiction or disequilibrium inherent in the relation between a living system and its surroundings. We also get at the notion that the canalisation of entropy also generates entropy which can be used at a later stage. At a global level there is always an increase in entropy. Living organisation counteract this tendency locally but cannot stop the global trend towards increased entropy. When a living system reproduces its organisation, it also produces entropy and disorganisation.[67]

Why is this important? For starters, it shows that anti-entropy is not merely the inverse of entropy but itself contributes to its production. Local anti-entropy makes use of available energy (exergy) but also releases entropy into the surroundings.[68] The exergy is therefore dependent on the historical couplings between the organism and its environment.[69] This circumstance hints at why self-determination includes the environment in which the organism is situated. Importantly, the production of entropy is therefore a source of variability, and thus potentially useful for the organism in situations that require it to adapt. It is the imperfect reiteration of the reproduction of the whole organisation that produces this entropy:

> biological reproduction, as morphogenesis, is *intrinsically associated to variability* and, thus, *it produces entropy also by lack of (perfect) symmetries*. By this, it induces *its proper irreversibility*, beyond (and in addition to) thermodynamic irreversibility.[70]

In physical systems, *symmetries* are invariant structures that only change rarely, that is, at specific critical thresholds. An example is the phase change when water goes from a liquid to a frozen or gaseous state. It has a clear limit at which the change occurs, and it happens in a predictable manner. Biological systems, on the other hand, are characterised

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66 Francis Bailly and Giuseppe Longo, "Biological Organisation and Anti-Entropy," *Journal of Biological Systems* 17, no. 01 (March 1, 2009): 65, https://doi.org/10.1142/S0218339009002715.

67 Longo and Montévil, *Perspectives on Organisms.* Strictly speaking, the organisation of living system does not stem from negative entropy but from available energy, *exergy*, the quantity of usable energy that organisms can put to work. But the amount of exergy available is not given. Instead, it is the product of the interaction between the organism and environment. See Schneider and Sagan, *Into the Cool: Energy Flow, Thermodynamics, and Life*.

68 Montévil, "Entropies and the Anthropocene Crisis."

69 "Couplings are far more proteiform in biology than in the standard framework of thermodynamic. In artifacts and industrial processes, let us recall that the thermodynamic couplings correspond to the processes' purpose to generate usable work. In biology, couplings' plasticity corresponds to the variability of biological functions that is intrinsic to the historical changes of biological objects." Montévil, "Entropies and the Anthropocene Crisis", no pagination.

70 Longo and Montévil, *Perspectives on Organisms: Biological Time, Symmetries and Singularities*, 218.

by inherent instability and historicity. They undergo symmetry breaks continuously to stay alive. Thus, the situation is reversed compared to physics. Variance comes before invariance, and what is invariant is a product of history. This formalises Hegel's notion that biological systems only conserve their identity through constant change. They embody negativity through their ability to sustain this contradiction. Thus, we see how the notion of anti-entropy is inherently dialectical.

Part 5: The Dialectics of Habits

Entropy is contradictory since it spurs the process of complexification forward, while at the same time undermining this process. Similarly, negativity is initially generic but develops into increasingly complex determinate negations. Should we not say that anti-entropy is to entropy what determinate negations is to negativity, that we speak about something abstract, a lack, which is instantiated in positive shapes but never stabilised because it is not a thing, but a process? In this view, we get a clearer sense of the dual nature of entropy; we also arrive at a notion of interaction as a concretisation of entropy.

We saw that negation of the abstract beginning produces determinate negations, but that these never sublate the abstract negativity. Another way to say this is to underscore how anti-entropy or organisation does not cancel entropy but canalises it, and thereby produces its own free energy or negativity. The reason we can call this entropy production "negativity" is because it is not positively given as a thing. It is only found in the individuation of living beings, as their inherent lack. One evident overlap between negativity and anti-entropy, then, is that neither is about cancellation but about canalisation. We could say that anti-entropy is entropy in the form of its other—itself in a fragmented form, in concrete identities that cannot be predicted from the law of entropy itself.

In this sense, when we view negativity and entropy as ongoing process of negation of determinate forms of organisation, the mutual benefit of comparison is evident. We get a clearer sense of the processual nature of entropy, and its dialectics with anti-entropy, and we can make negativity more scientifically intelligible. In a way, we get a sense of how we can understand Hegel's concepts more fully by updating them in light of scientific studies. This is related to the notion that logic cannot deduce the concrete instances of nature, and therefore needs to rely on natural science to disclose these instances. In the case of entropy, Hegel was on to something that was not yet discovered scientifically. He saw that development and evolution works through simultaneous synthesis and separation, that any complex system must be stable *and* fragile to develop. Hence, it is not enough to say that entropy is lack. Like negativity, entropy is lack but also the ongoing response to this lack, the negation of this lack in the form of anti-entropy.

Discussing the role of negativity in the interplay of entropy and anti-entropy which influences the behaviour and development of organisms, leads us to Hegel's concept of habit (*die Gewohnheit*) in understanding how living organisms reduce their own entropy yet increase the entropy of the wider system to which they belong. Habits, as behavioural predispositions towards the repetition of an action, are not easily classifiable as entropic or anti-entropic properties of the mind.[71] Apart from the normative conception of habits as "good" or "bad," the concept has an intrinsic relevance to questions about energy-efficient ways of dealing with the world. From one point of view, habits are anti-entropic in maximising the work that can be done with available cognitive resources, preventing the increase of entropy required by learning to execute a novel action. On the other hand, habitual behaviour is prone to error; prevents the exploration of more energy-efficient habits and can impede an increase in complexity which as we have seen is the fundamental process of how organisms resist entropy. Habits provide a mechanism to produce order that resists disorder, yet they might cause disorder indirectly through the generalised decrease of complexity. When habits are no longer aligned with the goals and the continuity of the living system, more energy might be required to transform or replace existing ones. This is particularly true when a habit become an addiction.

Hegel discusses the difficult and often-misunderstood nature of habit when he writes: "Habit is often spoken of disparagingly and taken to be a lifeless, contingent and particular thing." Yet, for him "habit is the most essential feature of the existence of all mental life in the individual subject."[72] The importance of habit lies in the fact that it mediates the contradictory processes of self-determination and world-determination.[73] Through habit the soul acquires its skills, abilities and predispositions which creates an inextricable connection between habit formation and ethical life.[74] For Hegel, habit has an all-encompassing character: "The form of habit includes all kinds and stages of spiritual activity. [...] Similarly seeing, and so on, is the concrete habit which immediately unites in one simple act the many determinations of sensation, consciousness, intuition, intellect, etc."[75] Being a "mechanism of self-feeling" and a "second nature posited by soul,"[76] habit

71 Kevin Maréchal, "An Evolutionary Perspective on the Economics of Energy Consumption: The Crucial Role of Habits," *Journal of Economic Issues* 43, no. 1 (March 1, 2009): 69–88, https://doi.org/10.2753/JEI0021-3624430104.

72 Georg Wilhelm Friedrich Hegel, *Philosophy of Mind*, trans. A.V. Miller and W. Wallace (New York, NY: Oxford University Press, 2007), 133.

73 Xabier E. Barandiaran and Ezequiel A. Di Paolo, "A Genealogical Map of the Concept of Habit," *Frontiers in Human Neuroscience*, 2014, 6, https://doi.org/10.3389/fnhum.2014.00522.

74 Elisa Magrì, "The Place of Habit in Hegel's Psychology," in *Hegel's Philosophical Psychology* (London and New York: Routledge, 2016).

75 Hegel, *Philosophy of Mind*, 132.

76 Hegel, *Philosophy of Mind*.

allows the individual to reach a level of self-determination which Hegel associates with freedom. Yet, habit can also enslave the individual. Hegel's theorisation of habit is fundamentally ambiguous: On the one hand, habit is about deadening and ritualisation; on the other, it is the precondition for any exercise of freedom, the historical basis upon which creative activities may appear.

This perspective reminds us of Stiegler's concept of the *pharmakon* which, following Plato's suspicion towards writing in his *Phaedrus* and Derrida's uptake of this idea, allows him to conceptualise technical artefacts as both curative and toxic.[77] Habits, being inherently pharmacological in their simultaneously creative and entropic properties, constitute technologies of freedom which organisms use to transform themselves and their environments. However, as all technologies, habits can regress to automatisms leading to a decrease rather than an increase in functionality. While Stiegler understood the ambiguity of these phenomena, he ascribed to them a non-dialectical promise of *composition*, failing to follow through his own understanding of the dynamics between entropy and anti-entropy. The contradictory processes of habit formation provide a promising avenue for exploring the relevance of the Second Law and dialectics in how organisms shape themselves and their world.

77 Plato, *Phaedrus*, trans. Harvey Yunis (Cambridge, UK: Cambridge University Press, 2011); Jacques Derrida, *Dissemination*, trans. Barbara Johnson (Chicago, IL: University of Chicago Press, 2017).

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The Thermodynamics of Life as a Speculative Model for Planetary Technology

Cristian Hernandez-Blick

Abstract

Originating from nineteenth century physics, the concept of entropy—a measure of disorder, randomness, and/or the dissipation of useful energy—underlay a cosmology where order and complexity were seen as highly improbable phenomena in a universe tending toward chaos and disorganisation. Nearly a century later, theoretical frameworks were developed for understanding the production of entropy as an enabling feature of self-organized complexity in the natural world. These ideas would contribute to establishing connections between the origins, development, and evolution of life and the principles of a thermodynamic universe. For some, they also supplied the conceptual foundations for theorizing about a universal natural tendency driving the development of increasingly complex and ordered systems which amplify processes of entropy production and energy dissipation and dispersal. In this paper I chart a path through the aforementioned ideas and present their relevance in framing a relationship between our technological civilization and the Earth system. I then speculate about the prospect of a technosphere whose constitution and activity are aligned with thermodynamic principles of dissipation and entropy-production, drawing on theoretical biology and recent developments in bioengineering to envision a paradigm where technology becomes living matter itself.

Keywords: Dissipative systems, entropy, thermodynamics, biology, self-organization, living technology.

 Corresponding author: Cristian Hernandez-Blick, hernandez.cristian@proton.me

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Biology in the Context of Cosmological Entropy

The concept of entropy originates from nineteenth century thermodynamics and is meant to describe a measure of disorder, randomness, and/or the dissipation of useful energy in a system. It's often associated with the general idea that natural processes tend to move toward more disorderly states over time. A few simple examples will serve to illustrate this concept. Consider a drop of ink inside a glass of water. Initially, the molecules which make up the ink are concentrated in a small area. However, as time passes, they disperse and spread throughout the molecules of water, leading to a more disordered and random distribution. Eventually, the molecules will become uniformly distributed within the glass, mixing completely with the water and reaching a highly entropic state of thermodynamic equilibrium. Another example is observed when you place a warm object, such as a cup of hot tea, inside a room with a lower temperature. Over time, the temperature differential between the cup and the room will become equalized as heat, or thermal energy, from the tea transfers to the surrounding molecules in the air of the room. Similar to the dissipation of ink in water, the temperature of the tea and the room together will eventually reach an equilibrium where the entropy of the whole system has increased, and heat has been evenly distributed over the total space.

The latter example of heat flow in a system was precisely what physicist and mechanical engineer Sadi Carnot discovered through his analysis of the efficiency of steam engines[1]: i.e., that heat always moves down a gradient from hotter to cooler states. This basic insight would later become the basis for the second law of thermodynamics. The transformation of thermal energy into mechanical energy—as in the case of a temperature differential powering a steam engine—also, perhaps unsurprisingly, involves the dissipation of useful energy into the environment in the form of heat, becoming spread out into the surroundings and therefore incapable of performing work once more.

In the mid 1800s, Carnot's idea would be refined by Lord Kelvin (William Thomson) and Rudolf Clausius[2], two seminal physicists who were instrumental in unifying the emerging field and providing formal clarity and rigour to the notion of entropy as well as the first two laws of thermodynamics. Together, these two laws described a universal tendency toward the dissipation of mechanical energy in a cosmos where the total amount of energy is fixed and conserved, while entropy referred to a measure of the energy in a system which is no longer available for work. Physicist Ludwig Boltzmann supplemented these ideas with a statistical interpretation of the second law which defined the tendency for

1 Sadi Carnot, Rudolf Clausius, and William Thomson Baron Kelvin, *The Second Law of Thermodynamics: Memoirs by Carnot, Clausius, and Thomson* (New York: Harper & Brothers, 1899).

2 Carnot, Clausius, and Kelvin, *The Second Law of Thermodynamics: Memoirs by Carnot, Clausius, and Thomson.*

orderly components of a system—particularly molecules in a container—to spread out toward more probable arrangements, or dispersed and disorderly configurations, until they approach a state of elevated entropy and thermodynamic equilibrium. It follows, therefore, that the spontaneous generation of orderly configurations from disordered states was considered by Boltzmann to be infinitely improbable.[3] These ideas played a significant role in shaping a cosmological model where living systems were thought to be anomalous, improbable, and contingent accidents in a universe running down toward a "heat death,"[4] with all its parts drifting toward increased disorder and degradation.[5]

However, unlike purely physical, non-living processes, biological systems seem to strike a peculiar balance between the second law of thermodynamics and the ability to generate, maintain, and propagate complexity and order. This kind of activity appears at odds with the above description of the nature of physical reality: if the state of the universe is thought to be lurching toward an increase in cosmic disorder—as the second law of thermodynamics is often interpreted—why then do we observe an abundance and increasing development of structure, order, organization, and complexity within our planet's biosphere?

During the last century, the notion of living systems as thermodynamically open systems operating in far from equilibrium conditions has emerged as a compelling theoretical framework to clarify this enigmatic property of biology and reconcile it with the laws of

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3 Ludwig Boltzmann, "The Second Law of Thermodynamics," in *Theoretical Physics and Philosophical Problems: Selected Writings*, ed. Brian McGuinness, Vienna Circle Collection (Dordrecht: Springer Netherlands, 1974), 13–32, https://doi.org/10.1007/978-94-010-2091-6_2.

4 Boltzmann uses the term "thermal death" in his 1886 essay *The Second Law of Thermodynamics*, while others like physicist Hermann Von Helmholtz, in his 1854 lecture *On the Interaction of Natural Forces*, referred to Lord Kelvin's work in identifying the conditions for a universe threatened with "eternal death" or "condemned to a state of eternal rest." Hermann von Helmholtz, *Science and Culture: Popular and Philosophical Essays*, ed. David Cahan (University of Chicago Press, 1995). The impact these ideas had on intellectual culture may have been existentially profound. For instance, in correspondence with physicist John Tyndall, philosopher and scientist Herbert Spencer wrote "your assertion that when equilibrium was reached life must cease, staggered me. Indeed, not seeing my way out of the conclusion, I remember being out of spirits for some days afterwards." David Duncan, *Life and Letters of Herbet Spencer* (New York: Appleton and Company, 1908). Charles Darwin himself wrote of the "intolerable thought that … all sentient beings are doomed to complete annihilation." Charles Darwin and Nora Darwin Barlow, *The Autobiography of Charles Darwin, 1809-1882* (London: Collins, 1958). Scholarship has also shown the effects of nineteenth century thermodynamics on philosophical discussion concerning time, cosmology, and ethics among thinkers such as Eugen Dühring, Friedrich Engels, Eduard von Hartmann, and especially Friedrich Nietzsche. Joel White, "How Does One Cosmotheoretically Respond to the Heat Death of the Universe?," *Open Philosophy* 6, no. 1 (January 1, 2023), https://doi.org/10.1515/opphil-2022-0233.

5 William Thomson Baron Kelvin, "On the Age of the Sun's Heat," in *Popular Lectures and Addresses: Constitution of Matter*, vol. 1, 3 vols., Nature Series (London: Macmillan and Company, 1889).

thermodynamics.[6] In this view, living systems engage in a dynamic interplay with their environment, selectively exchanging matter and energy with their surroundings in order to generate the work required to produce and maintain a self-organized state of organic individuation and local entropy minimization. Put plainly, biological systems transform external resources into internal order.

The process of localized entropy reduction embodied by self-organized living systems is non-contradictory with respect to the physical laws it appears to evade, since the flows of matter and energy underpinning organic form necessitate the exogenous displacement of entropy from the living process in the form of waste and heat. This consequently produces a global net increase of entropy within the surroundings of a given biological system. In his pioneering work, *What Is Life?* physicist Erwin Schrödinger offered one of the earliest articulations of this general idea. In Schrödinger's words, what a biological system "feeds upon is negative entropy. Or, to put it less paradoxically, the essential thing in metabolism is that the organism succeeds in freeing itself from all the entropy it cannot help producing while alive."[7]

In Schrödinger's writing, these intuitions about the generation and stabilization of order in living systems aren't supported by much empirical knowledge and are expressed primarily through statistical equations and speculations about the organism "feeding" upon negative entropy or "sucking orderliness from its environment."[8] Schrödinger would ultimately connect these ideas to the unique molecular arrangements of "aperiodic solids" with hereditary properties, a hypothesis which would later inform geneticists in their understanding of the structure of DNA and the role this was thought to play in supplying informational content for organismal form and function. However, subsequent work by researchers in biochemistry, biophysics, theoretical biology, complexity science, and other related areas, would also build upon Schrödinger's impressions to flesh out a more robust theory of the relationship between non-equilibrium thermodynamics, self-organization, and the complexity and order found in biological systems.

In the following section, I turn to some of this work to provide an overview of the entangled

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6 Stephen Ornes, "How Nonequilibrium Thermodynamics Speaks to the Mystery of Life | PNAS," accessed June 4, 2023, https://www.pnas.org/doi/10.1073/pnas.1620001114; Ilya Prigogine and Isabelle Stengers, *Order Out Of Chaos: Man's New Dialogue With Nature* (New York, NY: Bantam Books, 1984); Eric D. Schneider and Dorion Sagan, *Into the Cool Energy Flow, Thermodynamics, and Life* (University of Chicago Press, 2005); Jeffrey S. Wicken, *Evolution, Thermodynamics, and Information: Extending the Darwinian Program* (Oxford University Press, 1987).

7 Erwin Schrödinger, *What Is Life? The Physical Aspect of the Living Cell with Mind and Matter & Autobiographical Sketches* (Cambridge University Press, 2013).

8 Schrödinger, *What Is Life?*.

and dialectic nature of entropy and dynamic order, self-organized complexity, and life. In doing so, I will highlight a spectrum of self-organizing processes by drawing a path from non-living dissipative systems to the far-from-equilibrium thermodynamics of life and its activity.

Dissipative Systems: From Self-Organization to Autopoiesis

Physical chemist Ilya Prigogine's work on dissipative systems is arguably one of the most significant contributions to the line of thought connecting thermodynamic principles with the generation of natural order. In a nutshell, dissipative systems—a term coined by Prigogine and his colleagues in a number of publications produced during the late 1960s, and first introduced at a conference on theoretical physics and biology[9]—are complex dynamic structures operating far from conditions of thermodynamic equilibrium. These open systems tend to spontaneously self-organize into spatiotemporally ordered processes whose metastable steady states are reproduced by exchanging energy and matter with their environments. Such systems can be both naturally occurring, like whirlpools, flames, tornados, or Jupiter's Giant Red Spot, as well as artificially generated, as in the case of Bénard cells.[10] In a recent paper on the topic of Schrödinger's *What Is Life?* lectures, theoretical biologist Stuart Kauffman discusses the illustrative example of Bénard cells in some detail:

> there is a pan with a shallow layer of viscous liquid … heated slowly from below, creating a temperature gradient, hotter on the bottom than top of the fluid. The temperature gradient induces an overall heat flow to the environment … When the temperature gradient surpasses the Rayleigh threshold, convective cells arise and dissipate heat more effectively. The convective cells are the Bénard cells … [whose] patterns are sustained by the continuous flow of energy through the system that results by heating the pan from below.[11]

9 René Lefever, "The Rehabilitation of Irreversible Processes and Dissipative Structures' 50th Anniversary," *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 376, no. 2124 (June 11, 2018): 20170365, https://doi.org/10.1098/rsta.2017.0365.

10 Rod Swenson, "Autocatakinetics, Evolution, And the Law of Maximum Entropy Production: A Principled Foundation Toward The Study of Human Ecology," *Advances in Human Ecology* 6 (1997): 1–47; E. B. P. Tiezzi et al., "Dissipative Structures in Nature and Human Systems," in *Design and Nature IV*, vol. I (DESIGN AND NATURE 2008, Algarve, Portugal: WIT Press, 2008), 293–99, https://doi.org/10.2495/DN080301; John Dupré and Daniel J. Nicholson, *Everything Flows: Towards a Processual Philosophy of Biology* (Oxford University Press, 2018).

11 Stuart Kauffman, "Answering Schrödinger's 'What Is Life?,'" *Entropy* 22, no. 8 (July 25, 2020): 815, https://doi.org/10.3390/e22080815.

Much like Bénard cells, cyclones such as tornados or hurricanes, and other similarly structured natural phenomena like whirlpools or turbulent flow, maintain the emergent macroscopic patterns which constitute their dynamical form through the incessant flux of their components—i.e., via the constant flow of energy and matter through the system supplied by an energy gradient. In other words, the dynamic regularities, or structural identity, of a dissipative system emerges and develops through a continuous and directed flow of energy and matter which is resultantly dispersed more effectively into the surroundings as entropy.

We can see here the beginnings of a theory of natural phenomena which describes the tendency for order to emerge from the enabling conditions of a thermodynamic universe. From this perspective, the relationship between entropy and order is dialectically entangled such that the production of entropy acts as a natural, generative condition for the emergence of structure, organization, and complexity, and not simply disorder and equilibrium. In other words, entropy functions as a progenitor of dynamic order for a certain class of physical systems which leverage or exploit, so to speak, the same thermodynamic principles which lead to disorganization and decay in other contexts. The spontaneous development of complexity and organization is therefore equally as natural as the propensity for chaos and disorder in a universe whose activity conforms with thermodynamic laws.[12]

This theoretical framing is thought to provide a basis for understanding certain primordial and fundamental properties of biological systems, as well. For instance, biophysicist Jeremy England has suggested that non-equilibrium physical systems tend to vary in their structure over time in a manner which correlates with their ability to optimally absorb and dissipate energy from their environment. England bridges physics and biology by connecting this historical and quasi-adaptive property with the evolutionary dynamics of living systems,[13] proposing maximal entropy production as a common principle driving the activity and morphology of self-organizing physical systems, as well as minimal molecular systems and more complex biology. Kauffman has also offered a related narrative in his work on self-organization and complexity, building on various frameworks in the complexity sciences to study the relationship between laws of spontaneous order and self-organization and questions regarding the origin and evolution of life.[14] For Kauffman, the universe supplies order for free as a result of deeply natural laws shaping the behaviour

12 Prigogine and Stengers, *Order Out Of Chaos: Man's New Dialogue With Nature*; Schneider and Sagan, *Into the Cool Energy Flow, Thermodynamics, and Life*.

13 Nikolay Perunov, Robert A. Marsland, and Jeremy L. England, "Statistical Physics of Adaptation," *Physical Review X* 6, no. 2 (June 16, 2016): 021036, https://doi.org/10.1103/PhysRevX.6.021036.

14 Stuart Kauffman, *At Home In The Universe: The Search for the Laws of Self-Organization and Complexity* (New York, NY: Oxford University Press, 1995).

of non-equilibrium systems. In this view, living systems are seen as expressions of the coupling of spontaneous, self-organizing complexity and the dynamics of evolutionary selection.

Similarly, environmental scientist Eric Schneider and theorist Dorion Sagan have maintained that the tendency for non-equilibrium systems to optimize for dissipation, via their exploitation of various energy sources, is fundamental to all complex biological structures and processes—from the origin of life to evolution and ecology.[15] The authors elevate this tendency to the status of a natural principle, arguing that biological systems are enabled by the same physics of energy flow operating in non-living dissipative systems: "[non-equilibrium thermodynamics] connects life to nonliving complex systems … life's complexity is a natural outgrowth of the thermodynamic gradient reduction implicit in the second law."[16] Echoing this sentiment in an earlier publication, biochemist Jeffrey Wicken has also linked thermodynamics with the historical and ecological development of molecular and organismal complexity. Wicken argues that "life's emergence was not at all accidental" but arose quite naturally from "the free energy gradients (solar and geothermal) of prebiotic Earth," continuing to produce entropy at elevated rates by discharging these gradients, and others, during the history of its continued evolutionary diversification.[17]

We might also turn to Prigogine once again to explore a related set of ideas. One crucial theoretical development to emerge from Prigogine and his collaborators' work on dissipative systems was the Brusselator, a theoretical model for an autocatalytic system.[18] Autocatalysis—a process whereby one or more reaction products act as a catalyst for the same reaction—can be seen as a minimal requirement for defining living systems and their metabolic and replicative properties.[19] These kinds of looping reaction cycles are thought to be vitally important for describing self-organizing, far-from-equilibrium structures as well as certain regulatory mechanisms underpinning metabolic functioning and specific organizational processes unique to biological systems.[20] Others have formulated comparable ideas through the lens of their own work, most notably Kauffman's theory of autocatalytic sets and neuro-anthropologist Terrence Deacon's model of the autogen. With the latter, a synergetic loop between multiple thermodynamic self-organizing processes

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15 Schneider and Sagan, *Into the Cool Energy Flow, Thermodynamics, and Life*.

16 Schneider and Sagan, *Into the Cool Energy Flow, Thermodynamics, and Life*.

17 Jeffrey S. Wicken, "Evolution and Thermodynamics: The New Paradigm," *Systems Research* 6, no. 3 (1989): 181–86, https://doi.org/10.1002/sres.3850060301.

18 Ilya Prigogine, *From Being To Becoming: Time and Complexity in the Physical Sciences* (New York: W. H. Freeman and Company, 1980).

19 Olga Taran and Günter von Kiedrowski, "Autocatalysis," in *Encyclopedia of Astrobiology*, ed. Muriel Gargaud et al. (Berlin, Heidelberg: Springer, 2011), 128–29, https://doi.org/10.1007/978-3-642-11274-4_138.

20 Prigogine and Stengers, *Order Out Of Chaos: Man's New Dialogue With Nature*.

generates the conditions for the maintenance and replication of a self-enclosed system and its autocatalytic components.[21] A similar logic informs the idea of autocatalytic sets, whereby the general metabolic activity and self-replicating behaviour which underlie all organismic activity is posited as a typical outcome of the dynamic stability of autocatalytic networks.[22]

A handful of thinkers have also touched more specifically on the structural and organizational relationship between the thermodynamic properties of open systems and the continuous flow of energy and matter which sustains the self-organizing, self-maintaining, and self-producing behaviours of minimal biological systems. An early and influential contribution to this area can be found in the research of neurobiologists Humberto Maturana and Francisco Varela. Maturana and Varela's work on the concept of "autopoiesis" highlights not only the closed recursiveness of a self-producing network of molecular relations (much like autocatalytic sets) but the necessary and enabling condition of such a system to remain open to flows of matter and energy through it.[23] That is to say, a fundamental property of biological organization is its continuous realization through the process of incessant energy dispersal and material turnover.

Continuing in this tradition, theoretical biologists Alvaro Moreno and Matteo Mossio assert the need to ground this unique property of biology in thermodynamics, qualifying living systems as "dissipative systems dealing in a constitutive way with a thermodynamic flow that traverses them."[24] This perspective is also reflected in a recent compilation of essays titled *Everything Flows*, edited by philosophers and historians of biology John Dupré and Daniel Nicholson. In their introduction, Dupré and Nicholson write of the organism's existential condition of needing to be continuously thermodynamically active in order to exist.[25] Biological systems must metabolize

21 Terrence W. Deacon, Alok Srivastava, and Joshua Augustus Bacigalupi, "The Transition from Constraint to Regulation at the Origin of Life," *Frontiers in Bioscience-Landmark* 19, no. 6 (June 1, 2014): 945–57, https://doi.org/10.2741/4259.

22 Stuart A. Kauffman, "Cellular Homeostasis, Epigenesis and Replication in Randomly Aggregated Macromolecular Systems," *Journal of Cybernetics* 1, no. 1 (January 1, 1971): 71–96, https://doi.org/10.1080/01969727108545830.

23 H. Maturana, "Autopoiesis, Structural Coupling and Cognition: A History of These and Other Notions in the Biology of Cognition," *Cybernetics & Human Knowing* 9, no. 3–4 (March 1, 2002): 5–34; F. G. Varela, H. R. Maturana, and R. Uribe, "Autopoiesis: The Organization of Living Systems, Its Characterization and a Model," *Currents in Modern Biology* 5, no. 4 (May 1974): 187–96, https://doi.org/10.1016/0303-2647(74)90031-8.

24 Alvaro Moreno and Matteo Mossio, *Biological Autonomy: A Philosophical and Theoretical Enquiry*, vol. 12, History, Philosophy and Theory of the Life Sciences (Springer Berlin Heidelberg, 2015).

25 John Dupré and Daniel J. Nicholson, *Everything Flows: Towards a Processual Philosophy of Biology* (Oxford: Oxford University Press, 2018).

matter from their surroundings to acquire and dissipate energy, rebuild and replenish cells, and maintain their identity in a steady state. In other words, an organism's stability derives from a continuous circulation of its components, driven by the non-equilibrium dynamics of dissipating energy from its environment. Much like the Bénard cell, the maintenance of organized and ordered living states, or dynamic biological stability, requires a continuous movement of energy passing through an open system.

Philosopher Rod Swenson has explored related ideas in his work on the thermodynamics of self-organization, ecology, and evolution. In his research, Swenson expounds upon a notion of autocatakinesis, or "identity through flow,"[26] whereby both living systems and self-organizing physical systems maintain their dynamic spatio-temporal coherence through a circular causal regime realized by far-from-equilibrium thermodynamic conditions. Swenson draws on the likes of Prigogine and Schrödinger, as well as philosophers and scientists such as Heraclitus, Gottfried Wilhelm Liebniz, and Ludwig Von Bertalanffy, to stress the connection between dissipative systems and living beings, both of which are open non-equilibrium systems whose structural and organizational identity is constituted by continuous coordination of its parts via the relentless flow and degradation of energy and matter from their respective environments.[27]

It's important to pause briefly at this juncture to highlight an important distinction between living beings and non-living, strictly physical, dissipative systems, despite the continuity presented here between the thermodynamic properties of the latter and the origins, behaviour, and evolution of life. While biological systems are energetically open systems—operating in far-from-equilibrium conditions maintained by a constant throughput of energy and matter—they're also characterized by their ability to realize closure.[28] Closure refers to the collective activity and mutual dependence of various interrelated constraints which constitute bounded individuation, organizational complexity, and functional differentiation in living systems.[29] This notion is closely related to the concept of autopoiesis: i.e., a system constituted by the interdependence between an internal reaction network and a boundary, each of which continuously supplies the necessary conditions for the other's regeneration and enables the system to emerge as a

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26 Swenson, "Autocatakinetics, Evolution, And the Law of Maximum Entropy Production: A Principled Foundation Toward The Study of Human Ecology."

27 Rod Swenson, "End-Directed Physics and Evolutionary Ordering: Obviating the Problem of the Population of One," in *The Cybernetics of Complex Systems: Self-Organization, Evolution and Social Change*, ed. F. Geyer (Salinas, California: Intersystems, 1991).

28 The author would like to thank Reviewer A for their recommendation to clarify this distinction and their input regarding the significance and implications of this difference.

29 Matteo Mossio and Alvaro Moreno, "Organisational Closure in Biological Organisms," *History and Philosophy of the Life Sciences* 32, no. 2–3 (2010): 269–88.

topological unity distinct from its milieu.

Indeed, it can be said that biological systems are a more sophisticated subset of far-from-equilibrium, self-organizing, dissipative systems. That is to say, life employs internal organizational and functional complexity to achieve intricate, selective, and adaptive means of pursuing, channelling, transforming, and dispersing the sources of matter and energy which must traverse them as a requirement of thermodynamic openness. These distinctive features are closely connected to a particular property of living beings which makes them especially unique as non-equilibrium systems: their persistence is not self-undermining, unlike dissipative systems whose entropy maximization exhausts the energy gradients which create and sustain their structural regularities.[30] I will return to this point in a later section, after first discussing the idea of a directional trajectory to the dynamics of energy transformation and dispersal favoured by the evolutionary development of living systems and their activity.

A relatively common theme for many of the authors referenced above is the idea that there is some progressive trajectory implicit in the emergent self-organizing and dissipative properties of non-equilibrium systems. That is to say, many of these thinkers champion the view that life and all its various features are inevitable outcomes of a physical reality shaped by thermodynamic principles. This lies in contrast with a cosmological interpretation of entropy which sees life as an improbable and aberrant phenomenon appearing inconsistent with the laws of physical reality. For some, this alternative view motivates theoretical explorations of the relationship between thermodynamics and the origins of rudimentary forms of intelligence, meaning, and/or cognition in living beings.[31] For others, the history of biological complexification also points to a tacit purposiveness in living systems of all scales to develop toward increasingly effective forms of accelerated energy exploitation, transformation, and dispersal. It is the latter of such views which I will describe in the following section, connecting it with theoretical frameworks such as Gradient Reduction Theory and the Maximum Entropy Production Principle, and relating these perspectives to ideas regarding planetary-scale energy transformations in the development of both natural and technological global spheres.

30 Terrence W. Deacon and Miguel García-Valdecasas, "A Thermodynamic Basis for Teleological Causality," *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 381, no. 2252 (June 19, 2023): 20220282, https://doi.org/10.1098/rsta.2022.0282.

31 Terrence W. Deacon, *Incomplete Nature: How Mind Emerged from Matter*, 1st ed. (W. W. Norton & Company, 2011).

Entropy and the Directional Trajectory of the Biosphere and Technosphere

Many of the researchers highlighted earlier share an interest in aligning their ideas about the relationship between life and dissipative, nonequilibrium systems with an historical or evolutionary framework of some kind.[32] Additionally, some seek to explore how such processes might manifest and operate in systems which occupy vast temporal and spatial scales such as ecosystems, civilizations, or the planetary biosphere. In the section that follows, I will provide a few examples of such thinking, each of which adopts a somewhat unique approach to this theme, yet both of whom share a common theoretical foundation in the dissipative properties of far-from-equilibrium thermodynamic systems. I will then highlight the relevance of such thinking for framing the relationship between the Earth system and our modern technological civilization.

One expression of this evolutionary, ecological perspective on non-equilibrium systems is Gradient Reduction Theory [henceforth GRT], proposed by Dorion Sagan and Earth scientist Jessica Hope Whiteside in their contribution to a collection of essays re-examining the conceptual foundations of the Gaia hypothesis.[33] In this publication, Sagan and Whiteside explore the idea that non-equilibrium thermodynamics connects purely physical flow structures to biological processes and systems of varying degrees of complexity—from prokaryotic metabolism to complex animals, human civilization, and the biosphere, or "Gaia", itself. Furthermore, these biological systems are thought to be long-evolved manifestations of an inclination belonging to all natural processes on Earth: a tendency in the evolutionary development of far-from-equilibrium systems to accelerate increasingly effective forms of entropy production, or energy transformation and dispersal.[34]

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32 Jeremy England, *Every Life Is on Fire: How Thermodynamics Explains the Origins of Living Things* (Basic Books, 2020); Schneider and Sagan, *Into the Cool Energy Flow, Thermodynamics, and Life*; Kauffman, *At Home In The Universe: The Search for the Laws of Self-Organization and Complexity*; Swenson, "Autocatakinetics, Evolution, And the Law of Maximum Entropy Production: A Principled Foundation Toward The Study of Human Ecology"; Wicken, "Evolution and Thermodynamics."

33 D. Sagan and J. H. Whiteside, "Gradient-Reduction Theory: Thermodynamics and the Purpose of Life," in *Scientists Debate Gaia: The Next Century*, ed. Stephen H. Schneider et al. (MIT Press, 2004), 173–86, http://mitpress.mit.edu/books/scientists-debate-gaia.

34 It's worth noting that Sagan and Whiteside technically do not subscribe to the notion that entropy is being explicitly maximized by the behaviour of gradient-degrading thermodynamic systems, preferring to focus the reader's attention on the energy flows alone which organize such systems. In their thinking, GRT is a restating of the second law of thermodynamics, albeit one which emphasizes energy potentials and flow through complex systems over universal net entropy production. Despite this, their explanation of the general mechanics of their subject of interest remains relatively similar to most thinkers in this area and the difference they highlight does not seem considerable enough to put them appreciably at odds with others interested in the directed development of complex systems driven by thermodynamic principles. Indeed, in more recent work, Sagan uses the terms gradient

For instance, Sagan and Whiteside propose that the widespread proliferation of humans relative to other species "is in large part due to … a much enhanced ability to identify and deploy the food and other gradients necessary to move agricultural and technical civilization into the material evolutionary form which is humanity."[35] They also argue that the thermodynamic imperative to exploit energy potentials points not only to "the process of life's origination" but also to a directionality to life's development at the planetary scale, in the form of "growth (increase in biomass), reproduction, increase in respiration, energy efficiency, number and types of taxa (biodiversity), rates of circulation of elements, numbers of elements involved in biological circulation, and [an] increase in intelligence."[36] This sentiment is repeated in Sagan's 2016 article *Möbius Trip: The Technosphere and Our Science Fiction Reality*, wherein he writes of how "life's entropy-producing systems are completely natural within the cosmic context of the observed tendency of energy to spread. Indeed, life's ability to identify and delocalize concentrated pockets of energy is arguably its natural reason for being, why it is favored in a thermodynamic universe."[37] This tendency underpins energy-driven evolutionary "trends ranging from expansion of the area inhabited by life to increase in respiration efficiency … to increase in sensory modes, increase in information processed, and increase in energy stored, commandeered, and deployed in life's operations at Earth's surface."[38] For Sagan, this suggests "a more-than-human, thermodynamically driven, ecosystemic increase in biodiversity, net intelligence, perceptual and metabolic modes … over evolutionary time."[39]

We find a related perspective contained in the idea of the Maximum Entropy Production Principle [henceforth MEPP]. According to this view, non-equilibrium systems will develop toward optimizing for states where the rate of entropy production via energy flux and dissipation is maximized given their environmental constraints.[40] In addition

reduction and entropy production interchangeably, suggesting that while the latter may not be maximized it is nonetheless thought to be amplified by living dissipative systems.

35 Sagan and Whiteside, "Gradient-Reduction Theory."

36 Sagan and Whiteside.

37 Dorion Sagan, "Möbius Trip: The Technosphere and Our Science Fiction Reality," Technosphere Magazine, accessed June 10, 2023, https://technosphere-magazine.hkw.de/p/Mobius-Trip-The-Technosphere-and-Our-Science-Fiction-Reality-fq6MUxZjiBx7pzKPMKZfcb.

38 Sagan,. "Möbius Trip."

39 Sagan, "Möbius Trip."

40 L. M. Martyushev, "Maximum Entropy Production Principle: History and Current Status," *Physics-Uspekhi* 64, no. 6 (September 1, 2021): 558, https://doi.org/10.3367/UFNe.2020.08.038819; Leonid M. Martyushev, "The Maximum Entropy Production Principle: Two Basic Questions," *Philosophical Transactions of the Royal Society B: Biological Sciences* 365, no. 1545 (May 12, 2010): 1333–34, https://doi.org/10.1098/rstb.2009.0295; Leonid M. Martyushev, "Entropy and Entropy Production: Old Misconceptions and New Breakthroughs," *Entropy* 15, no. 4 (April 2013): 1152–70, https://doi.org/10.3390/e15041152; Leonid M. Martyushev, "Life Defined in Terms of Entropy Production: 20th Century Physics Meets 21st Century Biology," *BioEssays: News and Reviews in Molecular, Cellular and Developmental Biology* 42, no. 9 (September 2020): e2000101, https://doi.org/10.1002/bies.202000101.

to this generalized formulation, proponents hold that a variety of non-trivial features in the evolution of life can be traced to this thermodynamic property of open systems. Physicist and mathematician Leonid Martyushev has published extensively on the topic, drawing from the work of mathematical biologist Alfred Lotka, Earth systems scientist Axel Kleidon, ecologist Howard Odum, and others to explore the relevance of the MEPP in describing evolving biological systems. Increases in the complexity and organization of living systems—from microbes to metazoans—are thought to develop in accordance with this common principle, whereby "increasing the metabolic rate in order to maximize the consumption of free energy" drives "organisms [to] gradually become more complex in a natural way."[41]

Contemporary advocates of the MEPP such as Kleidon and Odum also view these energy-driven evolutionary dynamics as pivotal to describing the activity of the Earth system more broadly, focusing on energy flow through large complex systems—such as economic systems and ecological networks—that emerge as a result of life's activity.[42] In a similar vein, Martyushev holds that the MEPP is "the most important principle explaining the direction (progression) of biological and technological evolution" as it corresponds with "the increase in complexity of living creatures in the course of evolution, the emergence of human beings, and the entire course of the development of our civilization (from humans that started using fire to humans widely using oil fuel and atomic energy)."[43] The scope of GRT or the MEPP therefore appears inclusive enough to address questions concerning the relationship between thermodynamics and the origin of life, its adaptive historical development, and various scales of its hierarchical organization. At their highest strata of application, these views encourage us to see the development and operation of large-scale biospheric, social, and technological organization in accordance with a natural principle driving the energetic dynamics of non-equilibrium systems.

What we have then, are various researchers working in areas related to physics, chemistry, biology, philosophy, complex systems, and Earth sciences who have developed kindred theoretical frameworks for understanding the production of entropy as an enabling feature of self-organized complexity in the natural world. From this perspective, spatiotemporally ordered systems tend to emerge spontaneously as a means to degrade energy at elevated rates, with their recursive, self-organized complexity facilitated by a continuous flux of matter and energy from the environment. Living systems are constituted in a similar

41 Martyushev, "Life Defined in Terms of Entropy Production."

42 Axel Kleidon, "Beyond Gaia: Thermodynamics of Life and Earth System Functioning," *Climatic Change* 66, no. 3 (October 1, 2004): 271–319, https://doi.org/10.1023/B:CLIM.0000044616.34867.ec; Howard T. Odum, *Ecological and General Systems: An Introduction to Systems Ecology* (University Press of Colorado, 1994).

43 Martyushev, "Maximum Entropy Production Principle."

manner and have evolved more complex and specific means of intentionally locating, exploiting, and dissipating energy in order to produce, maintain, and replicate their organizational identity. Phenomena such as this can therefore be understood as a natural outgrowth of the second law of thermodynamics, underpinning nonequilibrium systems both nonliving and living alike.

This principle of energy dissipation may also be implicated in the growth and adaptive development of increasingly complex living systems and many of the products of their activity. This is thought to include evolutionary developments in organismal complexity, ecosystemic biodiversity, social organization, and technological systems, and their total contribution to an expanded rate of energy transformation occurring on this planet. In other words, adopting the aforementioned perspectives on the role of entropy in the generation and development of biological order might allow us to understand the activity of life at multiple levels—including aspects of human civilization such as the technosphere[44]—in concordance with the conditions of a thermodynamic universe. In a sense, the universal thermodynamic principle of entropy production lies at the heart of a worldview which naturalizes life's activity, situating it in a quasi-purposeful cosmos directed toward generating increasingly sophisticated dissipative systems.

For the human species, a perspective such as this could have a significant impact on how we frame the relationship between our technological civilization and Earth system functioning. Insofar as we can talk about the evolutionary development of human technology, the pace at which such change occurs is thought to be significantly more rapid than that which transpires through the phylogenetic history of biological systems.[45] This accelerated rate of change in our technological landscape has also been at the

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44 The technosphere here refers to the term as it was recently popularized by geologist and engineer Peter Haff in a series of publications over the last couple of decades. See Peter Haff, "Technology as a Geological Phenomenon: Implications for Human Well-Being," *Geological Society, London, Special Publications* 395, no. 1 (January 2014): 301–9, https://doi.org/10.1144/SP395.4; Peter Haff, "Humans and Technology in the Anthropocene: Six Rules," *The Anthropocene Review* 1, no. 2 (August 1, 2014): 126–36, https://doi.org/10.1177/2053019614530575; Jan Zalasiewicz et al., "Scale and Diversity of the Physical Technosphere: A Geological Perspective," *The Anthropocene Review* 4, no. 1 (April 1, 2017): 9–22, https://doi.org/10.1177/2053019616677743. According to Haff, the technosphere is the technological analogue to the various natural geological paradigms or planetary spheres that constitute and sustain the Earth system, such as the geosphere, the hydrosphere, the atmosphere, or the biosphere. Put briefly, it is a global interconnected system of technological artifacts, social structures, and physical infrastructure which constitute the totality of the built human environment, the particular energy and resource transformations underpinning the system's metabolic profile, and the emergent principles that govern our relationship with the system's functioning.

45 Robert Boyd, Peter J. Richerson, and Joseph Henrich, "The Cultural Evolution of Technology: Facts and Theories," November 1, 2013, https://doi.org/10.7551/mitpress/9894.003.0011; Sara Walker, "AI Is Life," April 27, 2023, https://www.noemamag.com/ai-is-life.

centre of profound Anthropogenic transformations in multiple planetary spheres, while simultaneously imposing conditions of critical interdependence between our species, the biosphere, and the continued viability of a functioning technosphere.[46] It's possible that situating the technosphere within the context of a thermodynamic drive toward enhanced rates of energy transformation and dispersal might shed some light on how to ensure the viability of our technological systems by aligning aspects of their development with at least one crucial, deeply natural feature of planetary life.

Indeed, some researchers have already made efforts to explore the relationship between planetary technology, thermodynamics, and the Anthropocene, such as Axel Kleidon, who has written about the energetics of the technosphere, "the ultimate thermodynamic imperative to evolve to states of greater energy conversions and higher levels of entropy production at the planetary scale", and the Earth system's need for "the technosphere to make this evolutionary step to the next thermodynamic level of greater energy conversions."[47] How then might the technosphere complement this "thermodynamic imperative" which biological systems seem to embody so effectively? How might we characterize the technosphere's ability to dissipate energy, and how does it compare in this regard to living systems? In the final portion of this paper, I speculate about this conceptual relationship between the technosphere and biosphere by turning my focus toward the material constitution of human technological artifacts. The following considerations will be used to guide this inquiry:

> (i) How does current human technology differ from evolved, living nonequilibrium systems?
> (ii) Could modelling our technology on the dialectic of entropy and life be advantageous for the viability of the technosphere?
> (iii) How might theories of energy dissipation in living systems inform the design of human technology?

Nonequilibrium Thermodynamics: Biology Versus Technology

How does human technology differ from evolved, living nonequilibrium systems?

Many of the authors previously cited give us good reason to distinguish living systems, such as organisms, from existing artifactual systems, such as machines. One significant

46 Haff, "Humans and Technology in the Anthropocene."

47 Axel Kleidon, "How the Technosphere Can Make the Earth More Active," Technosphere Magazine, accessed July 28, 2023, https://technosphere-magazine.hkw.de/p/How-the-Technosphere-Can-Make-the-Earth-More-Active-2sLVHbYfUTS8sKUtkZAGWq.

difference involves a comparison between the processual dynamism of biology and the engineered stability of mechanical artifacts. For instance, Swenson writes of machines being constituted by the static order of fixed and functional components, all of which have been designed by an artificer. In contrast with this, living systems are defined by a self-organized, dynamic order whose identity is self-produced "through the incessant flux of their components, which are continuously being replaced from raw materials in their environments and being expelled in a more dissipated form."[48] All extant human artifacts, machines, or other technological devices and systems lack this autocatakinetic property of being constituted through continuous, dynamic flows of material and energetic dissipation.

This difference has also been described in terms of the transitional and stable identities of biological systems and machines, respectively. Daniel Nicholson writes that while "an organism naturally maintains itself in a state of continuous flux" as a "temporary manifestation of the self-producing organizational unity of the whole," a machine and its components "remain distinct, stable, and identifiable over time."[49] That is to say, living systems are grounded in the thermodynamic principles which compel them to "break down the materials they take in from their environment in order to acquire the energy they need to rebuild their constituents … maintain themselves in a steady state far from thermodynamic equilibrium … and dissipate energy and excrete material wastes back into their environment."[50] Human technology does not operate like this in any credible sense, its structural and organizational identity is completely unlike the processual dynamism of open dissipative systems described here.[51]

48 Swenson, "Autocatakinetics, Evolution, And the Law of Maximum Entropy Production: A Principled Foundation Toward The Study of Human Ecology."

49 Daniel J. Nicholson, "Organisms ≠ Machines," *Studies in History and Philosophy of Biological and Biomedical Sciences* 44, no. 4 Pt B (December 2013): 669–78, https://doi.org/10.1016/j.shpsc.2013.05.014.

50 Dupré and Nicholson, *Everything Flows: Towards a Processual Philosophy of Biology*.

51 There is a sizeable and growing body of literature in the history and philosophy of biology addressing the ontological and the epistemological relationship between biology/organisms and machines/technology which I am unable to adequately unpack within the limited scope of this paper. Those who are interested should see, for instance, Georges Canguilhem, "Machine and Organism," in *Knowledge of Life* (New York City, New York: Fordham University Press, 2022), 200; Andrea Gambarotto and Auguste Nahas, "Teleology and the Organism: Kant's Controversial Legacy for Contemporary Biology," *Studies in History and Philosophy of Science* 93 (June 1, 2022): 47–56, https://doi.org/10.1016/j.shpsa.2022.02.005; Hans Jonas, *The Phenomenon of Life: Toward a Philosophical Biology* (Illinois: Northwestern University Press, 2001); Tim Lewens, *Organisms and Artifacts: Design in Nature and Elsewhere* (Cambridge, Massachusetts: The MIT Press, 2005); Matteo Mossio, "Purposiveness, Directionality and Circularity" (Workshop on Goal-Directedness, Spain, February 3, 2022), https://www.youtube.com/watch?v=b7YZmNPnxPY; Nicholson, "Organisms ≠ Machines"; Daniel J. Nicholson, "The Machine Conception of the Organism in Development and Evolution: A Critical Analysis," 2014, https://philarchive.org/rec/NICTMC-2; Jessica Riskin, *The Restless Clock: A History of the Centuries-Long Argument*

Framed alternatively, biological systems are ascribed as having a much greater degree of autonomy than machines. Part of what it means for dynamic living order to be constituted by a flux of energetic and material processes is that thermodynamically open systems of this kind acquire self-organizing and self-constructing properties and functions which contribute to the system's own determination, maintenance, and persistence. In other words, living systems are considered both causes and effects of themselves, capable of promoting the conditions of their own autopoietic existence through thermodynamically-grounded environmental interactions shaping intrinsic energetic and material circulation.[52] By contrast, nearly all of our technological systems are allopoietic or heteropoietic: that is to say, many "have as the product of their functioning something different from themselves," relying in nearly all respects on human agency, design, and intervention to become organized, perform functionally, and persist and evolve through time.[53]

Another salient difference between living and technological systems can be illustrated by their respective energy dissipation rates. Drawing considerably on the work of environmental scientist Vaclav Smil, philosopher Thomas Nail has argued that, despite an exponential rise in human-induced energy expenditure during the last century, the technosphere is still orders of magnitude less effective than the biosphere when it comes to rates of energy expenditure and dissipation, paling in comparison to biodiverse ecosystems such as old-growth forests.[54] For Nail, both vegetal and animal life are "massive energy-degrading [processes] of radical expenditure and waste," with plants acting as "powerful dissipative systems that degrade solar energy into low-grade heat energy, water, and oxygen" and animals dissipating 80–90% of the energy they consume as heat.[55] Schneider and Sagan similarly emphasize the powerful entropy producing features of biodiverse Amazonian rainforests,[56] which Sagan has differentiated from what he sees as the current technosphere's "unsustainable rates of entropy production, which tend to be associated with unsustainable exponential growth and the early, passing stage of pioneer

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over What Makes Living Things Tick (Chicago: University of Chicago Press, 2016); Robert Rosen, *Life Itself: A Comprehensive Inquiry Into the Nature, Origin, and Fabrication of Life* (New York, NY: Columbia University Press, 1991); Günther Witzany and František Baluška, "Life's Code Script Does Not Code Itself. The Machine Metaphor for Living Organisms Is Outdated," *EMBO Reports* 13, no. 12 (December 2012): 1054–56, https://doi.org/10.1038/embor.2012.166.

52 Moreno and Mossio, *Biological Autonomy: A Philosophical and Theoretical Enquiry*.

53 Humberto Maturana and Francisco J. Varela, *Autopoiesis and Cognition: The Realization of the Living*, vol. 42, Boston Studies in the Philosophy of Science (Holland: D. Reidel Publishing Company, 1980).

54 Thomas Nail, *Theory of the Earth* (Stanford University Press, 2021); Vaclav Smil, "Harvesting the Biosphere: The Human Impact," *Population and Development Review* 37, no. 4 (2011): 613–36, https://doi.org/10.1111/j.1728-4457.2011.00450.x.

55 Nail, *Theory of the Earth*.

56 Schneider and Sagan, *Into the Cool Energy Flow, Thermodynamics, and Life*.

monocultures in immature ecosystems."[57] In other words, despite an unprecedented era of accelerated, energy-intensive technological development—one which corresponds with the rapid growth of the modern technosphere—our contemporary technological systems appear largely incapable of matching the sustainable, biologically-effective rates of energy transformation and expenditure measured in the highly entropic activity of the biosphere.

Could modelling our technology on the dialectic of entropy and life be advantageous for the viability of the technosphere?

Comparisons between the dissipative properties of the technosphere and the biosphere are especially interesting because they suggest that the kind of entropic destruction resulting from contemporary fossil-fuel civilization is in fact quite different from the more widespread entropy-amplifying processes which have characterized the history of life on Earth. If anything, humans have reduced the planet's overall energy expenditure by eradicating dissipative biological systems, indirectly replacing them with technological systems of inferior entropy-producing capabilities. Nail's recent book *Theory of the Earth* builds on this idea in order to advance an ethics of dissipative energy expenditure which advocates for bringing environmental politics and philosophy into alignment with the thermodynamic principles shaping biospheric energy flow.[58] I wish to orient my thinking in a similar direction by speculating about aligning human technology with the principles of nonequilibrium thermodynamics which shape the identity and activity of biological systems.

As mentioned earlier, the uniquely self-sustaining tendencies of biological dissipative activity would likely be a critical consideration for any effort to contemplate the prospect of modelling technological systems on nonequilibrium thermodynamics, as it pertains to the dialectic of entropy and life. To reiterate, the structural order of non-living dissipative systems can only persist in the presence of an energy gradient and ceases as soon as the energy source is depleted. However, the patterns of dynamic regularity which constitute such systems emerge as pathways to amplify the rate at which energy passes through them. This has the consequence of reducing the long-term persistence and propagation of the system's self-organized identity.

Life, by contrast, extends this dissipative energetic process over much greater timescales, both ontogenetically—over organismal development and life-cycles—and phylogenetically—through reproduction and evolution. In other words, biology is capable of embodying the dynamics shared by open, nonequilibrium, dissipative systems while

57 Sagan, "Möbius Trip: The Technosphere and Our Science Fiction Reality."

58 Nail, *Theory of the Earth.*

avoiding the process whereby such activity threatens to undermine the orderliness generated therefrom. While I am unable to provide a detailed account of how this is accomplished, I will quickly share a few examples which touch on how these dynamics might factor into minimal and proto-biological systems, as well as ecological or biospheric processes.

Firstly, previous works by Deacon[59] have sought to develop a theory of "the distinctive modification of thermodynamic processes that characterize the intrinsic end-directed dynamics characteristic of life."[60] Referred to as "teleodynamics," this theoretical approach is intended to highlight the teleological properties of living systems which are otherwise both continuous with, yet simultaneously transcend, the self-eliminating activity of purely physical nonequilibrium systems. Recall Deacon's autogen, a model for a minimal teleodynamic system. The autogen is a simple molecular cycle consisting of two dissipative self-assembling systems coupled synergistically such that each supplies a boundary condition for the other's activity. These mutually limiting, reciprocal constraints endow the emergent macrosystem with a primitive means of regulating otherwise self-terminating nonequilibrium thermodynamic processes, while enabling the global system to approximate end-directedness as a result of its ability to maintain historical continuity over generations of replication and repair.

Zooming out to a planetary scale, we might turn our attention back to the dynamics of one of life's maximally dissipative extant systems—the collective activity of photosynthetic organisms. Forest ecosystems, for example, are enormously dissipative although their transformation of solar energy crucially involves generating oxygen as a molecular waste product. Indeed, all photosynthetic life-forms, especially marine microorganisms, partake in this biospheric process of energy transduction and dispersal critical to sustaining the expansive diversity of aerobic life on Earth. Moreover, plants in particular play a role in global evapotranspiration, helping to regulate surface and air temperatures through feedback loops between warming environments and cooling mechanisms, involving the release of excess evaporated water and the resultant creation of cloud cover.[61] As put forward by ecologist James Lovelock and evolutionary biologist Lynn Margulis, there is

59 Deacon, *Incomplete Nature: How Mind Emerged from Matter*; Terrence W Deacon, "Teleodynamics: Specifying the Dynamical Principles of Intrinsically End-Directed Processes" (Superior, CO: International Association for the Integration of Science and Engineering (IAISAE), June 2020); Deacon and García-Valdecasas, "A Thermodynamic Basis for Teleological Causality."

60 Deacon, "Teleodynamics: Specifying the Dynamical Principles of Intrinsically End-Directed Processes."

61 "Seeing Leaves in a New Light," Text Article (NASA Earth Observatory, May 6, 2002), https://earthobservatory.nasa.gov/features/LAI/LAI2.php; Sagan, "Möbius Trip: The Technosphere and Our Science Fiction Reality."

reason to believe the Earth has maintained a relatively metastable state of atmospheric homeostasis for hundreds of millions of years as a result of complex regulatory feedback processes facilitated, more generally, by the living biosphere.[62]

With these examples in mind, it could be said that to some degree living dissipative systems owe their emergence and persistence to relational, regulative, and regenerative dynamics which they both embody internally and enact reciprocally with other dissipative systems. For example, a crucial ingredient in the emergence and perseverance of autopoietic systems is the intrinsic, mutually-regulating boundary conditions, and subsequently evolved organizational constraints, of various holistically interrelated thermodynamic processes—allowing the system to harness flows of energy and matter and effectively generate entropy without compromising its identity.[63] Furthermore, the far-from-equilibrium energetic landscape of the biosphere sustains dissipative activity through multi-metabolic processes which involve recycling waste products and exporting entropy as heat away from its surfaces and into outer space.[64] That is to say, life enables augmented entropy production through adaptive and self-regulatory activity, circumventing the self-eliminating properties of non-living dissipative systems while becoming ecologically integrated with other living systems. These properties seem especially well suited to facilitating elevated rates of long term, biologically-effective energy dispersal without undermining biospheric viability.[65] It might be interesting then to consider the idea of assimilating such properties into the constitution and operations of technological systems as a means to ensure the viability of an "energetically prodigious and sustainable"[66] planetary technosphere.

Orienting ourselves toward the possibility of a technosphere embodying far-from-equilibrium, continuously self-organizing, dissipative properties might also reframe our relationship with technological systems in a similar way to how theories regarding the thermodynamics of self-organization and biological order reframed life as a natural and expected feature of the cosmos. That is to say, it may give us reason to see the potential for

62 James E. Lovelock and Lynn Margulis, "Atmospheric Homeostasis by and for the Biosphere: The Gaia Hypothesis," *Tellus* 26, no. 1–2 (1974): 2–10, https://doi.org/10.1111/j.2153-3490.1974.tb01946.x; Sagan, "Möbius Trip: The Technosphere and Our Science Fiction Reality."

63 Moreno and Mossio, *Biological Autonomy: A Philosophical and Theoretical Enquiry*; Deacon and García-Valdecasas, "A Thermodynamic Basis for Teleological Causality."

64 Sagan, "Möbius Trip: The Technosphere and Our Science Fiction Reality."

65 The author would like to thank Reviewer B for prompting the inclusion of this admittedly underdeveloped point and the antecedent paragraphs which only begin to expand upon it. Relatedly, it should also be noted that biospheric dissipative activity has been operating in a relatively self-sustaining manner for billions of years, in contrast with only a few hundred years of entropy production generated by a modern technosphere that is currently straining the limits of planetary viability.

66 Sagan, "Möbius Trip: The Technosphere and Our Science Fiction Reality."

technology to become more like the complex and ordered natural systems which appear to spontaneously emerge from, and thrive in, a thermodynamic universe. At the very least, it may motivate us to imagine how we might engineer the technosphere and its artificial components to be more reciprocally connected with the ubiquitous material and energy flows shaping bio-terrestrial expenditure. In both cases, human technology could be guided toward a paradigm where it operates in harmony with, and not distinct from or hostile to, living systems. At the core of such a transformation, should it happen to be feasible, would be an objective to approximate or reproduce with our technological systems the activity and associated dissipative properties of open, nonequilibrium, biological systems.

How might theories of energy dissipation in living systems inform the design of human technology?

This question is a highly speculative prompt, to be sure, and should be considered as no more than a loosely sketched thought experiment. I do not purport to offer any precise or concrete proposals for how one might go about developing living technology with thermodynamic properties that correspond precisely to those exhibited by biological systems. Instead, I wish to provide only a general outline of this hypothetical technological future by pointing to a few promising developments in bioengineering and synthetic biology, briefly elaborating on why these advances may warrant further attention in the context of our exploration of the dialectical relationship between entropy and open nonequilibrium systems.

One area of interest which may prove to be relevant to this conceptual endeavour is synthetic morphology. This emerging sub-discipline of synthetic biology began to take shape around 2008, when developmental biologist Jamie Davies published a paper outlining the prospects of engineering "self-constructing assemblies of cells."[67] Practitioners in this nascent field are generally interested in understanding the rules of morphogenesis and their application in the construction of devices using, or entirely comprised of, engineered living tissues.[68] In other words, these researchers are interested in how living matter self-organizes, studying the unique properties of individual cells and the collective behaviour they exhibit when assembling into various pluricellular configurations and using that knowledge to develop new hybrid living-technological systems.[69]

67 Jamie A. Davies, "Synthetic Morphology: Prospects for Engineered, Self-Constructing Anatomies," *Journal of Anatomy* 212, no. 6 (June 2008): 707–19, https://doi.org/10.1111/j.1469-7580.2008.00896.x.
68 Philip Ball, "Synthetic Morphology Lets Scientists Create New Life-Forms," *Scientific American*, 2023, https://www.scientificamerican.com/article/synthetic-morphology-lets-scientists-create-new-life-forms/.
69 Mo R Ebrahimkhani and Miki Ebisuya, "Synthetic Developmental Biology: Build and Control Multicellular Systems," *Current Opinion in Chemical Biology*, Synthetic Biology • Synthetic Biomolecules, 52 (October 1, 2019): 9–15, https://doi.org/10.1016/j.cbpa.2019.04.006; Mo R. Ebrahimkhani and

While thermodynamics does not currently play much of a role in this work, for our purposes, developments in synthetic morphology point toward a horizon where technological systems are brought into even closer proximity with living systems—not merely in an attempt to emulate biology, as is often the case in areas of biomimetic design, but by comprehensively devising novel engineered systems composed of living matter itself. Learning to design technological systems using "agential materials"[70] may require engineering considerations of the material, energetic, and organizational properties of living nonequilibrium systems and the characteristics of such systems which are instrumentally relevant to synthetic morphology—e.g., autopoietic and teleological causality, self-organization, adaptivity and agency.[71] Efforts in this field might also chart a path toward the symbiotic integration of a new class of biological artifacts into the broader dissipative flows that characterize the thermodynamic activity of organisms and ecologies.

This nascent field complements similar aims in other areas of synthetic biology, reflecting a general disposition toward engineering technological systems using biological and/or biochemical components and processes. These include applications in cellular agriculture and other bioeconomic platforms,[72] experiments in the design and construction of built environments grown using engineered living material,[73] as well as various efforts to transform industrial processes involved in chemical, pharmaceutical, and material manufacturing, energy and fuel production, and waste remediation via the deployment of metabolically engineered molecular systems.[74] Similarly, advances in biological computing point towards a potential future where emerging technological systems may hold the promise of operating more congruously with living dynamics as a result of biological embodiment. Notable examples include the development of microprocessors

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Michael Levin, "Synthetic Living Machines: A New Window on Life," *iScience* 24, no. 5 (May 2021): 102505, https://doi.org/10.1016/j.isci.2021.102505.

70 Jamie Davies and Michael Levin, "Synthetic Morphology with Agential Materials," *Nature Reviews Bioengineering* 1, no. 1 (January 2023): 46–59, https://doi.org/10.1038/s44222-022-00001-9.

71 Deacon and García-Valdecasas, "A Thermodynamic Basis for Teleological Causality"; Tom Froese et al., "From Autopoiesis to Self-Optimization: Toward an Enactive Model of Biological Regulation" (bioRxiv, June 9, 2023), https://doi.org/10.1101/2023.02.05.527213.

72 "Cellular Agriculture Society," Cellular Agriculture Society, accessed June 23, 2023, https://www.cellag.org/.

73 "HBBE – Biotechnology in the Built Environment," accessed June 23, 2023, http://bbe.ac.uk/.

74 "Ginkgo Bioworks | Industrials," Ginkgo Bioworks, accessed June 23, 2023, https://www.ginkgobioworks.com/offerings/industrials/; Ahmad S. Khalil and James J. Collins, "Synthetic Biology: Applications Come of Age," *Nature Reviews Genetics* 11, no. 5 (May 2010): 367–79, https://doi.org/10.1038/nrg2775.

powered by photosynthetic algae[75] and early research into the use of stem cell-derived neural organoids in biological computing.[76]

Once more, although thermodynamics does not yet appear to be central to these advances in synthetic biology, the general impetus to explore the frontiers of engineered systems comprised of biological matter may be a desired direction in the path toward living technology with embodied dissipative and metabolic properties.[77] It may indeed be one of the first steps toward the construction of a technosphere which can begin to match the amplified entropy-producing features of organisms and ecosystems, while reflecting life's ability to sustain dissipative activity without compromising its own existence. As researchers like Nail have indicated, a significant fraction of the planet's most effective dissipative systems (living ecosystems) have been, and continue to be, decimated as a result of the accelerated technological and economic growth associated with the Anthropocene, lowering the planet's total rate of entropic expenditure.[78] Relying on the affordances of our contemporary technosphere alone may be insufficient to compensate for this loss, as its dissipative properties appear to be both orders of magnitude less effective than the terrestrial biosphere's and its growth, self-maintenance, and stability are far from guaranteed.[79] Earth's biological systems may be incapable of evolving rapidly enough to respond to this change, as well, further deferring the emergence of novel entropy producing systems on a planetary scale. So, along with the many practical and imperative measures required to address various, profound transformations engendered by the Anthropocene, working towards the development of bio-engineered artifacts embodying the dissipative properties of living nonequilibrium systems could be a fruitful avenue towards post-Anthropocene terraforming in service of restoring and ideally augmenting a sustainable thermodynamic imperative for energy to spread—however abstract or imaginative this may seem at present.

75 P. Bombelli et al., "Powering a Microprocessor by Photosynthesis," *Energy & Environmental Science* 15, no. 6 (June 15, 2022): 2529–36, https://doi.org/10.1039/D2EE00233G.

76 Lena Smirnova et al., "Organoid Intelligence (OI): The New Frontier in Biocomputing and Intelligence-in-a-Dish," *Frontiers in Science* 0 (2023), https://doi.org/10.3389/fsci.2023.1017235.

77 Perhaps one day we might traverse blurred boundaries between living and machinic in a manner similar to the Oankali of Octavia Butler's sci-fi novel *Dawn*, who maintain a symbiotic relationship with technological systems that are fully alive, composed of living tissues which are "both, and more" than plant and animal, and exhibit properties such as metabolism, growth and development, dynamic embodied responsiveness, and intelligence. Octavia E. Butler, *Dawn* (London : VGSF, 1988), http://archive.org/details/dawn0000butl.

78 Nail, *Theory of the Earth*; Thomas Nail and Dorion Sagan, "A New Theory of the Earth: Thomas Nail and Dorion Sagan."

79 For more on the possible shortcomings and self-undermining activity of the technosphere's energetic and material metabolic recycling processes, see Haff, "Technology as a Geological Phenomenon."

Conclusion

In surveying a literature on the notion of entropy and its enabling role in the generation of self-organized complexity in open nonequilibrium systems, a throughline can be traced from non-living physical systems to forms of biological organization and activity at multiple scales—from individual autopoietic cells to planetary systems. The view that the conditions of a thermodynamic universe provide an impetus for the emergence and development of increasingly sophisticated vehicles for amplifying planetary rates of energy dispersal provides a conceptual paradigm for thinking about connections and divergences between two global energetic systems: the biosphere and the technosphere. Drawing on theoretical biology and recent developments in bioengineering, we might aspire to imagine a future technosphere comprised of living matter, whose material, energetic, and organizational properties are more closely aligned with the nonequilibrium thermodynamics which permeate naturally ordered systems and the self-sustaining activity and constitution of life.

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Diversity and Biocultural Invention

Eduardo Makoszay Mayén

Abstract:
In non-modern biocultures, contextual human technicity has played a key role in shaping the behaviors and the morphology of non-human species, which in return has simultaneously modulated human morphology and behavior: *behavior affords behavior*. Studies intersecting anthropology and ecology have framed this process as a biological feedback in which species co-evolve through the constitution of biocultural diversification, thus producing negative entropy through technical activities.

Keywords:
Evolution, Plasticity, Bioculture, Invention, Techniques, Fractals

©Author(s), 2023. Corresponding author: Eduardo Makoszay Mayén, emakoszay@gmail.com

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Evolution is things changing when they must. - Kinji Imanishi[1]

1. Beyond the NBIC Paradigm

While change is an unavoidable characteristic among living things, the convergence of the fields of Nanotechnology, Biotechnology, Information technology and Cognitive science (NBIC), constrain our modes of human enaction by naturalizing consumer logics. The change produced within this framework is mainly directed towards capitalist accumulation, standardizing all sorts of variables through an accelerated production of entropy which diminishes the diversity of the biocultural fabric. Invention within the NBIC paradigm approaches issues from the decontextualized point of view of calculation and statistics; aimed to be deployed massively, it avoids, or even disables the invention of localized solutions to overcome urgent contemporary issues.

The expression of technology inherent to the NBIC paradigm standardizes –and thus stabilizes– the behavior of the human population at large, while homogenizing landscape management through monocultural food production and massive resource extraction. Although most humans are apparently docile regarding normative top-down regulations, the rest of the biotic and abiotic members of the planetary ecology, as well as those humans existing outside of hegemonic paradigms, are producing ever increasing unforeseeable events in shorter iterations, as a reaction to the constraints and enablements installed by the modern human world. Random variation plays a key role in biological evolution, but selection canalizes it. In the balance between randomness and non-randomness the possibility for navigation emerges.

According to Stengers and Prigogine, the emergence of modern science happened with the discovery of a specific form of communication with nature–that is, the conviction that nature responds to an experimental interrogation, which presupposes a systematic interaction between theoretical concepts and observation.[2] Modern technology is erected on top of modern scientific endeavors while simultaneously constraining them for its benefit, therefore they are part of the same process: *modern technoscience*. This process has an inherent entropic tendency towards biological and ontological standardization that not only affects humans, but all biotic and abiotic members of the biosphere.
By creating ruptures in the metabolic fabric of specific localities through the imposition of one-size-fits-all approaches which modulate the current social and cultural order,

1 Kinji Imanishi, "A Proposal for Shizengaku: The Conclusion to My Study of Evolutionary Theory," *Journal of Social and Biological Systems* 7, no. 4 (October 1984): 363.

2 Ilya Prigogine and Isabelle Stengers, *Order out of Chaos: Man's New Dialogue with Nature* (Toronto: New York, N.Y: Bantam Books, 1984), 5.

modern technoscience decontextualizes subjects from their direct concrete realities, rendering a particular human ontology as a universal standard. Stengers and Prigogine further consider that according to modern technoscience, nature is nothing more than a submissive automaton, to the point that it can be described as "constituted against nature, since it denies complexity and evolution, alleging an eternal and knowable world governed by a small number of simple and immutable laws."[3]

But even if the modern technoscientific enterprise and mass culture attempt to present an image of scientific progress as a linear and univocal way of understanding and acting within the world, when rigorously delving into scientific research, it is impossible to not notice that pluralism has always existed. The illusion of science as a monotheistic realm is only a matter of which are the scientific activities that get the most funding for both research and marketing strategies.

2. Shizengaku: Towards an Intersubjective Biology

As Giuseppe Longo and his colleagues have clarified, the attempt to create a priori mathematical models for the possible trajectories of biological evolution is not only incoherent, but has also hindered the progress of biological research. The impossibility to apply the mathematical models (which are so abundant in physics) comes from the fact that biological species modify —and are modified by— their ecological niches, constituting a positive feedback between organisms and their ecological niche.[4] As a biological species whose evolutionary trajectory is correlated with those of the multiple species that constitute our niches, randomness is constantly emerging, meaning that unforeseeably events are modifying both our lifelines as individuals and our evolutionary paths as a species.

Kinji Imanishi argues that we can only interpret and express the world in our own human terms and thus a biology "that lacks an intuitive knowledge of resemblances [which] can provide only an impoverished, mechanistic view of the living world."[5] We read this as a call to acknowledge our human position on the planet from an intersubjective understanding and to actively perform ourselves as co-constituents of ecosystems. But to arrive at a more intuitive understanding of evolutionary trajectories, we first need to scrutinize the

3 Ilya Prigogine and Isabelle Stengers, *La nueva alianza: metamorfosis de la ciencia* (Madrid: Alianza, 1997), 47.

4 Giuseppe Longo et al., "In Search of Principles for a Theory of Organisms," *Journal of Biosciences* 40, no. 5 (December 2015): 955-68.

5 Kinji Imanishi, *A Japanese View of Nature: The World of Living Things*, trans. Pamela J. Asquith. Japan Anthropology Workshop Series (London; New York, NY: Routledge, 2002), 62.

modern synthesis, also known as Neo-Darwinism.

Lynn Margulis argued that the practitioners of this hegemonic view of life "widely believe and teach–explicitly and by inference–that life is a mechanical system fully describable by physics and chemistry."[6] While Neo-Darwinists proffer formal mathematical explanations for the ways in which organisms evolve, Margulis argues that biologists who "live among and observe metabolizing animals, plants, and microbes have difficulty measuring the quantities or even understanding general concepts labelled and taken as directly observable."[7]

Prigogine and Stengers consider that the kind of scientific invention that emerges from these contexts denotes a driving force which stubbornly applies to nature the same homogeneous techniques and concepts, and always ends up encountering an equally stubborn resistance from nature.[8] They describe this way of relating as violent, and thus, it is no wonder that such mechanistic understandings of life has played a key role in enabling the multi-directional violence that characterizes modern human society.
Inventors arrange cultural controls (e.g. technological devices, experimental situations) to consciously interpret nature, objectifying a culture which enables a way of "using," "experiencing," or "inventing" nature; and the outcomes of these cultural controls are used again and again to re-create an experience of nature.[9] What is then the experience of nature created through the perspective of the modern synthesis? How does it affect our daily lives?

By conducting processes of artificial selection in the search to enhance or perpetuate desired traits in other biological species, unforeseeable characteristics also emerge. The *domestication syndrome* refers to the processes in which a biological species loses or acquires new characteristics as a result of the processes of artificial selection. For example, in the monocultural production of agave in Mexico used for distilled beverages, the domestication syndrome becomes observable as the gigantism which emerges in different parts of the plant, and a lack of stability in the leaves, among others.[10] This modern agriculture of agaves happens in deforested areas, contrary to the mesoamerican agroforestry systems in which agaves used to thrive in correlation to other biological species; in the latter, each agave plant may present variable and particular features

6 Lynn Margulis, "Big Trouble in Biology," in Lynn Margulis and Dorion Sagan, *Slanted Truths: essays on Gaia, symbiosis, and evolution* (New York: Springer, 1997), 266.

7 Margulis, "Big Trouble in Biology," 271.

8 Prigogine and Stengers, *Order out of Chaos: Man's New Dialogue with Nature*, 308.

9 Roy Wagner, *The Invention of Culture* (Chicago: London: University of Chicago Press, 1975), 100.

10 Alejandro Casas et. al., "In Situ Management and Domestication of Plants in Mesoamerica," *Annals of Botany* 100, no. 5 (July 2007): 1101–15.

depending on its specific environmental pressures. In the former, the whole population of plants is managed statistically.

Imanishi considers that statistics, which are central to the western mode of thinking, report on things as static and species as unchanging: "if we interpret it statistically, the variation expressed by most individuals, or something like the average variation, may be considered the equivalent of not changing at all."[11] Absolute stasis is not possible for living organisms; creativity is at our core, and this is noticeable in our most basic behaviors. When walking through a seemingly straight path I encounter objects of different scales that may require a drastic modification of my whole trajectory or of a single step. Ignoring these objects could result in falling and hurting myself.

Living is creating, and thus, creativity plays a role of utmost importance within evolutionary trajectories. Imanishi argued that "evolution is creation and that creativity is an attribute of living organisms."[12] But, on the other hand, the illusion of creativity inherent to modern technoscience has had such a catastrophic impact on the planet's environment. How to constitute modes of creative enactment, between change and stasis, that not only possesses evolutionary potential, but is also situated from diverse and specific contexts? If humans are positioned within multiple and simultaneous evolutionary processes, our psychological, physical, and social structures become both the stage and the performers. Living things cannot exist in separation from the environment. Therefore when thinking about concrete forms of existence we always refer to the organism-environment relation; but the environment is constituted by biotic and abiotic members that according to Imanishi have grown and developed from one single thing;[13] To look at each living thing in its own right actually means making our recognition of them, and hence of their affinities, more accurate. Imanishi called for a new science of the living things, –*shizengaku*–, which is based on the apprehension of this intuitive understanding of similarity.[14]

The central hypothesis of shizengaku is that the heterogeneity of the constantly changing elements that constitute our ecosystems develop from a single unit that diversified through habitat segregation, meaning that specific traits and behaviors emerge during the distribution of a species throughout different habitats which results in a diversification of

11 Imanishi, *A Japanese View of Nature: The World of Living Things*, 134.
12 Imanishi, *A Japanese View of Nature: The World of Living Things,* 123.
13 Imanishi, *A Japanese View of Nature: The World of Living Things*, 80.
14 Imanishi, *A Japanese View of Nature: The World of Living Things*, 62.

affordances.[15] We thus consider that Imanishi's arguments can be read from the Mayan-Tseltal concept of *ch'ulel*, as described by Juan López Intzín:

> Contrary to positivist Western thought, which has classified existence into animate beings and inanimate things, in indigenous Maya thought, everything has life, source, matrix, heart, veins, bones, flesh, feelings, thoughts, language, and *ch'ulel*.[16]

In the Mayan languages, such as the Tseltal, the category of "object" does not exist[17] and therefore there is no asymmetrical relationship in the construction of knowledge between "subjects" and "objects." López Intzín further explains that:"*ch'ulel* turns everything in existence into a subject and allows us to interact with one another, subject to subject."[18] We thus realize the intersubjective character of the metabolic and trophic relations happening within and between all of the biotic and abiotic members that constitute an ecosystem. If evolutionary trajectories are creative fluctuations in constant intertwining, can we understand shizengaku as the blueprint for an intersubjective biology?

3. The Multiplicity of Individuality

Animals cannot be considered anatomical or physiological individuals because a diverse multiplicity of symbionts both inhabit and function within them, completing metabolic pathways and serving other physiological functions.[19] Thus, the notion of individuality has been constitutively redefined as 1) a *niche* inhabited by others or 2) a composite and

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15 In Augustin Berque, "The Perception of Space or a Perceptive Milieu?" *L'Espace géographique* 45, no. 2 (2016): 174: Berque mentions that what the animal encounters is the 'as' by which it perceives things: as food, as obstacles, as shelter, as housing, etc. "In other words, in a functional circle, this 'as' is the medial handle that an object offers the animal." In James Gibson, *The Ecological Approach to Visual Perception: Classic Edition* (New York; London: Psychology Press, Taylor & Francis Group, 2015), 129: These "as if's" were described by James Gibson as affordances, "An affordance cuts across the dichotomy of subjective-objective and helps us to understand its inadequacy. It is equally a fact of the environment and a fact of behavior. It is both physical and psychical, yet neither. An affordance points both ways, to the environment and to the observer."

16 Juan López Intzín, "The Ch'ulel-Multiverse and Intersubjectivity in the Maya Tseltal Stalel,"in *Resistant Strategies*, Taylor, Diana and Marcos Steuernagel, eds. Resistant Strategies. Digital Book. Durham: Duke University Press and Hemi Press. (Forthcoming).

17 Margara Millán, "En otras palabras, otros mundos: la modernidad occidental puesta en cuestión," in *Lengua, cosmovisión, intersubjetividad. Aproximaciones a la obra de Carlos Lenkersdorf*, ed. Márgara Millán and Daniel Inclán (México: Universidad Nacional Autónoma, 2015), 50.

18 López Intzín, "The Ch'ulel-Multiverse and Intersubjectivity in the Maya Tseltal Stalel," 18.

19 Scott F. Gilbert, Jan Sapp, and Alfred I. Tauber, "A Symbiotic View of Life: We Have Never Been Individuals," *The Quarterly Review of Biology* 87, no. 4 (December 2012): 325.

heterogeneous whole. Elena Gagliasso mentions that "apparatuses, cells and even our eukaryotic DNA include a huge prokaryotic world (bacteria) inhabiting them, which modulates their chemistry, and governs their metabolism."[20] The ambiguity brought forth by all of the micro-alterity that an "individual" is dependent on, is further amplified when we notice that throughout its lifetime, an individual drastically exchanges microorganisms with the ecosystems that it inhabits, to the extent that these "external" ecological fluxes become constitutive of itself.
While natural selection excludes traits or phenotypes that are not compatible with a given context, it is not an optimization process towards the generation of the 'fittest.' Fitness as a category is not absolute since it varies depending on environmental influences, and furthermore, the fitness of a phenotype can only be judged a posteriori. If the individual has such porous boundaries, which is then the unit of selection? On what level does natural selection act?

> From the side of "hosted" entities (symbionts) bacterial strains are selected by internal habitat changes (e.g. the interference of antibiotics), so that the major body is the context (milieu) where plural micro-diversity evolves. In this case the individual is replaced by nested systems of various different entities, a micro-ecology where what matters are the boundaries between parties, membranes, trophic exchanges (i.e. "microbiota"). From the major organism's perspective (holobiont/hologenome), instead, the "dividual" is selected as a cohesive unit.[21]

The holobiont concept emerges in the tension between the *individual as a multiplicity* and the *dividual as a unit virtually separated from the whole*; as a cohesive unit constituted from a multiplicity of organisms, it can do things that none of its parts could while maintaining a degree of independence from the biosphere. There is no sharp distinction between the subject and the environment. Without such dynamic coupling, neither the organism nor its adaptation would be possible. While at the same time, if the coupling is extremely tight, the organism might lose its identity.[22]

The holobiont is a dynamic entity in which certain microorganisms multiply and others decrease in number: "microbial amplification is a powerful mechanism for adapting to changing conditions."[23] The subject is like a warp and weft fabric in which a multiplicity

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20 Elena Gagliasso, "Individuals as Ecosystems: An Essential Tension," *PARADIGMI*, no. 2 (August 2015): 87.

21 Elena Gagliasso, "Individuals as Ecosystems: An Essential Tension," 93.

22 Susan Oyama, *The Ontogeny of Information: Developmental Systems and Evolution*, (Cambridge: New York: Cambridge University Press, 1985), 182.

23 Ilana Zilber-Rosenberg and Eugene Rosenberg, "Role of Microorganisms in the Evolution of Animals and Plants: The Hologenome Theory of Evolution," *FEMS Microbiology Reviews* 32, no. 5 (August

of fluctuations of different scales and orders spiral through each other, bringing forth our perceptual experience and determining our understanding of nature and our attitude towards it. Shizengaku—which literally translates as nature-ology (*shizen* means 'nature' and -*gaku* means "study of")—postulates a three level structure for understanding nature: *specion*, *specia*, and *holospecia*.

Specion refers to an individual organism (or holobiont). *Specia* refers to all the individuals of a species understood as an "existent entity with an autonomous nature;"[24] where each of the members contributes to the perpetuation of the specia to which it belongs. And finally, the *holospecia* is understood as a "unit composed of all the extant specia on the Earth."[25] Even if living organisms have developmentally diverged in myriad forms from a single unit, all of them are interwoven by an immanent force: the *ch'ulel*.[26] Imanishi considers that all structures are the result of gradual development, and thus, if we want to speak about living organisms we always need to consider them as alive: they are continuously changing in relation to the other biotic and abiotic subjects that co-constitute their ecosystem. As a call for an intersubjective life science, it inter-relates the myriad of living things which are continuously turned against each other by western technoscience.

Oyama argues that the belief in genetic determination seems to be rooted in our desire to derive from science the answers to very old questions about what we are meant to be and what we can be,[27] but which ultimately remain unresolved, and further confused in the rationale of abstract mathematical formulas. If modern science cannot solve such questions, what could solve them? When thinking about ontogeny, meaning the development of an organism during its lifespan, Oyama mentions that the developmental information itself has a developmental history, which "neither preexists its operations nor arises from random disorder."[28] Developmental information is then constructed as an organism constructs its own evolutionary path; but not as a function of pure chance. Random variation is crucial to its formation and its functioning, where intentionality and adaptation are involved too.

2008): 723.

24 Imanishi, "A Proposal for Shizengaku: The Conclusion to My Study of Evolutionary Theory," 361.

25 Imanishi, "A Proposal for Shizengaku: The Conclusion to My Study of Evolutionary Theory," 361.

26 López Intzín, "The Ch'ulel-Multiverse and Intersubjectivity in the Maya Tseltal Stalel," 13, 18.

27 Oyama, *The Ontogeny of Information: Developmental Systems and Evolution,* 8.

28 Oyama, *The Ontogeny of Information: Developmental Systems and Evolution*, 3.

4. Cascade of Symmetry Changes

Prigogine and Stengers consider that modern technoscience was axiomatized by a homogeneous and isotropic space as conceptualized by Euclid, contrary to the Aristotelian space, "for which one source of inspiration was the organization and solidarity of biological functions."[29] In their theory of dissipative structures, which relies on the latter, fluctuations are able to cause instabilities in which symmetry breaks emerge.[30] A dissipative structure is an open system operating out of, and often far from, equilibrium. Differently from close-to-equilibrium situations, in far-from-equilibrium systems behaviors become highly specific. When far from equilibrium, universal laws are no longer valid to deduce the overall behavior of a system.[31] In each particular system, qualitatively different behaviors may emerge. Thus, the trajectory of the diverse systems continuously bifurcate, as cascades of symmetry change define particular structures and functions that may appear as completely dissimilar from the once homogeneous single unit which Imanishi considers as the basis of the fundamental relationship between every biotic and abiotic subject.[32]

Bifurcation points are the critical moments from which a new state becomes possible: "The points of instability around which an infinitesimal perturbation is sufficient to determine the macroscopic operating regime of a system."[33] Far from equilibrium, new structures and functions become possible, destabilizing the system from which they emerged, developing a succession of amplified instabilities and fluctuations.[34] Unlike physical systems which can be analyzed through their instantaneous flows, understanding a biological organization requires a historical analysis too. Evolutionary history is thus an ever growing fractal of phylogenetic and ontogenetic trajectories in which cascades of symmetry change generate anatomical and functional variability.[35]

Longo and his colleagues propose a Theory of Organisms with two founding principles: (1) the default state of cells as proliferation with variation and motility, and (2) non-identical iterations of a morphogenetic process as the framing principle. The first one refers to variation as a symmetry change happening through reproduction, a "descent with modification," which is driven by motility: the capacity of an organism to move independently using forces and flows of energy and matter. The second refers to life

29 Prigogine and Stengers, *Order out of Chaos: Man's New Dialogue with Nature*, 171.

30 Prigogine and Stengers, *Order out of Chaos: Man's New Dialogue with Nature*, 171.

31 Prigogine and Stengers, *Order out of Chaos: Man's New Dialogue with Nature*, 145.

32 Imanishi, *A Japanese View of Nature: The World of Living Things*, 2.

33 Prigogine and Stengers, *Order out of Chaos: Man's New Dialogue with Nature*, 186.

34 Prigogine and Stengers, *Order out of Chaos: Man's New Dialogue with Nature*, 186.

35 Longo et al., "In Search of Principles for a Theory of Organisms," 955–68.

phenomena as non-identical iterations of a morphogenetic process through which organization is iterated and maintained.[36] Can this Theory of Organisms be intermixed with the theory of lateral gene transfer? In recent years, the idea of *reticulate evolution* has been conceptualized as a way to conceive biological evolution in a web-like pattern instead of a tree. In addition to the descent with modification and the non-identical iterations of morphogenetic processes, which could be described as the vertical threads of our evolutionary fabric, lateral gene transfers can be understood as the horizontal threads which interweave evolutionary processes as a web of life.

The theory of lateral gene transfer has posited that apart from the vertical gene transfer that happens in a species' reproductive cycle, an individual may exchange genes with other living organisms and with other viral genetic agents which are traditionally conceived as non-living beings. Natalie Gontier argues that the acquisition of foreign DNA through lateral gene transfer allows us to think about evolution beyond the rigidity of common descent with modification. And thus, gene exchange can occur between organisms that are commonly rendered as distant by the image of the tree of life.[37]

Contrary to Neo-Darwinian thought, genes do not merely "move" out of selfish "needs" for propagation, several mutualistic benefits can be identified which result from horizontal gene transfer, including DNA repair, genome growth, and acquisition of novel functions. Reticulate evolution enables us to render a weblike image of life in which plural mechanisms, patterns and processes are constantly changing the symmetries of biocultural systems. For Oyama, a "view of the biological world that reduces cause to discrete genetic and environmental forces reduces living beings to infinitely thin membranes resonating to signals from within or without but lacking the substance to generate signals of their own."[38]

5. Negentropy and Antidomestication

In the experience of life as rendered through NBIC technoscience, the domestication syndrome is becoming an almost generalized characteristic for several members of the biocultural world. Thus, the production of diversity –as a negentropic process– becomes a necessity if we ever want to experience life outside of modernity's monoculture. Modern

36 Longo et al., "In Search of Principles for a Theory of Organisms," 955–68.

37 Nathalie Gontier, "Historical and Epistemological Perspectives on What Horizontal Gene Transfer Mechanisms Contribute to Our Understanding of Evolution," in *Reticulate Evolution: Symbiogenesis, Lateral Gene Transfer, Hybridization and Infectious Heredity,* ed. Nathalie Gontier (Cham: Springer International Publishing, 2015), 161.

38 Oyama, *The Ontogeny of Information: Developmental Systems and Evolution*, 162.

progress is a linear movement that progressively closes its trajectory towards decline; and in this process, human invention is only enacted towards conventionalization to maintain the constraints which render the ways of modernity as unconditional. The experience of life, as run through NBIC technologies, produces biocultural entropy and therefore diminishes diversity.

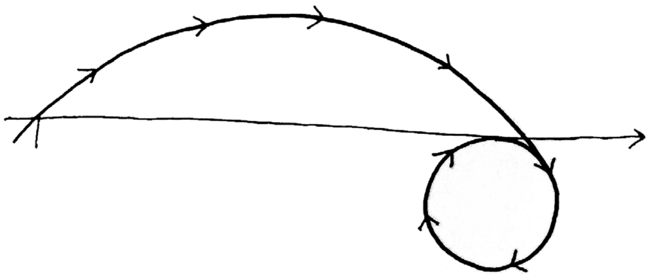

Figure 1. *The self-closure of a bioculture.* (Drawn by Diego García).

Experiencing the rise of mass biological and ontological homogenization imposed by modern human activity, is it possible that human technical activities can produce biological diversity? While modern human enaction imposes its entropic tendency to whatever it touches, in several non-modern biocultures the production of biological diversity is inherent to technical activities. Manuela Carneiro da Cunha describes people in the Amazon –specifically women agriculturalists– as *producers of biodiversity*:

> Women will attentively observe the new-comers [seedlings]. They will separate spots for them and they will be experimented upon for at least two or three years. Their first year tubers–one single conical tuber per individual–will be unique and distinct from subsequent years' tubers. Only when they are replanted from stem cuttings will they show their true colors, qualities, or specificities.... Different varieties will be ripe at different moments. The earlier ones can be harvested after just six months. This is no doubt a practical reason for planting different varieties in a single garden. But it can hardly explain the excess that certain women indulge in, of cultivating up to 40 varieties in their gardens.[39]

Carneiro Da Cunha mentions that the people she worked with in the Rio Negro basin, maintain a minimum of three gardens at once, each in a different stage; they understand

39 Manuela Carneiro Da Cunha, "Traditional People, Collectors of Diversity," in *The Anthropology of Sustainability*, ed Marc Brightman and Jerome Lewis (New York: Palgrave Macmillan US, 2017), 263.

the new seedlings "as both coming from and belonging to 'the old folks' (*os antigos*) and paradoxically (since they are result of sexual reproduction) as orphans."[40] Can we also aim to become producers of biocultural diversity, not only through conducting technical activities such as agriculture and fermentation upon other biological species, but also by catalyzing divergence in our own selves, through the transformation of our microbiome, for example?

According to Nicholas Georgescu-Roegen the three basic elements needed for life are: "first, matter (such as natural resources); second, energy; [and] the third and more mysteriously is diversity, also known as low or negative entropy."[41] Entropy is low when internal diversity is high, and it grows as diversity decreases. The concept of entropy introduced the idea of irreversibility to the reversible physicist's world.[42]

Structure and function develop as two spirals that revolve around each other through the arrow of change that is time. And this interplay of emergence is intersected by the technical activities of organisms, which generate constraints on evolutionary trajectories and at times create cascades of symmetry change. Prigogine and Stengers argue that entropy, as the dissipation of energy and matter, is generally associated with the concepts of loss and evolution towards disorder, but far from equilibrium it can turn into a source of order.[43] Just like the forest after the slash-and-burn process of agroforestry, an almost desertified biological and ontological landscape could allow the possibility of a reforestation in which diversity flourishes.

Cultivating the seeds that remain from the human premodern biocultures, the futures we want to harvest are more similar to the premodern modes of enaction—the *ancestral futures* as Ailton Krenak conceptualizes—than to the technocratic fantasies of the NBIC paradigm.[44] Can localized biocultural invention enable biological and ontological diversification processes that take us beyond the contemporary state of things? Can the processes of bio-ontological homogenization be stopped before the world-landscape is completely desertified?

Carneiro da Cunha has referred to the agroforestry activities enacted by the Jamamadi people of the Amazon with the concept of *antidomestication*. These people oscillate freely between forms of living; through their practice of swidden agriculture, they resist the so-called progress, the supposedly universal "evolution" assumed to be irreversible

40 Carneiro Da Cunha, "Traditional People, Collectors of Diversity," 263.

41 Carneiro Da Cunha, "Traditional People, Collectors of Diversity," 257.

42 Carneiro Da Cunha, "Traditional People, Collectors of Diversity," 258.

43 Prigogine and Stengers, *Order out of Chaos: Man's New Dialogue with Nature*, 143.

44 See Ailton Krenak. *Futuro ancestral*. (São Paulo: Companhia Das Letras, 2022).

from foraging to domesticated life.[45] As much as former nomads can become gardeners, agriculturalists are able to morph into foragers. This is possible through the constitution of synanthropic regenerative biocultural niches.

The interaction between Amazonian people and the tropical forest "implies that both are part of a social-ecological system, formed by mutually dependent feedbacks."[46] The Amazon tropical forests are composed of a multiplicity of other beings, and the Jamamani particularly understand that there is no such thing as wild plants, since everything is cultivated by some "other" cultivator.[47] Positive feedback within an agroforestry system such as the Amazon can then be understood as a multispecies interaction in which every member is participant in the axiomatization of the rest of the members; this amplifies food availability at large scales. In this contextual and local management of the tropical landscapes, the selection, cultivation and dispersing of plants intersects the ecological processes that shape the composition of the forest. A main quality of this positive feedback, is that when local people and their techniques are excluded from the system, landscape's composition changes too, since several non-human populations are dependent on human interaction.

Each ecological equilibrium is only temporary since all organisms are continuously constituting and modifying niches through their conscious and unconscious activities. The metabolic functions, which entail the acquisition of energy from food and beverages, can be more widely understood as the physical and chemical mode in which the environment is incorporated into the subject. Imanishi argues that "the digestive tract might be considered as a part through which the outside world penetrates our body and as such is an extension of the environment entering the body."[48] So even if a living organism is a self-contained system, its body assimilates food and thus continuously incorporates elements from the environment into itself. The metabolic coherence of behavior seems to be developmentally given for all species in the biosphere, except for modern humans who are continuously branching out from it. The possibility for organisms to change the symmetry of an evolutionary trajectory is conceptualized by Prigogine and Stengers as:

> Autocatalysis (the presence of X accelerates its own synthesis), autoinhibition (the presence of X blocks a catalysis needed to synthesize it), and crosscatalysis (two products belonging to two different reaction chains activate each other's

45 Manuela Carneiro Da Cunha, "Antidomestication in the Amazon: Swidden and Its Foes," *HAU: Journal of Ethnographic Theory* 9, no. 1 (March 2019): 185.

46 Bernardo M. Flores and Carolina Levis, "Human-Food Feedback in Tropical Forests," *Science* 372, no. 6547 (11 June 2021): 1146.

47 Carneiro Da Cunha, "Antidomestication in the Amazon: Swidden and Its Foes," 172.

48 Imanishi, *A Japanese View of Nature: The World of Living Things*, 26.

> synthesis).[49]

The development of the organisms' behavioral schemes happens in the same manner as the web-like image that reticulate evolution has brought forth to the development of biological species. Behaviors are also transferred vertically from generation to generation as descent with modification emerging in non-identical iterations, and also shared horizontally in intraspecies and interspecies transfers. Imanishi argued that species must be something which creates itself, meaning that its origin and transformation must be in the species itself;[50] In this view, the processes of autocatalysis, autoinhibition and crosscatalysis are enacted by its members. If these processes can be initiated by any member or group, this means that there can be wide degree of variation between the members of a species:

> this range of change among individuals does not indicate the absolute limit of mutability. Living things with the potential for random variation always have a limit relative to the environment. Yet there may be times when mutants go beyond this limit.[51]

According to Imanishi, a species suppresses extreme forms of mutation by modulating variability to maintain a state of equilibrium; this can be understood as the tendency to preserve the status quo, or to prevent the emergence of a weak line of development. The modulation of mutations concentrates variations to make as many individuals as possible maintain a middle path of change: this can also be thought of as the strengthening of the species itself, which is probably one expression of its autonomy.[52] In the contemporary world, unpredictable conditions are constantly emerging, and thus, environmental pressures are reaching a level of almost complete randomness.

While decontextualized top-down solutions are being imposed upon the whole planetary population, it is evident that the one-size-fits-all approaches have not only failed to work efficiently, but have also played a key role in the enablement of contemporary climate change. Inhabiting a planet in which environmental pressures are changing relatively fast, organisms need to adapt to emerging conditions in order to survive. How can processes of autocatalysis, autoinhibition and crosscatalysis be initiated by techniques developed through biocultural inventions?

Invention stands as the sign of differentiation, and the processes of differentiation are bounded in an interplay with processes of conventionalization. Differentiating

49 Prigogine and Stengers, *Order out of Chaos: Man's New Dialogue with Nature*, 153.

50 Imanishi, *A Japanese View of Nature: The World of Living Things*, 62.

51 Imanishi, *A Japanese View of Nature: The World of Living Things*, 148.

52 Imanishi, *A Japanese View of Nature: The World of Living Things*, 79.

symbolization delineates radical distinctions upon the flow of construction which are later assimilated by the processes of convention. Meanwhile, conventional symbolization reintegrates differentiations by bestowing order and rational constructions.[53] The collective viewpoint or orientation of a culture—meaning the way in which its members learn to experience the world—is created through the alternation between acts of differentiation and conventionalization.

This oscillation between differentiation and conventionalization is parallel to Imanishi's thought when he mentions that "in the body of a living thing certain characteristics actively change in a certain direction, but there are other characteristics that are conservative and offset the active change."[54] In shinzegaku, change is structural and morphological as much as functional and behavioral, asserting a continuity between the psychic and the physical realms:

> the origin of the species is a problem of how did these kinds of cultural characteristics diverge and develop to the point where they became a defining feature of the species.[55]

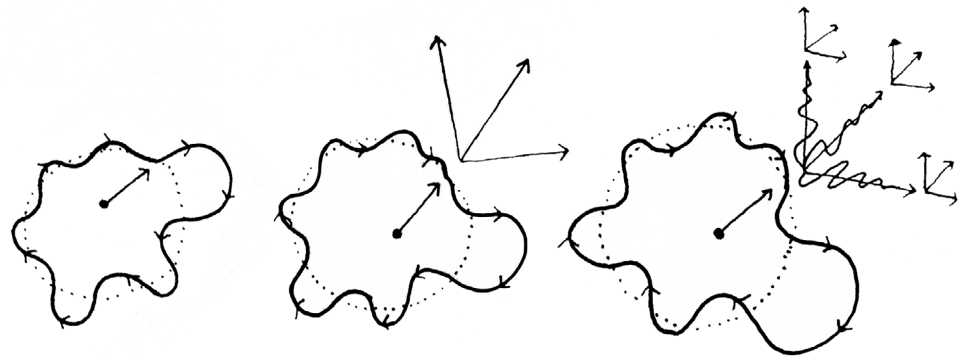

Figure 2. *Differentiation and conventionalization.* (Drawn by Diego García). When a difference emerges, it is amplified until becoming a figuration that is then conventionalized. In the moment in which a difference is conventionalized, it axiomatizes subsequent processes of differentiation.

Oyama mentions that a single genotype may be developmentally mapped onto many phenotypes, which do not necessarily emerge in continuous variation. Evolution is an interactive process whose constraints and causes emerge as it functions.[56] As contemporary

53 Roy Wagner, *The Invention of Culture*, 39.

54 Imanishi, *A Japanese View of Nature: The World of Living Things*, 80.

55 Imanishi, *A Japanese View of Nature: The World of Living Things*, 82.

56 Oyama, *The Ontogeny of Information: Developmental Systems and Evolution*, 45.

climate change exponentially escalates, biological species must find their way of survival within contingent environmental pressures that are continuously emerging. But, as it is described by the developmental theory of evolution, environmental pressures have constantly changed since the first organisms emerged. While some variations might only stay during the lifespan of an individual or a community when they encounter emergent environmental pressures, if "the aberrant life cycle becomes the typical one... the conditions for the new character will be present for each new generation."[57]

Phenotypic variation is not just different ways of *appearing*, it is different ways of *being*.[58] If variation is expressed in the human species through specific physical and behavioral characteristics, why does the vast and diverse human population tend towards homogenization? Modern technoscience, as an entropic force, has a tendency towards normative homogenization; its inventive processes are enacted within the NBIC framework, and its main goal is capitalist accumulation. The emergence and proper functioning of modern technoscience happens through the installment of a moral of compatibility as a source of normativity, which imposes a fundamental, a priori image that modulates the role of the person[59] to inherently allow the extractivism-pollution-exploitation of nature as a standing-reserve.[60] Stengers and Prigogine ask:

> What would happen if, as a result of certain uncontrollable events (e.g. mutations, technical innovations), constituents of a new type [of fluctuations] were introduced that could take part in the system processes and multiply with their help?[61]

New constituents introduced in small quantities bring a new set of reactions between the components of the system, which then begin to compete against the preexistent ones. When a system is structurally stable, the new mode of functioning won't be able to establish itself, and the "inventors" won't survive. But if these "inventors" are multiplied fast enough to invade the system instead of being destroyed, the whole system will adopt a new mode of functioning and its activity will be governed by a new 'syntax.'[62] A population's nonlinear interactions determine the possibility of appearance for particular modes of evolution (snowball effects, epidemic spreads, differentiation by amplification of small differences).[63] How to unchain such fluctuations?

57 Imanishi, *A Japanese View of Nature: The World of Living Things*, 175.

58 Imanishi, *A Japanese View of Nature: The World of Living Things,* 169.

59 Gilbert Simondon, *Imaginación e Invención*, (Buenos Aires: Cactus, 2015), 181–182.

60 Martin Heidegger, "The Question Concerning Technology," in *The Question Concerning Technology and Other Essays*, trans. William Lovitt (New York and London: Garland Publishing, 1977), 23.

61 Prigogine and Stengers, *La nueva alianza: metamorfosis de la ciencia*, 200.

62 Prigogine and Stengers, *Order out of Chaos: Man's New Dialogue with Nature*, 190.

63 Prigogine and Stengers, *La nueva alianza: metamorfosis de la ciencia*, 209.

Simondon considers that the most simple invention relies on the operational models that are already functioning within a system: "the operational models with their motor content constitute by themselves the most elementary of the axiomatics that do not need to be constructed since they are delivered by the organism itself."[64] That is to say that this mode of invention relies on the metabolic coherence of the biocultural axiomatics that bring forth a heterarchical organization between subjects. Such simple inventions inherently possess symbiotic characteristics, and thus, when enacted by humans, they cannot be differentiated from the technical activities of other species. The symbiotic invention of biocultural techniques takes advantage of ecological plasticity to reconfigure ecosystems.

Through a localized axiomatization, symbiotic inventions are individually and collectively applied to multiple scales: to an ecosystem as a whole in the process of niche constitution, to a community of individuals from another biological species, and to the body of oneself understood as an ecosystem. Symbiotic inventions can enable processes of autocatalysis, autoinhibition and crosscatalysis.

6. The Fractal of Evolutionary Warps and Wefts

Since an ecosystem is composed of a multiplicity of organisms interacting with one another, the behavior of one species has an influence on the axiomatization of another species' behavior, and thus: *behavior affords behavior*.[65] Relying on multi-species interaction, symbiotic invention happens as a subtle process through time and space, and given the necessary conditions for its amplification, it can unchain fluctuations that can destabilize, stabilize and reconfigure whole ecosystems. Evolutionary dynamics often involve causal interactions between entities from distinct levels of biological organization, or operating at different time scales, who are responsible not only for the destabilization of pre-existing entities, but also for the emergence and stabilization of novel entities.[66]

A main quality of imagination is "the capacity of the prediction of qualities that are not practical in certain objects, that are neither directly sensorial nor entirely geometric, that relate neither to pure matter nor to pure form, but are at this intermediate level of schemas."[67] How can we radicalize our imagination to predict and enable emergent qualities in our ecosystems, other species, and our own bodies, functionally, structurally

64 Simondon, *Imaginación e invención*, 170.

65 James Gibson, *The Ecological Approach to Visual Perception: Classic Editi*on (New York: London: Psychology Press, Taylor & Francis Group, 2015), 121

66 Eric Bapteste and John Dupré, "Towards a Processual Microbial Ontology," *Biology & Philosophy* 28, no. 2, 379.

67 Gilbert Simondon, *On the Mode of Existence of Technical Objects* (Minnesota: Univocal, 2016), 74.

and even aesthetically? We are interested in exploring the possibility of a system's destabilization and reconstitution through the modulation of the plasticity of biotic and abiotic subjects and of whole environments.

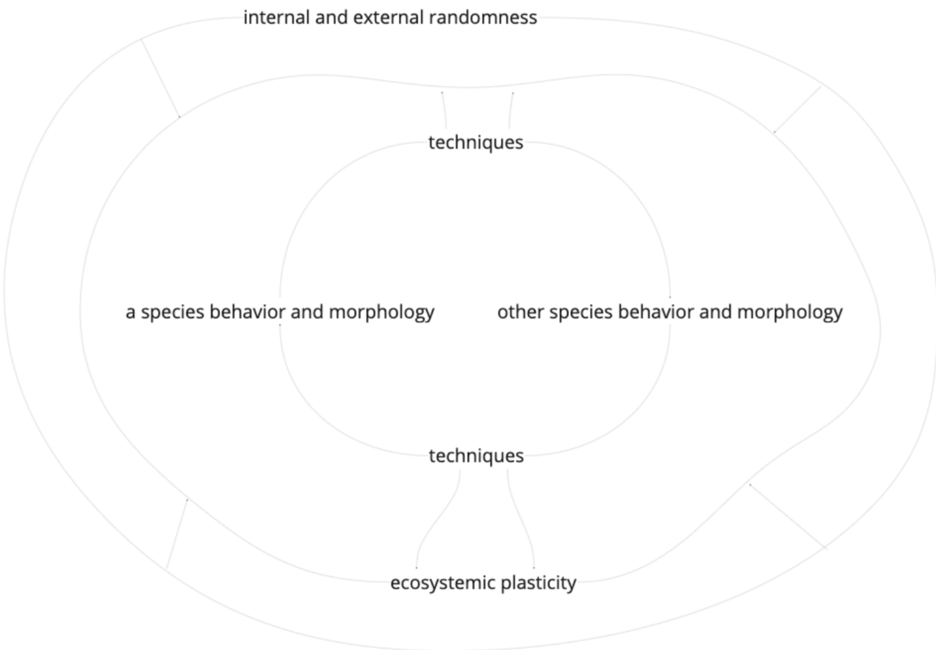

Figure 3. *Behavior affords behavior.*

The word plasticity unfolds its meaning "between sculptural molding and deflagration, which is to say explosion,"[68] and this precisely characterizes the relation that a subject maintains with events of different orders. Longo and colleagues consider that…

> evolution is both the result of random events at all levels of organization of life and of constraints that canalize it, in particular by excluding, by selection, incompatible paths — where selection is due both to the interaction with the ecosystem and the maintenance of a possibly re-newed internal coherent structure of the organism, constructed through its history.[69]

Organisms are in a state of permanent transition in which random events arising from both their internal and external ecosystems generate the necessity for adaptability. Mary Jane West-Eberhard mentions that environmentally induced variations are heritable insofar as

68 Catherine Malabou, *What Should We Do with Our Brain?*, trans. Sebastian Rand (Fordham University Press, 2008), 70.

69 Longo et al., "In Search of Principles for a Theory of Organisms," 955–68.

the ability to respond by producing them is heritable, meaning: genetically variable. The responsiveness of organisms to the influence of the environment involves mechanisms that normally are genetically complex and therefore subject to genetic variation.[70] While environmental factors can affect numerous individuals simultaneously, mutation may initially affect only one.

Plastic modulation refers to the modification of the interactions between the biotic and abiotic constituents of an organism/ecosystem. Modification can be applied to characteristics such as rhythm, frequency or degree of intimacy of the parts. This might allow the transformation of the size of a population or the efficacy of a function and a structure. Plastic modulation can be reparative to the extent that lost interactions can be re-established while undesirable interactions can be diminished. While we cannot define a standard set of rules to determine the efficient functioning of an ecosystem, the detailed observation of the localized metabolic dynamics should be the main indicator to understand the health of its trophic interactions. But instead of approaching our role as producers of diversity through the tools provided by the NBIC paradigm, can we conduct these technical endeavors through our intuition?

Antidomestication, as an approach for modulating the plasticity of organisms/ecosystems, can enable differentiating fluctuations that cause a state of instability to encourage environmental heterogeneity through the creation of ecological patches, mosaics, and edges. This mode of inhabiting a landscape avoids turning human interests into hegemony and unchains processes of ecological feedback towards humans.

Stengers and Prigogine consider that the absolute character of scientific statements used to be considered a sign of universal rationality, meaning that universality should entail the negation and overcoming of all cultural particularities. From their perspective there is a need to construct a way of conducting scientific endeavors where there is no longer a denial of the concerns and questions of the societies in which it develops, maintaining a dialogue with humans from all cultures, and learning to respect their particular questions.[71] Perhaps what Viveiros de Castro has referred to as *multinaturalism* can lead such an endeavor. The idea of multinaturalism affirms the multiplicity *in* cultures, bringing forth the naturalness of variation or, more precisely, championing that we need to apprehend variation *as* nature.[72]

Different organisms evolve at different time scales, and thus evolution operates in

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70 Mary Jane West-Eberhard, "Developmental Plasticity and the Origin of Species Differences," *Proceedings of the National Academy of Sciences* 102, no suppl_1 (May 2005): 6547.

71 Prigogine and Stengers, *La nueva alianza: metamorfosis de la ciencia*, 44.

72 Eduardo Viveiros De Castro, *Cannibal Metaphysic* (University of Minnesota Press, 2014), 65–75.

fragmentary multinatural relationality. Imanishi considers that to live is to act and to create, and in that sense, all the daily life of living things is part of evolution.[73] Is it possible then to diversify the imposed homogeneity of the current global order through differentiating fluctuations which start from local contexts? How to develop new structures and functions through contextual techniques?

Stengers and Prigogine assure us that "close to equilibrium, the laws of fluctuation are *universal*, while far from equilibrium, [...] the relative value of dispersion *no longer obeys* the general formula,"[74] and thus, the trajectory of each fluctuation becomes highly specific. Fluctuations emerging from the instability of a bifurcation point might be correlated, to the point that macroscopically distant regions will stay in relation, and thus local events might affect the totality of the system. The production of biodiversity (negative entropy) is an *immeasurability*,[75] and rather than conducting our life processes with the sole aim to produce biodiversity, the beings which maintain a metabolic coherence with the ecosystem are inherent producers of biodiversity. What is the role of intentionality then?

The discovery or introduction of a new technique can generate the axioms to overcome social, technological, economic or ecological orders through their radiation. The amplification of such innovations might need a ground in which they can flourish, but simultaneously establish never before seen conditions to propel their own multiplication. According to Oyama there are three kinds of radiation: (1) ontogenetic (differentiation), (2) phenotypic (variation among individuals with the same genotype, norm of reaction) and (3) evolutionary (phylogenetic divergence). All three of them share the qualities of constancy, change, and variability.[76] Dissipative structures irradiate fluctuations in multiple non-linear trajectories, and thus we can conceive evolution as fractalizing cascades of symmetry change. Danièle Dehouve contrasts natural fractals as the result of self-organization, with cultural fractals that proceed from human voluntary organization.[77] But what happens when we understand evolution as an interrelated fragmentary history with no barrier between nature and culture? Is there an actual difference between biological self-organization and human voluntary organization when speaking about biocultural fractals? Perhaps a more precise image of evolution would come as a multiplicity of interweaving spiral warp and weft fabrics –of variable scales, dimensions, and orders– in which each single fluctuation can further fractalize.

73 Imanishi, *A Japanese View of Nature: The World of Living Things*, 68.

74 Prigogine and Stengers, *La nueva alianza: metamorfosis de la ciencia*, 202.

75 Édouard Glissant, *Poetics of Relation*, trans. Betsy Wing (Ann Arbor: University of Michigan Press, 1997), 61.

76 Oyama, *The Ontogeny of Information: Developmental Systems and Evolution*, 52.

77 Danièle Dehouve, "El fractal: ¿una noción útil para la antropología americanista?" *Desacatos* 53, (Jan–April 2017), 136.

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A Conceptual History of Entropies from a Stieglerian Point of View: Epistemological and Economic Issues of the Entropocene

Anne Alombert

Abstract:
In this article I will try to suggest a transdisciplinary conception of entropy in order to analyse the contemporary ecological polycrisis which is usually described as the Anthropocene era. According to French philosopher Bernard Stiegler, the Anthropocence can be understood as an Entropocene, because the current ecological crisis consists of a process of massive increases of entropy in all its forms: thermodynamic entropy (that is, dissipation of physical or chemical energy), biological entropy (as the destruction of biodiversity), and psycho-social entropy (as the reduction of knowledge to data and calculations, through digital disruptive technologies). In order to analyse this situation, we need a transversal conception of entropy: from Bergson's philosophy of life to Stiegler's philosophy of technics, through Schrodinger's physics, Wiener's cybernetics, Lotka's biology and Levi-Strauss's anthropology, I will try to build a conceptual history of entropies from a Stieglerian point of view and to explore its economic and political consequences in Stiegler's thought, in order to open new paths beyond the Entropocene era.

Keywords:
entropy, Entropocene, neganthropy, economy, ecology, technology, Stiegler, Georgescu-Roegen

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Introduction

In 1971, a year before the publication of the Meadows Report titled *Limits to Growth*, mathematician and economist Nicholas Georgescu-Roegen published an article titled "The entropy law and the economic process"[1] in which he argued that economic theory should take into account the consequences of the entropy law, which is to say, of the second law of thermodynamics. According to Georgescu-Roegen, orthodox economics is based on a mechanistic epistemology that does not take into account the scientific revolution of thermodynamics, and which, for this precise reason, is no longer relevant. This mechanistic epistemology tends to represent the economic process as a circular process closed in on itself in a state of equilibrium, and thus prevents consideration of the interactions between the economic process and the natural environment. However, as Georgescu-Roegen reminded us, "nature plays an important role in the economic process … [and] … it is high time to accept this fact and to consider its consequences for the economic problem of humanity."[2] Georgescu-Roegen thus insisted on the necessity of rethinking the connections between entropy, ecology and economy.

Almost fifty years later, the French philosopher Bernard Stiegler, inspired by Georgecu-Roegen's analysis, also suggested that the question of entropy should be put back at the heart of ecological and economic debate. Indeed, in a book titled *Bifurcate*[3](2020), he describes the Anthropocene era as an "Entropocene era," that is to say, as a process of massive increase of entropy in all its forms, at the physical and biological level on one side and at the psychic and collective level on the other side: "the various disturbances afflicting the current stage of the Anthropocene era *all* consist in an increase of (1) thermodynamic entropy, as the dissipation of energy, (2) biological entropy, as the reduction of biodiversity, and (3) informational [or psychosocial] entropy, as the reduction of knowledge to data and computation.[4]" Such an analysis no longer relies on an opposition between humanity and life or between culture and nature: on the contrary, the concept of entropy is used to understand the transversal link between the destruction of ecosystems, species and biodiversity on one side (described as an increase in entropy at the environmental and biological levels) and the destruction of knowledge, cultures and "socio-diversity" on the other side (described as an increase in entropy at the informational, psychic and collective level).

1 Nicholas Georgescu-Roegen, "La loi de l'entropie et le problème économique," in *La décroissance: entropie, écologie, économie,* trans. Jacques Grinevald and Ivo Rens (Paris: Ellébore-Sang de la terre, 2006), chapter 1.

2 Georgescu-Roegen, "La loi de l'entropie et le problème économique."

3 Bernard Stiegler *et al.*, *Bifurquer : Il n'y a pas d'alternatives* (Paris: Les liens qui libèrent, 2020). Bernard Stiegler *et al.*, *Bifurcate: There is no alternative*, trans. Daniel Ross (Open Humanities Press 2021).

4 Stiegler *et al.*, *Bifurcate*, 28.

Nevertheless, this notion of an Entropocene raises many problems. One of the major problems lies in the fact that the physical concept of entropy cannot be sufficient in order to think the Entropocene, because the production of entropy does not take on the same forms or the same meaning in the context of physical, vital or psycho-social phenomena: biological life is irreducible to physical laws, just as noetic, cultural or social life is irreducible to biological laws. If we do not want to fall into reductionism, it is necessary, as Stiegler writes, to "specify the articulation of entropy and life, first with regard to the diverse forms of living things, and second with regard to the specific case of human societies."[5] But this is a quite complex task, since, as Stiegler also points out, "the academic system has not [yet] integrated entropy as a question of physics, nor its consequences for the definition of living beings [...], nor therefore the question of the resulting limits for human action."[6]. For Stiegler, this means that the question of entropy needs to be thought differently in the field of physics, in the field of biology, and in the field of anthropology and technology, but that all these fields also must cooperate together, which is particularly difficult given the current disciplinary frontiers.

So, in order to consider the Entropocene era, we need a transdisciplinary and differentiated conception of entropy, but such a conception does not yet exist, because the question of entropy has not been the object of any transversal theorization beyond the field of thermodynamic physics and theoretical biology. Moreover, even in these scientific fields, the question of entropy has been at the origin of many controversial debates between physicists and biologists. In the fields of social science, the situation is even more problematic, because the notion has been monopolized by information theory since the 1950s, which has prevented its appropriation from other perspectives. Although some authors today use such notions as "psychic entropy" to designate a state of "self-disorganization" caused by attention deficit disorder[7] or as "social entropy" to designate the institutional collapse caused by neoliberal and capitalist economies[8], such analyses do not rely on a specific theory of entropy, so they seem to use the notion in a quite metaphorical way.

We are thus faced with a double problem: on the one hand, we must avoid a reductionist conception of entropy (which would limit the concept to its thermodynamic meaning, thus denying the irreducibility of biological life and social life to the laws of physics), and, on the other hand, we must avoid a metaphorical conception of entropy (which would use the

5 Stiegler *et al., Bifurquer,* §20, 68. (*Bifurcate*, 52)

6 Bernard Stiegler, "Démesure, promesses, compromise," *Mediapart,* September (2020), https://blogs.mediapart.fr/edition/les-invites-de-mediapart/article/070920/demesurepromesses-compromis-23-par-bernard-stiegler.

7 Mihaly Csikszentmihalyi, *Flow: The Psychology of Optimal Experience* (London: Harper Perennial, 1990).

8 Wolfgang Streeck, *How Will Capitalism End? Essays on a Failing System* (London: Verso, 2017).

concept as an image to describe psychic disorganization or social disorder). To overcome this alternative, I will try to turn back to the history of this notion, not only in the fields of thermodynamics or information theory, but in the fields of biology, anthropology, and philosophy. Indeed, the discovery of the second law of thermodynamics had strong repercussions in all these fields during the twentieth century, and through its circulation in different fields, the notion of "entropy" also went through important transformations. From Bergson's philosophy of life to Stiegler's philosophy of technics, passing through Schrodinger's physics, Wiener's cybernetics, Lotka's biology and Levi-Strauss's anthropology, I will try to show that, today, we are in possession of some conceptual tools with which to build a transversal and transdisciplinary conception of entropy, which cannot constitute an integrated philosophical system, but which requires an articulation between different scientific fields. I will try to explore the economic and political consequences of this conceptual history of entropies in Stiegler's work, in order to open new paths beyond the Entropocene era : the second aim of this article is to show that we need an "anti-anthropic" economy in order to take care of biodiversity and of noodiversity.

I. From Thermodynamics to the Evolution of Life: From Entropy to Anti-entropy

1. Entropy in Thermodynamics: Degradation and Dissipation of energy

The notion of entropy emerged in the field of thermodynamic physics in the nineteenth century (through the works of Sadi Carnot, Rudolf Clausius, and Ludwig Boltzmann, in particular). In its classical sense, in thermodynamics, entropy designates a "measure of the non-usable energy in a system": in a thermodynamic system, an increase in entropy corresponds to a degradation or a dissipation of energy, which passes from a usable or free state (energy over which man can exercise almost complete control) to an unusable or bound state (energy which man can absolutely not use)[9] Therefore, the law of entropy shows that during the transformation of a physical system, the energy is not consumed but changes its state: for example, to take the case mentioned by Georgescu-Roegen, "when a piece of coal is burned, its chemical energy neither decreases nor increases … but the initial free energy has been so dissipated in the form of heat, smoke and ashes, that man can no longer use it."[10] Energy has been conserved, but it has been degraded: what is generally called "consuming energy," in fact, means dispersing and degrading it, for example, in the form of heat.

This degradation of energy corresponds to the passage from a certain ordered structure (an unlikely and improbable configuration) to a state of dispersion and disorder (a more

9 Georgescu-Roegen, "La loi de l'entropie et le problème économique," 68.

10 Georgescu-Roegen, "La loi de l'entropie et le problème économique," 68.

probable configuration): as Georgescu-Roegen puts it, "free [usable] energy implies a certain ordered structure comparable to that of a store where meats are on one counter, vegetables on another, etc." whereas "bound [non-usable] energy is energy dispersed in disorder, like the same store after being hit by a tornado."[11] This is why "entropy is also defined as a measure of disorder," and entropy increases as "the process of moving from less probable macroscopic states to more probable macroscopic states."[12] In this sense, entropy increase implies the disappearance of improbable characteristics, and their replacement by more probable ones, resulting in the erasure of the past: for example, a drop of ink will tend to disperse in water until it reaches a uniform situation, thus erasing the initial situation in which the drop had an improbable position.

So, at a physical level, the increase in entropy corresponds to a dissipation and degradation of energy: energy goes from a usable state to a non-usable state and from an improbable and structured configuration to a more probable but less ordered configuration. Entropy can therefore be defined as a tendency towards disorganization, destructuring and disorder. This tendency characterizes any isolated physical system: the second law of thermodynamics states that the entropy of a closed system is constantly increasing, which means that the order of such a system is continually being transformed into disorder. In a broader sense than the strict thermodynamic definition, an entropic process can therefore be described as a process in which a system tends to exhaust its dynamic potentials, as well as its capacity for conservation or renewal by dissipating its energy and gradually reaching a state of disorder and inertia.

2. The Creative Evolution of Life: Towards Negative Entropy

In *L'Evolution créatrice* (1907), Henri Bergson explicitly took the question of entropy into account where he considered the evolution of life. [13] Bergson was interested in the metaphysical consequences of the second law of thermodynamics, which states that entropy can only increase in isolated physical systems. This physical law has both scientific and cosmological consequences. At the scientific level, it leads to the idea of the irreversible nature of physical transformations, contrary to classical mechanics, which does not consider the arrow of time. According to Bergson, the law of entropy is "the most metaphysical of the laws of physics since it points out ... the direction in which the world is going."[14]. Indeed, according to Bergson, this law means that the heterogeneous changes and the diverse forms which are characteristic of nature and life will be more and more diluted into homogeneous

11 Georgescu-Roegen, "La loi de l'entropie et le problème économique," 68.

12 Georgescu-Roegen, "La loi de l'entropie et le problème économique," 68.

13 Henri Bergson, *L'Évolution créatrice* [1907] (Paris : PUF, 2013).

14 Bergson, *L'Évolution créatrice,* 244. (*Creative Evolution*, 265).

changes and elementary vibrations.[15]

But beside these considerations about the entropic physical becoming of the universe, Bergson also notices that within this entropic physical becoming, the activity of living organisms manifests a counter-tendency. In fact, as he points out, the activity of life consists in "suspending," "deferring" or "postponing" this dissipation and degradation of energy: while feeding and moving, organisms accumulate energy which they spend in various and unpredictable directions. According to Bergson, life can thus be described as "an effort to accumulate energy and then to let it flow into flexible channels, changeable in shape, at the end of which it will accomplish infinitely varied kinds of work." [16] Through the activities of plants and animals, which accumulate, transform and release energy, life thus constitutes a counter-tendency to the law of entropy: even if living beings can only temporarily defer the irreversible production of entropy (because all living beings end up dying), life appears as a counter-tendency to the dissipation of energy and as a way of postponing the state of inertia through the accumulation of energy, the organization of organic matter, the diversification of living forms, and the production of unpredictable changes.

Bergson's philosophical intuition, which was inspired by the works of Lalande and Boltzmann[17], was transformed in 1944 through the work of physicist Erwin Schrödinger, who, in *What is life*,[18] describes life as feeding on "negative entropy." Schrödinger's reflections are not the same as Bergson's : firstly, because they are not metaphysical speculations on the nature of life, but scientific descriptions of living organisms, and secondly, because the physicist does not maintain that life *is* negative entropy, but that living organisms *need* negative entropy in order to survive (organisms consume negative entropy). Through his theory, Schrodinger insists on the different behaviours of, on the one hand, physical systems, and, on the other hand, living organisms. Indeed, while physical systems tend to evolve towards disorder and to reach an inert state where no further events are observed (a state of thermodynamic equilibrium or of maximal entropy), Schrödinger notices that living organisms not only maintain their organization throughout their life, but also never stop moving and evolving, as if they were constantly postponing or deferring their ineluctable decay towards the state of maximal entropy, that is, death. Schrödinger then suggests the notion of "negative entropy" (which will later be called "negentropy") to describe this specific behavior of what he calls "living matter": "living matter, while not eluding the 'laws of physics' … is likely to involve 'other laws of physics' hitherto unknown."[19] What

15 Bergson, *L'Évolution créatrice,* 244. (*Creative Evolution*, 265–66).

16 Bergson, *L'Évolution créatrice,* 244. (*Creative Evolution*, 276–77).

17 Bergson, *L'Évolution créatrice*, 166–168, citing Ludwig Boltzmann, "*Vorlesungen* über *Gastheorie*," (1898), and André Lalande, *La dissolution opposée à l'évolution dans les sciences physiques et morales* (1899).

18 Erwin Schrödinger, *Qu'est-ce que la vie ?* [1944], trans. Léon Keffler (Paris: Points, 1993).

19 Schrödinger, *Qu'est-ce que la vie ?,* 166. (*What is Life?*, 68).

Schrödinger thus wants to say is that living systems or organisms, which exchange matter and energy with their environments, degrade energy and produce entropy, but at the same time, accumulate energy, maintain their organization, exchange with their environments, and continue to evolve. Thus, they slow down their descent towards death (and thermodynamic equilibrium). It is probably for this reason that five years after Schrödinger's theory, Norbert Wiener, in his book on cybernetics,[20] describes living organisms as "pockets of decreasing entropy in a framework in which the large entropy tends to increase," "local zone of organization in a world whose general tendency is to run down" where "locally anti-entropic processes … resist the general tendency for the increase of entropy," even if this resistance, as Bergson had already shown, is always local and temporary.[21] For Bergson, though, material decomposition (entropy) was conceived as a counter-tendency of living creation (negative entropy) which, for him, is at the origin and at the end of evolution. To the contrary, Wiener insists on the fact that through living, living organisms continue to degrade energy and to produce entropy: every living being will at some point end up dying, every living being will return to dust. Negative entropy is not eternal, whereas the entropic tendency is irrevocable.

3. Anti-entropy in Contemporary Biology: Organization, Historicity and Functional Novelties

In their more recent works in the field of theoretical biology,[22] Giuseppe Longo and Francis Bailly complicated Schrodinger's work, adding to the notion of negative entropy or negentropy the notion of anti-entropy, in order to give a more precise account of "biological organizations in their historicity" and of the functional novelties generated by living organisms. They state living organisms not only maintain their organization but also transform themselvesin the course of time by producing new functions, through which "new singular and viable organizations emerge. Contrary to the notion of negentropy, which, after Schrödinger, had been used in physics to describe the production or emergence of order from chaos, the notion of anti-entropy applies only to living beings, and is intended as a way of describing their evolutionary dynamics, which involves the conservation of the species' history and the constitution of functional novelties. The notion of anti-entropy thus makes it possible to consider the irreducible nature of living systems. Indeed, living organisms are not reducible to physical systems insofar as living structures are characterized not only by

20 Norbert Wiener, *Cybernétique et société: L'usage humain des êtres humains* [1952], trans. Pierre-Yves Mistoulon (Paris: Points, 2014).

21 Wiener, *Cybernétique et société : L'usage humain des êtres humains,* 65–66.

22 Giuseppe Longo and Francis Bailly, *Mathématiques et Sciences de la Nature: La singularité physique du vivant* (Paris: Hermann, 2006) and Francis Bailly, and Giuseppe Longo, "Biological Organisation and Anti-Entropy," *Journal of Biological Systems* 17, no 1 (2009): 63–96.

a certain level of complexity or by a certain order, but by the cohesion between their parts (the whole of the organism is greater than the sum of its parts), by their historicity (the organization of living organisms results from a singular history and not from the random aggregation of elements) and by the emergence of functional novelties (new organizations which are functional for the organism). The concept of anti-entropy thus makes it possible to consider the irreducibility of the character of life to physical laws, thanks to the distinction between a complex order (negentropy) and a living evolution (anti-entropy): for example, in the case of a tumour, there is an increase in complexity (so an increase in negentropy in the physical sense of the term), but there is a decrease in functionality because this complexity is not functional for the organism; or, when an organism dies, we witness the transformation of biological anti-entropy into physical negentropy (there is still an organization or an order, but it is no longer functional, and it will eventually degrade and lead to a production of entropy.[23]

Whether it is Bergson, who considers life as a struggle against entropy, Schrödinger, who considers living organisms as attracting upon itself a stream of negative entropy, Wiener, who considers living organisms as anti-entropic processes, or Bailly and Longo, who insist on the need to distinguish between physical negentropy and biological anti-entropy, the issue is always the same: living organisms need to be considered in ways that are not explainable simply by invoking physical laws, not only because living organisms exchange matter and energy with their environments, but also because life involves an accumulation and expenditure of energy, along with a conservation of memory and the production of unpredictable functional novelties. Through this memory and these novelties, living organisms introduce the possibility of a bifurcation in entropic becoming, even if this bifurcation is always local and temporary.

II. From Anthropology to Economy: From Anthropy to Anti-anthropy

1. Exosomatic Evolution: the Anthropic Power of Technical Externalization

The concepts of negative entropy or anti-entropy thus make it possible to describe the evolution of life or the behaviour of organic matter, as distinguished from physical becoming or the behaviour of inorganic matter. But a new problem arises when it comes to thinking about technical living beings, i.e., about organisms which cannot survive only with the aid of their biological organs, but who need to produce artificial organs and who therefore constitute arrangements between organic matter (organisms) and organized inorganic

23 Maël Montévil, "Entropies and the Anthropocene crisis," *AI & Society : Knowledge, Culture and Communication* (Berlin: Springer Verlag, 2019); and Montévil Maël, "Sciences et entropocène," *Ecorev' - Revue critique d'écologie politique* 50, no.1 (2021): 109–125.

matter (technical organs). Indeed, one year after the publication of Schrödinger's book on life, mathematician and biologist Alfred Lotka wrote an article titled "The law of evolution as a maximal principle," published in *Human Biology*,[24] in which he shows that the form of life that we usually call "human" not only involves the production of biological organs and organizations, but also the production of artificial or technical organs and organizations. Lotka describes this as a process of "exosomatisation": "exosomatic" organs are those which are situated outside of the body, such as technical prostheses or artificial tools, as opposed to "endosomatic" or biological organs, which belong to organisms. According to Lotka, these exosomatic organs raise new questions for the theory of life as negative entropy, because contrary to biological or endosomatic organs, technical or exosomatic organs do not necessarily generate evolution and diversification. Indeed, these organs are ambivalent. First, they complete human organisms and increase their sensory functions and their motor functions, so they are necessary to human life, and they allow the human species to accumulate huge quantities of energy. They are negentropic in this sense. But at the same time, they carry a huge destructive potential, especially if they are not "adjusted" to the needs of the species, and in this sense, they can produce huge amounts of entropy. According to Lotka, a great danger arises because scientific and technical knowledge has developed very quickly since the nineteenth century, whereas the wisdom which was supposed to adjust technical developments to the need of the human species did not develop at the same rhythm: "'knowledge comes but wisdom lingers' if by wisdom we understand that adjustment of actions to ends which is for the good of the species."[25] According to Lotka, the consequence of this dis-adjustment is that "from preservation of life we have turned to the destruction of life, and from expansion of the human race we have, in some of the most advanced communities, turned to its curtailment."[26] In other words, according to Lotka, the technical development necessary for the preservation of exosomatic life can also serve the destruction of this very same life and accelerate entropic becoming in an exponential way.

In 1955, ten years after the publication of Lotka's article, the anthropologist Claude Lévi-Strauss, who was undoubtedly unaware of Lotka's work, reached the same conclusion: in the conclusion of *Tristes tropiques*,[27] Lévi-Strauss also insists on the highly entropic potential of technical and industrial developments. Lévi-Strauss thus suggests that through the process of technical and industrial evolution, "*anthropos*" (which is the object of anthropology) is actively participating in the "process of degradation" which characterizes the physical universe. Indeed, Lévi-Strauss asks, "From the time when he first began to breathe and eat, up to the invention of atomic and thermonuclear devices, by way of the discovery of fire …

24 Alfred Lotka, "The law of evolution as a maximal principle," *Human Biology* 17, no. 3 (1945): 167–194.

25 Lotka, "The law of evolution as a maximal principle," 192.

26 Lotka, "The law of evolution as a maximal principle," 192–193.

27 Claude Lévi-Strauss, *Tristes Tropiques* (Paris: Plon, 1955).

what else has man done except blithely break down billions of structures and reduce them to a state in which they are no longer capable of integration?"[28] Through the extraction of mineral resources and the degradation of biodiversity, human civilizations thus participated in "the disintegration of the original order of things and hurrying on powerfully organized matter towards ever greater inertia, an inertia which one day will be final."[29] For this reason, according to Lévi-Strauss, "civilization, taken as a whole" has the function "to produce what physicists call entropy": this is why he maintains that "anthropology" should be described as "entropology."[30]

2. The Possibility of Anti-anthropy: Social Organization and Noetic Diversity

Sixty years after Lévi-Strauss' statements, in 2015, in a book entitled *Automatic Society*,[31] Bernard Stiegler engaged in a discussion with the entropologist on this precise point. Of course, like Lotka and Lévi-Strauss, Stiegler insists on the fact that the production of technical organs through the process of exosomatization and industrialization can lead to an acceleration of entropy: not only because the production of technical organs always requires a process of combustion and dissipation of energy, but also because "*industrial standardization* seems to be leading the contemporary Anthropocene to the possibility of a destruction of life as the burgeoning and proliferation of differences – as … biodiversity, sociodiversity ('cultural diversity') and psychodiversity."[32] Nevertheless, according to Stiegler, and contrary to the nihilistic perspective of Lévi-Strauss, exosomatic life is not only entropic, but also constitutes "an agent of *increased differentiation*," through the diversification of technical organs and social organizations.[33] Indeed, as the paleoanthropologist André Leroi-Gourhan has shown,[34] technical externalization leads to a new type of evolution and diversity: beyon vital evolution and biodiversity (through the emergence of biological organs and organisms) there is also technical and social evolution, technodiversity and sociodiversity (through the production of new technical organs, new ways of life, new social organizations). According to Stiegler, these new forms of organization, evolution and diversity can be described as neganthropic or anti-anthropic, in order to distinguish them from biological forms of organization, evolution and diversity. Indeed, Stiegler argues that in the case of the exosomatic form of life, "the questions of life and negentropy arising with Darwin and

28 Lévi-Strauss, *Tristes Tropiques,* 495.

29 Lévi-Strauss, *Tristes Tropiques,* 495.

30 Lévi-Strauss, *Tristes Tropiques,* 495.

31 Bernard Stiegler, *La Société Automatique t.1 L'avenir du travail* (Paris: Fayard, 2015). Bernard Stiegler, *Automatic Society, Volume 1: The Future of Work*, trans Daniel Ross (Hoboken: Wiley, 2017).

32 Stiegler, *La Société Automatique t.1 L'avenir du travail,* 31. (*Automatic Society*, 13).

33 Stiegler, *La Société Automatique t.1 L'avenir du travail*, 31. (*Automatic Society*, 13).

34 André Leroi-Gourhan, *Le geste et la parole t.2 La mémoire et les rythmes,* (Paris: Albin Michel, 1965).

Schrödinger must be redefined,"[35] in order to take into account the ambivalent character of exosomatic organs : exosomatic organs can lead to the destruction of ecosystems and biodiversity, but can also serve as supports for the formation of social organizations and sociodiversity, provided that individuals develop the various kinds of knowledge which are necessary to adopt them.

Indeed, according to Stiegler, it is only through the practice of different types of knowledge (not only theoretical knowledge but also every form of know-how, including knowing how to live, practical knowledge, along with familial, artistic, technical, existential and spiritual knowledge) that exosomatic beings can adopt their constantly changing technical milieu. In other words, only in this way can they learn to live together in a milieu and to take care of their technical organs and environments so as to ensure that these technical organs do not become destructive for natural environments, for social organizations, and for individual organisms or minds. According to Stiegler, the practice of different kinds of knowledge:

> is what allows human beings to make their exosomatic organs bearers of more neganthropy than anthropy. In all its forms, as knowing how to live, knowing how to do or knowing how to conceptualize, knowledge is what allows human beings to take care of themselves, and with them, of their environment and of the future of life on Earth.[36]

This is why Stiegler maintains that activities of work (which he defines as the practice of any kind of knowledge) are necessary to adopt the technical milieu:

> Only by understanding work in this way can we identify the exosomatic innovations (whether technical or technological) actually required by and compatible with a desirable future for a locality …. This is the work of *noesis*, that is, of thinking, in *all* its forms, and as practical as well as theoretical, familial, artisanal, sporting and artistic knowledge, and thus theoretical, juridical and spiritual knowledge in the broadest sense. This belongs to what we therefore call *noodiversity* and *noodiversification*.[37]

Indeed, through the practice of such knowledge, exosomatic beings form collective groups with collective rules, which vary from place to place and evolve with time: the practices of all kinds of knowledge are thus necessary for social cohesion as well as for social diversity and social evolution., They are what allow human groups to maintain and transform themselves, through the re-appropriation and transformation of a collective memory or

35 Stiegler, *La Société Automatique t.1 L'avenir du travail*, 31. Stiegler, *Automatic Society*, 13.

36 Bernard Stiegler, *L'Emploi est mort, vive le travail* (Paris: Fayard, 2015), 66.

37 Stiegler *et al.*, *Bifurcate*, 57.

an inherited past, and which can open an unpredictable and incalculable future. Thus, the different kinds of knowledge produce organization, diversification and novelty at a psychic and social level: they are at the basis of social organization and of cultural diversification and evolution, and this is why they can be said to have an anti-anthropic value.

3. Towards an Anti-anthropic Economy: Valorization of Knowledge and Revival of Desire in Digital Consumerist Societies

Therefore, an economy which aims at limiting the entropic and anthropic effects of exosomatic organs should work towards a revalorization of the different kinds of knowledge which, since the beginning of the Anthropocene, have been *"progressively transformed into machinic formalisms"*[38] and into proletarianized activities. Indeed, Stiegler identifies different stages of automation, each one of which involves an anthropic process of proletarianization, through the decomposition of singular and diverse knowledge into simple and homogeneous tasks. First, in the nineteenth century, the externalization of know-how into machines led to the industrial division of work and the proletarianization of workers. Then, in the twentieth century, the prescription of "ways of life" through marketing and cultural industries led to the standardization of the knowledge of how to live and the proletarianization of consumers. And finally, in the twenty-first century, algorithmic automation led to the externalization of theoretical knowledge and its reduction to statistical calculations performed on massive amounts of data, which implies the proletarianization of thinkers. Stiegler describes this process as "generalized proletarianization":

> Nineteenth-century industrial capitalism destroyed work-knowledge [*savoir-faire*] by turning workers into proletarians, in the sense defined by Karl Marx. In the twentieth century, this proletarianization was extended to practical and theoretical knowledge: the knowledge of everyday life has been destroyed by the cultural industries and by permanent innovation based on marketing, and intellectual knowledge is now disintegrated by software substitution, including in scientific activities.[39]

This disintegration of knowledge produces a situation of symbolic misery in which individuals, lacking the power to individuate themselves collectively through neganthropic or anti-anthropic activities, compensate for their frustrations through anthropic consumerist behaviours:

38 Stiegler *et al.*, *Bifurcate*, 24.

39 Stiegler *et al.*, *Bifurcate*, 97.

> We ingest more and more sugar and fat, we eject and *produce more and more CO_2 because we are in this situation of symbolic misery, and we try to make up for it through things that make us consume an enormous amount of materials*, and materials that, consumed under those conditions, produce an enormous amount of toxins. But this toxicity is first of all that of the destruction of the symbolic.[40]

For Stiegler, this symbolic misery produced through the industrialization of culture, lifestyles and desires must be understood as a problem of ecology and energy:

> *when desire is treated industrially, it leads to the destruction of desire*, which triggers the demotivation of the worker and the consumer. … *We say that this is an ecological problem*. We have exploited oil fields, coalmines, and we have destroyed that which we exploited, and we must find renewable energies. It's the same in the realm of desire: *we must find a renewable energy of the libido*.[41]

According to Stiegler, only a "revival of desire" could stimulate the necessary imperative: "individual behaviors must become more conscious, more attentive, more caring towards that which surrounds them" and initiate "meaningful transformations … in the future of the planet."[42]

Thus, in the Entropocene era, the necessity of saving or economizing natural resources (chemical, physical or mineral energies) is intrinsically linked with the necessity of saving and economizing psycho-social resources and libidinal energies. Just as Georgescu-Roegen insisted on the need to stop exploiting the stock of fossil fuels and to base the economy and industry on renewable energy flows (such as sun or wind), Stiegler insists on the need to stop exploiting the drives of consumers and to base the economy and industry on the renewal of libidinal energy, that is, on the valorisation of contributory activities through which people practise, share and transform different kind of knowledge. The function of the contributory income promoted by Stiegler in *Automatic Society*[43] and in *Bifurcate*[44] is precisely to renew these libidinal energies, through the remuneration and valorisation of anti-anthropic activities, through which individuals socialize their drives, produce collective desires and invest their libidinal energies into local and singular projects, and through which they take care of themselves and their environments.

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40 Bernard Stiegler, "De l'économie libidinale à l'écologie de l'esprit," Entretien avec Frédéric Neyrat," *Multitudes,* no. 24 (2006): 94 (Bernard Stiegler, "From Libidinal Economy to the Ecology of Spirit," interview with Frédéric Neyrat, trans. Arne De Boev, *Parrhesia* no.14 (2012): 14.

41 Stiegler, "De l'économie libidinale à l'écologie de l'esprit" interview with Frédéric Neyrat, 88.

42 Stiegler, "De l'économie libidinale à l'écologie de l'esprit" interview with Frédéric Neyrat, 94.

43 Stiegler, *La Société Automatique t.1 L'avenir du travail,* 81.

44 Stiegler *et al.*, *Bifurquer,* 127.

According to Stiegler, such activities can be defined as activities of work, which he distinguishes from labour or employment: activities of work are neguanthropic or anti-anthropic because they are based on the practice of different kind of knowledge, which imply "techniques of the self and others" and lead to the "trans-formation of oneself" and "trans-formation of others"[45], psychic and collective evolution and diversification. Through the practice of knowledge, people acquire automatisms, but they also de-automatize and transform what they have learned, producing different kind of bifurcations (artistic bifurcations, political bifurcations, technical or theoretical bifurcations, etc.) which are intrinsically improbable, and can be said anti-anthropic in this sense. On the contrary, employment most of the time requires repetitive behaviours through which people cannot transform themselves and others because they have to adapt to "protocols supported and defined by machines, apparatus, manuals, procedures, reporting systems and management control."[46] Such activities can easily be automatized and can be said entropic, because they are not open to any evolution or diversification. For this reason, contributory economy is also an attempt to switch from an economic model based on employment to an economic model based on work, in which "the time saved by automatization must be invested in new capacities for dis-automatization, that is, for the production of negentropy."[47]

The aim of the contributory economy is to go beyond a consumerist and entropic economic model based on employment—which increases proletarianization, depletes psychic energies, and destroys ecosystems through addictive consumption—by opening up the possibility of an anti-anthropic economic model based on work, which would valorise and intensify the practice of different kinds of knowledge in order to protect biodiversity, sociodiversity and noodiversity.

Conclusion

We can see that through Stiegler's reflections, the question of entropy becomes a question of political economy : the notion of entropy, which was first raised in the field of physics seems to have crossed many different theoretical fields in the XXth century, from biology to anthropology and economy. This article aimed at giving a partial overview of the history of the notion, in order to understand the Stieglerian political propositions from an epistemological point of view and to show their necessity in the current context of the Entropocene.

45 Stiegler, *La Société Automatique t.1 L'avenir du travail*, 185.

46 Stiegler, *La Société Automatique t.1 L'avenir du travail*, 161.

47 Stiegler, *La Société Automatique t.1 L'avenir du travail*, 7.

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Short-Circuits at the Speed of Anaphylaxis: Politics, Law and the Fourth Kind of Memory

Daniel Ross

Abstract:

If, as Canguilhem argues, the emergence of exosomatic life involves the introduction of a new inconstancy into life's environment, then both juridical and scientific law can be understood as a response that aims at a new constancy or fidelity, but one that always requires interpretation. Today, however, there is a crisis of law, due to a speed differential between the speed of legal change and the speed of digital network technology. This crisis can be understood in relation to Stiegler's account of exosomatic life as involving three kinds of memory that struggle against the entropic tendency, but here we argue that there is also a fourth memory: the immune system. Taking this into account can further elucidate Stiegler's claim that the *pharmakon* has a third, psychosocial dimension: the *pharmakos*. By understanding immune function not just as discriminating proper and foreign elements, or friend and enemy, but rather as a retentional and interpretive system, we can understand phenomena such as the designation of a scapegoat as a fault of interpretation that can be compared with accounts of the onset of paranoia. This in turn makes it possible to understand the crisis of contemporary experience as an anaphylactic reaction resulting from a collapse of resonance that amounts to a loss of the knowledge and desire required to live in tension, where the latter is the only meaningful definition of peace.

Keywords:

Canguilhem, Stiegler, entropy, law, immune system, paranoia

 Corresponding author: Daniel Ross, djrossmail@gmail.com

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1. The New Inconstancy of Exosomatic Life

Georges Canguilhem defined the health of the endosomatic organism as "a margin of tolerance for the inconstancies of the environment": even though the physical universe is "a system of mechanical, physical and chemical constants" that seem invariant, the living thing "does not live among laws but among creatures and events," which is to say, "in a world of possible accidents." The inconstancy of the environment, then, "is simply its becoming, its history"—*entropy*—and disease, conversely to health, is "a reduction in the margin of tolerance for the environment's inconstancies." Already for Canguilhem, the situation in which what Bernard Stiegler calls the *exosomatic* organism finds itself is more complicated: by enlarging its existence technically and prosthetically, new vistas of possibility arise, such that, for this organism, "good health" no longer means just to be adequately adapted to an environment, subsisting with a normal margin of tolerance. What Canguilhem calls the "normative" is an enlargement of the normal, such that good health means to be "capable of following new norms of life."[1]

What Stiegler adds to this thought consists in pointing out that this technical and prosthetic enlargement also brings with it the introduction of a new inconstancy, an inconstancy that has its own becoming, its own history, especially when it begins to coalesce into technical systems. More than that, it is *because* this form of life introduces this new inconstancy that it *must* remain capable of adopting new norms, new rules of life. This new inconstancy of the environment, this new instability introduced into the course of life, unfolds initially and for a long time at a very slow rate, undetectable to the organisms living through this process of gradual but ineluctable change brought by technics. But as this inconstancy unfolds, it becomes necessary to form new constancies around this process, new regularities that "metastabilize" this instability specific to a form of life that is no longer just organic, but "exorganological."

In other words, if, as a result of exosomatic evolution, we need to be constantly capable of following new norms of life, which means, capable of adopting new criteria for the selection of what to do and how to behave, then this need itself tends to form into systems, not just at the level of the individual (the simple exorganism: an individual together with its technical organs), but at the level of the group (the complex exorganism: a collection of individuals and their social organizations). Law is the very general name we give to this systematization of the metastabilization of social life in the face of this inconstancy of the environment. A bit less generally, it is the name we give to these systems after the invention of writing, which, once processes of education make it possible to form

1 Georges Canguilhem, *The Normal and the Pathological*, trans. Carolyn R. Fawcett, with Robert S. Cohen (New York: Zone Books, 1991), 197–200.

publics capable of reading and writing, makes possible new ways of metastabilizing these systems of law themselves. More than that, reading and writing made it possible to give law the character of exactitude, and this "literalization of laws"[2] meant that it also became possible to discuss law in precise ways, and therefore to interpret and reinterpret it, deliberate about it, and make decisions concerning the way that law itself should change, forming its own history of becoming. Politics would then be understood as the struggle to form agreements about how to metastabilize the systems of law, in a situation where a literate public composed of singular individuals tends to disagree about ways of doing so.

When law is written down, it makes it possible, as we just said, for it to be interpreted and reinterpreted. More than that, the very operation of law relies on interpretation, in the sense that the text that is written must be articulated with the circumstances of a case, such that it becomes possible to apply this law to those circumstances in the form of a judgment. A judgment is always a decision that by definition goes beyond any analysis: what occurs in judgment is a synthesis of law and fact, and such a synthesis is always an interpretation whose possibility arises from that conjunction. In short, the operation of law is never automatic, and the history of its judgments and the interpretations on which they are based forms a key component in the unfolding of law itself, one that runs parallel to politics as the process of forming legislative agreements.

In this way, the relationship of fact and law involved in collectively taking care of the inconstancies of the environment is just one particular form of the relationship between fact and law that *always* operates in our way of understanding the world around us and deciding what that understanding means for the ways we should live and want to live. Scientific disputation, too, which tries to collectively interpret the facts of the world with the aim of forming testable hypotheses in order to arrive at a metastable account of scientific laws on the basis of peer review, certified authority and so on, can then be seen as just another (no doubt very particular) case of the general relationship of fact and law that always involves the relationship between analysis and synthesis. But this relationship between analysis and synthesis must then be understood in terms of the history of exorganogenesis in general, and in terms of the history of mnemotechnics in particular, and even more particularly in terms of the history of writing that first made possible the conceptual discrimination of analysis and synthesis.

2 Bernard Stiegler, *Nanjing Lectures 2016–2019*, ed. and trans. Daniel Ross (London: Open Humanities Press, 2020), 135.

2. Law and Speed

Today, the juridical sense of law (but in fact this also applies to law of all kinds, including in the fields of science) finds itself in crisis. Fundamentally, there are two problems faced by law, which we must turn into questions, which is to say, which must become the object of a critique, as the means by which we can hope to remedy a crisis. Both of these problems stem from a single fact: the introduction of a new inconstancy of the exosomatic environment as a result of the vast increases in speed made possible by the continuous development of digital and network technical systems, unfolding as a result of what becomes possible thanks, among other things, to that performative quasi-prophecy that is Moore's Law. But speed is always relative: this increase of speed must be understood first of all as a *relative* increase when compared to the metabolic rate of social activity made possible by writing and the deliberative techniques on which all legal systems continue to be based. It is a question of a speed *differential*.

The first of these problems is the fact that legal systems seem powerless to make any significant difference to the way in which large digital platforms seize hold of and exploit the data and consciousness (and the unconscious) of users. Whatever the idea—whether it is to compel platforms to obtain permission for the data they receive, to make them pay for this data, to break up the vast monopolies to which they amount (what are Google and Facebook if not monopolies? and the US does have strong anti-trust laws, after all, if it was ever prepared to use them, as Standard Oil learned in 1911), or a thousand other legal strategies compelling these corporations to do or not do this or that—nothing ever seems capable of making any real dent in the informational strategies they have for amassing unimaginable fortunes.

This bears some similarity to the difficulties governments have had in trying to deal with the tobacco industry: even after it became clear that cigarettes are in fact very harmful, no government moved simply to ban them, not just because, as cynics sometimes like to say, governments are themselves addicted to the tax revenues brought in by cigarette sales, but because it just did not seem possible to eliminate a product to which a significant proportion of the electorate was addicted. Consequently, all kinds of strategies designed to discourage and reduce sales have been pursued in this jurisdiction or that, justified on the grounds of long-term benefits, while of course still continuing to allow large profits to be made from a product known to often lead to fatal consequences for the consumer—a fundamental compromise with the protective function of government and law.

This in turn relates to the second reason that law, as a regulatory mechanism or metastabilizing process, finds itself challenged in a very fundamental way by very powerful computing technologies that take advantage of the constant two-way stream of data occurring on global networks. For these technologies function in a way that is akin to a drug such as nicotine, or for that matter, heroin: what a drug of that kind does, as Stiegler points out, is produce something that your body normally produces, but where the drug produces it *better* than your body produces it, with the consequence that the body "unlearns" how to produce it and delegates this production to the *pharmakon*, which the body therefore ends up needing as compensation for what it has forgotten how to do.[3] Likewise, the second fundamental challenge to law presented by "platforms" consists in the fact that the speed at which they send, receive and process data is in some important respects quicker than the functioning of the nervous and cerebral processes of the human body, and *this* speed differential, too, affects the possibility for law to function.[4]

Law is necessarily an analytical, deliberative and interpretive process that requires an exercise of judgment, where these same factors are necessary, not just for jurisprudence but for those political, democratic, or legislative processes by which laws are decided upon, but the extreme rapidity of these algorithmic, network and computational processes means that, in some way (but in some *limited* way), these high-powered calculative and analytical processes are *better* at producing and arranging the individual's relationship to its future than it is itself. As a consequence, the individual forgets how to produce the desire and knowledge by which it would otherwise ordinarily organize its relationship to the future, and through which the relationship between the scales of the individual and the collective, too, are organized. The resulting automatization of life is a kind of performative structuring in advance of existence that tends to close off possibilities for dis-automatization, where the latter is the condition of possibility of autonomy, that is, of deliberation, interpretation, decision and the *synthesis* of analyses on which all of these operations depend.[5]

In short, both juridico-political systems and consumer-capitalist systems fundamentally involve processes of adoption, that is, they depend upon the encouragement of the adoption of aims and desires that are always and from the outset artificial (law as the concretization of justice, in one case, consumer products as the concretization of new needs, in the other). To this extent, both law and capitalism may be described as

3 Bernard Stiegler, *The Neganthropocene*, ed. and trans. Daniel Ross (London: Open Humanities Press, 2018), 166–67.

4 See Bernard Stiegler, *Automatic Society, Volume 1: The Future of Work*, trans. Daniel Ross (Cambridge: Polity Press, 2016), 140.

5 See Bernard Stiegler, "Bernard Stiegler on Automatic Society: As Told to Anaïs Nony," *Third Rail Quarterly* 5 (2015): 16–17, available at: <http://thirdrailquarterly.org/wp-content/uploads/05_Stiegler_TTR5.pdf>.

protentional systems. What has occurred in the shift from producer capitalism to consumer capitalism, however, and even more in the shift to so-called platform capitalism, is the rise of a protentional system that constantly accelerates the pace of economic and technological change in a way that far outstrips legal processes, and that even outstrips the pace at which exosomatic life protentionalizes its experience, which is to say, its own relationship to an open future. To the extent this is the case, these systems might be described as being in principle protentional, but in practice *anti*-protentional—yet another species of difference of law and fact.

3. From Three Kinds of Memory to Four

For Stiegler, all of these operations and processes of which exosomatic life is composed—and through which the organizations of exosomatic life persist against the tendency to decompose, and do so by keeping themselves open to future recompositions—are a matter of *memory*. What is memory? Above all, it is the possibility of an organized tendency that runs counter to the overall ("universal") tendency we call entropy, where the latter consists above all in the probabilistic tendency for the past to be erased over time.[6] For Stiegler, all of these operations and processes of exosomatic life ultimately consist in the way that *three kinds* of memory compose: *genetic memory* (contained in the proliferation of variations of the DNA molecule), *nervous memory* (contained in the synapses and neurons of the brain and central nervous system) and *technical memory* (contained in the organized inorganic artifacts that make this life, precisely, *exo*-somatic).

The first two of these organized ways of keeping the past in order to keep *open* a future, against the entropic tendency for that openness to close, make up *endosomatic* life. The first, genetic memory, does not learn lessons from the experience of the individual organism but very gradually evolves over multigenerational time. The second, nervous memory, may learn lessons but these lessons are as a rule lost to the species with the death of the individual. It is only with exosomatic life that a mechanism emerges that not only keeps those lessons learned by the individual, but makes possible their condensation, recapitulation and transmission in a cumulative way. This is precisely the mechanism that adds a new inconstancy to the exosomatic environment, which means that the struggle of this form of life is against not only the entropic tendency of the universe but the "anthropic" tendency introduced by this form of life itself, as it passes through an "outside" that becomes constitutive for it (without which it cannot live,

6 Maël Montévil et al., "Anthropocene, Exosomatization and Negentropy," in Bernard Stiegler and the Internation Collective (eds), *Bifurcate: "There is No Alternative,"* trans. Daniel Ross (London: Open Humanities Press, 2021), 47.

and through which it forms its interiority), while at the same time being perpetually "destitutive" (undoing the ways of "neganthropic" life that have arisen to support and take care of life that is irreducibly exteriorized).[7]

All of Stiegler's work is premised on this idea of understanding exosomatic evolution in terms of the constant advance and delay of the processes by which these three memories are arranged. All of the three kinds of memory pointed out by Stiegler are "material": memory can only ever be a question of organized structures with the potential to, in one way or another, locally persist (within a locality that is both spatially and temporally local). But in *Psychopolitical Anaphylaxis* I began to argue that there is, in fact, a *fourth kind of memory*, a fourth material mechanism for improbably keeping the past in the present in order to maintain the consistency and viability of the organism as it encounters environmental inconstancy. That fourth kind of memory is the immune system.[8]

The immune system is indeed a retentional system: among its operations is the fact that "guardian cells" literally "cut out a part of the proteins" of which invaders are composed, so that the system will later be able to "display" this "portion of non-self [...] inserted in a portion of self (the display),"[9] and, through that, identify the return of an identical or similar pathogenic element, in order to trigger the organism to prophylactically respond to that element. Of course, this function of the immune system that consists in identifying dangerous foreign invaders in order to eliminate them and thereby maintain the health of the organism is both why it is often used as a metaphor for certain phenomena occurring in the collective existence of exorganisms and why that metaphor is often viewed with suspicion, on the grounds that it legitimizes xenophobic reactions of all kinds.

Yet however justified that suspicion may be, the fact remains that the immune system itself is undeniably a kind of retentional system—a fourth kind of memory. Moreover, it operates "protentionally," not strictly in the sense of intentional consciousness, but in the sense that it is functionally devoted to the future viability of the organism. In what follows, we will try to reflect further on this retentional and protentional character of the endosomatic immune system, in order to see what significance it might have for

7 See Bernard Stiegler, in Bernard Stiegler, Judith Wambacq and Bart Buseyne, "'We Have to Become the Quasi-Cause of Nothing—of *Nihil*': An Interview with Bernard Stiegler," trans. Daniel Ross, *Theory, Culture & Society* 35, no.2 (2018): 141.

8 Daniel Ross, *Psychopolitical Anaphylaxis: Steps Towards a Metacosmics* (London: Open Humanities Press, 2021), 227–38 and 344–55.

9 Jean-Claude Ameisen, *La sculpture du Vivant: Le Suicide cellulaire ou la Mort créatrice* (Paris: Seuil, 1999), 76, quoted in Francesco Vitale, *Biodeconstruction: Jacques Derrida and the Life Sciences*, trans. Mauro Senatore (Albany: State University of New York Press, 2018), 179.

conceiving exosomatic life, beyond its long history of being understood as a metaphor or paradigm for social and political processes of dealing with the distinction between friends and enemies.

4. Immunity and Speed

Beyond the simple statement that the biological immune system is concerned with "identifying enemy intruders"—and without concerning ourselves here with recent arguments that this is only one limited part of what is a much more general system characterizing the individual as a whole and possessed with a multiplicity of functions[10]—why do we have an immune system? Why did vertebrates evolve to possess this *new* retentional system dedicated to metastabilizing the life of the organism? The answer to this question has everything to do with speed, and with speed differentials: the benefit granted by the evolution of the immune system was to enable the organism to respond to pathogenic elements that affect the body more rapidly and/or mutate more rapidly than could be effectively responded to by previously existing systems and functions of the endosomatic organism. Rapidly acting and rapidly mutating pathogenic elements have the potential to quickly cause a crisis for the older systems and functions of the endosomatic organism, and the evolution of the immune system amounts to an effect of selection pressures that eventually gave rise to a new mechanism for responding to such crises. One of the first and most obvious lessons of the colonization of the New World, after all, was that this immune system involves the acquisition and transmission of a history, and that, for those indigenous human populations without the protection of this immune memory, the vulnerability to European viruses was immense, and the consequences rapid and devastating.

Writing the metaphors of endosomatic life and immunity in our own terms, we might say that the structure of the DNA molecule is akin to the political constitution that sets the framework for the governing of a polity: this sacred or founding document, the genetic molecule, is itself either unchanging (for the organism) or very slow and difficult to change (for the species, and for good reason: if it changes other than slowly, the risk is great of producing monsters). The immune system is then ultimately legislated as a new function (a new "institution") within the organism that is always in the end governed according to the possibilities dictated by its founding document, where this new function consists in a retentional mechanism capable of responding to the crises arising from diseases brought by bacterial or viral elements that act quickly and mutate much more quickly than the ability of the genetic molecule itself to adapt. The immune

10 Thomas Pradeu, *Philosophy of Immunology* (Cambridge: Cambridge University Press, 2019).

system is "quicker" precisely because it is retentional and epigenetic: it learns the lessons of what happens to it within the life of the individual organism (or transmitted via mother's milk), rather than responding at the speed of the genetic drift of the species.

Whichever retentional system is in question, whether it be a political constitution or a DNA molecule, whether it be the set of laws legislated by a social organism such as a parliament or the expression of DNA in the organs and functions of an organism, the premise and condition of the successful functioning of that retentional system is that the inconstancies of the environment change *more slowly* than the ability of the retentional system of the organism itself to adjust to that change. *All* of these systems *do* change, and in fact *must* change, but they change at a rhythm that has to be quick enough to respond to those inconstancies and slow enough that harmful changes do not accumulate rapidly enough to have a strong likelihood of threatening the organism itself.

It is for this very reason, for example, that law changes at the speed of deliberation, where this deliberation is institutionally organized with an *in-built* slowness: the virtues of slow deliberation are, in general, in the institutions and bureaucracies of political life, *preferred* over too great an efficiency of very rapid changes, precisely because the undeniable risks brought by that slowness were long thought to be proportionate to the pace of change of the sociotechnical environment. The benefits of very rapid change can frequently turn out to be outweighed by the risks of perpetrating harmful error as a result of ill-considered changes brought by sociopolitical mutations arising from insufficiently careful and cautious decision-making procedures.

A conservative, pre-industrial figure such as Edmund Burke, for example, argues that what has lasted in law and society for a long time should be trusted much more than what presents itself as novel and revolutionary improvement. Nevertheless, Burke recognizes that the "two principles of conservation and correction" are both necessary, for a "state without the means of some change is without the means of its conservation." Even if it "is far from impossible to reconcile […] the use both of a fixed rule and an occasional deviation," it is obvious to Burke in 1790 that "change is to be confined to the peccant part only, to the part which produced the necessary deviation; and even then it is to be effected without a decomposition of the whole civil and political mass."[11] And even more than this restriction to the "peccant part," what ensures the virtuousness of any necessary deviation is the speed of the method of its institution:

11 Edmund Burke, *Reflections on the Revolution in France* (New Haven and London: Yale University Press, 2003), 19.

> It is one of the excellences of a method in which time is amongst the assistants, that its operation is slow and in some cases almost imperceptible. If circumspection and caution are a part of wisdom when we work only upon inanimate matter, surely they become a part of duty, too, when the subject of our demolition and construction is not brick and timber but sentient beings, by the sudden alteration of whose state, condition, and habits multitudes may be rendered miserable.[12]

Over the long course of exosomatic evolution, from Oldowan tool use until today, the pace of sociotechnical change was indeed mostly very slow, and it was still *relatively* slow at the time of the Solonian constitution (6th century B.C.E.) or the Magna Carta (1215), or even at the time of the Constitution of the United States (1789) and the Declarations of the Rights of Man and of the Citizen (1789). What all of these documents have in common is the fact that they *are* documents: texts engraved or inscribed in letters and words into stone, or on papyrus, parchment or paper, and held to be either unchangeable or changeable only via exacting processes instituted so as to ensure great care is taken. The retentional system at the basis of all of these approaches to the local metastabilization of exosomatic life is alphabetical writing, and the deliberative mechanisms they set into motion are designed to function at a pace capable of generating written law that responds *quickly* enough to handle the inconstancies of a slowly changing sociotechnical milieu, and *slowly* enough not to jeopardize the viability of those local exosomatic formations by promulgating laws whose interaction with sociotechnical realities has not been properly considered.

As everyone knows, however, from the time of the Industrial Revolution, the pace of technical change accelerated greatly. And if the two fundamental problems brought by digital networks, social media, algorithmic platforms and the like are both related to a speed differential between the technological processes and the processes of law and regulation, is this not fundamentally because the latter cannot be divorced from *written* constitutions, *written* laws, and *deliberations* about the meaning and consequences of new possible written laws? These new technological processes, however, even if they are *in a sense* a new kind of writing (engraved, so to speak, in silicon), are not bound by the temporal constraints and requirements associated with these kinds of documentary, constitutional, jurisprudential and deliberative retentional processes that have governed exosomatic life in many localities for many centuries.

Does it not seem practically *inevitable* that these *computational* processes, which amount to the *latest form* of the inconstancies of the exosomatic environment, will *always* unfold,

12 Burke, *Reflections on the Revolution in France*, 143.

change and mutate more rapidly than the pace of change that is allowable under regimes based on written political constitutions that legislate processes of political and legal deliberation and that arose at a time when such rapidly changing environments were unimaginable? Is this not why an ideology centred on "disruption" has arisen, and why it has gained a substantial sway over economic policies and entrepreneurial practices? But if we wish to say that such an ideology fails to meet the challenges we have just outlined, and only exacerbates the problems brought by these challenges, then what *could* be the solution to this problem of a speed differential that is highly detrimental to the functioning of all retentional systems founded on the writing of documents?

5. The Third Pharmacological Dimension

What I would like to focus on here, however, are the consequences of considering the immune system less directly in terms of its putative function of distinguishing friend and enemy, and more directly in terms of the fact that it is a retentional system, a fourth kind of memory. If it *is* a retentional system, and if it has the function of *discriminating* what it encounters, in the sense of initiating or not initiating an immune response, then we could say, using the term in a basic or primitive way, that the immune system is an *interpretive* system. By keeping remnants of the past in the present, counter-entropically holding onto them as a kind of memory store, the immune system is able to make comparisons between what it keeps and what it meets, where what it *does* is the result of this comparison—this interpretation.

It is this aspect of the immune system—its basic interpretive capacity—that means that the immune system is also capable of *mis*interpretations. For a start, as everyone knows (especially in the post-Covid era), the immune system suffers from retentional finitude, and from forgetfulness: what it remembers, what it keeps in its archive, can be lost, just as libraries can burn down, ink can fade and books can be lost forever, and just as our own (cerebral) memories are finite and forgetful. But beyond forgetfulness, it is immune misinterpretations that result in those auto-immune disorders that seem to be ever-expanding (both in terms of our knowledge of them and their prevalence), and that were of such (metaphorical) interest to Derrida, in whose hands they were turned into a kind of pharmacology of immunity always containing and contaminated by auto-immunity.

Auto-immunity is not all, however: there is also anaphylaxis, a kind of extremity of auto-immunity—auto-immunity as extremism, even, involving a maximum of shock, up to (and including) the point of fatality. Nevertheless, according to Canguilhem, anaphylaxis is not in any way *opposable* to ordinary immune function, because both are a kind of reaction, and each of them are an expression of a single "normal" process:

> While immunity makes the organism insensible to an intrusion of microbes or toxins in the inner environment, anaphylaxis is an acquired *supersensitivity* [...]. The presence of antibodies in blood serum is thus always normal, the organism having reacted by modifying its constant to a first aggression of the environment and being regulated by it, but in one case the normality is physiological, in the other, pathological.[13]

The "fault" of anaphylaxis is thus a matter of a degree of sensitivity, where the fault is not a *failure* of sensitivity, but rather a kind of misjudgment taking the form of an excess of sensitivity. Whether physiological or pathological, the functioning of the system *itself* does not really deviate from "normality," but in the case of anaphylaxis the supersensitive character of this functioning amounts to a fault of interpretation. The immune system is a *sensitive* system (even though it is not a "sensible" system, in the sense in which Aristotle talks about a sensible soul as distinct from a vegetative or a noetic soul), and it is so in both senses of the term: it is sensitive in the sense that it "detects" and is *moved* by what it detects; and it is sensitive in the sense that it is delicate, finely balanced, and susceptible to losing this balance by becoming either overly sensitive or insufficiently sensitive.

What I would here like to argue is that this way of thinking about the immune system can aid us in understanding what Stiegler says in *Pharmacologie du Front national*, when he states that the *pharmakon* has a "*third pharmacological dimension*," in addition to the fact that it is both curative and poisonous, a dimension "that has not previously been thematized or explored, namely, the dimension of the *pharmakos*—the scapegoat."[14] As others have noted, the tendency towards an extremification, in the sense of designating enemies of the system, is a kind of counter-tendency produced by the overall tendency of a capitalist system that eventually undermines every social regulatory mechanism, even though this system disavows this connection and almost always acts as if this "reaction" originates either from outside or from a cancerous element located within. In 2013, Stiegler understands this "logic of the scapegoat" as well as anyone, and, in particular, how it arises not just within industrial society, but especially in the latest intensifications of this technico-economic system:

> The Conservative Revolution unleashed the toxic and poisonous dimension of the industrial *pharmakon* by blocking all of its therapeutic possibilities, and the National Front extremized this ideology by making the *pharmakos* the

13 Canguilhem, *The Normal and the Pathological*, 206–7.

14 Bernard Stiegler, "The National Front and Ultraliberalism (extract from *Pharmacologie du Front national*, 2013)," trans. Daniel Ross, *Cultural Politics* 18, no.2 (2022): 133.

> cause of all ills. The *pharmakos* is the third dimension of the pharmacology that defines the human situation in general qua technical life [...]. In the absence of a reasoned positive pharmacology, stated as such and explained widely, struggling against the negative pharmacology that, in the epoch of neoconservative globalization, has become diabolical in the strict sense (in the sense of the Greek *diabolē*)—that is, atomizing and disintegrating all social organizations, and thus all forms of attention and care—the exploitation of the logic of the *pharmakos* and the sacrificial persecution of scapegoats will continue, and will end by eventually bringing to power the extreme right.[15]

Furthermore, Stiegler understands better than anyone that these reactions are precisely a case of *over*reaction, that is, of supersensitivity. He knows that those who are most prone to be sensitive, to *suffer* in a protentional system that self-destructively undermines the protentions of the consumers on which it depends (by exploiting them), are those who are most prone to react, and to react by despair, by scapegoating, and by voting for the far right. It is because he recognizes this sensitivity and this suffering, it is because recognizing it makes *him* suffer, that Stiegler dedicates a lecture and a book to those who vote for the National Front, because these voters suffer "like you and I but perhaps more than you and I."[16]

6. Paranoia and the Default Mode of Interpretation

Let us pursue further the question of why *exactly* the industrial *pharmakon* produces the *pharmakos*, but let us do so in a slightly different, and perhaps unusual, direction. A more common approach might be to refer to Carl Schmitt, for whom the "specific political distinction to which political actions and motives can be reduced is that between friend and enemy," where this criterion is irreducible, "not derived from other criteria," ultimately because it "denotes the utmost degree of intensity of a union or separation, of an association or dissociation."[17] But even were we to accept Schmitt's claim of the irreducibility of this "antithesis," it would leave the question of the mechanism by which friends and enemies are identified, known or designated, which, even were this to give us the ultimate "what" of political distinction, and even were we to understand this criterion as originating from some fundamental characteristic of "life," would still require a *process*, and this process would seem to involve an interpretive aspect that

15 Stiegler, "The National Front and Ultraliberalism," 147.

16 Bernard Stiegler, *Acting Out*, trans. David Barison, Daniel Ross and Patrick Crogan (Stanford: Stanford University Press, 2009), 42, and see the dedication that appears on page 38.

17 Carl Schmitt, *The Concept of the Political*, trans. George Schwab (New Brunswick and New Jersey: Rutgers University Press, 1976), 26.

would be equally irreducible, that is, unavoidable.

Instead of reading Schmitt further, then, let us approach this question from another angle altogether, by reflecting on what we could call the *anaphylactic default* of this discrimination of friend and enemy. What is this anaphylactic default? We will argue here that it is paranoia.

When someone speaks to us, how is it that we know what they mean? Perhaps this question is not as simple as it sounds. We might immediately answer by saying, very straightforwardly, "Because we share a knowledge of the same language, and this makes it possible to understand a speaker's words." A moment's reflection, however, will remind us that it is possible to speak in an ironic or sarcastic way, so that the intended meaning could very well be the very opposite of what we would call the "literal" meaning. And there are all kinds of shades and dimensions of meaning that lie between or to the side of the literal and the ironic. So how do we know what someone who speaks to us is *really* trying to tell us?

When someone becomes paranoid, whether because of an onset of schizophrenia or because of some other psychosis (and paranoia is in fact very common, at least as a tendency of personality, and very dependent on social conditions as well as psychological factors), there is often a preceding phrase, an initial period of confusion. There is a feeling that something is not quite right, that everything feels kind of off, but without being able to put a finger on exactly why. There is a loss of having a viewpoint on things. This is often characterized as a loss of common sense or "natural self-evidence," referred to as the *premorbid stage* of psychosis.

This premorbid stage is followed by a *prodromal stage*, consisting very often in a state of tension that is also a feeling of uncanniness, of something about to happen, of important meanings that are about to be discovered. But eventually, there occurs a third, *apophanic stage*, frequently involving what is known as the "aha experience," when all of the confusion and all of the tension suddenly fall away in the crystallization of a revelatory discovery: "Aha! All of these feelings I've been having are because of the signs I was picking up that there is a gigantic conspiracy going on, and, however unbelievable it sounds, it's all centred around me!" Psychosis, then, and in particular paranoid psychosis, often progresses through these three stages.[18]

What is happening across the course of this movement through premorbid disorientation,

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18 See Paolo Fusar-Poli et al., "The Lived Experience of Psychosis: A Bottom-Up Review Co-Written by Experts by Experience and Academics," *World Psychiatry* 21, no.2 (2022): 168–88, available at: <https://onlinelibrary.wiley.com/doi/epdf/10.1002/wps.20959>.

prodromal uncanny tension and apophanic revelation? The way in which we will venture to approach this question here is through the interpretivity and sensitivity we have ascribed to immune processes. Our aim, again, is to show how conceiving the immune system as a retentional system makes it possible to reinterpret paranoia as a default of interpretation occurring when this sensitive system dysfunctions, and through that to be able to say something about the "third dimension" of the *pharmakon* (the *pharmakon* always being a kind of retention, an exteriorized memory): the *pharmakos*.

Returning to the question, "When someone speaks to us, how is it that we know what they mean?", we have to add: beyond the knowledge we have of the language being spoken, which is only one dimension of the conveying of meaning, there are many other expressive dimensions of the given that we are receiving when someone communicates with us. What is given to us, which we take in as a kind of "cinematic" stream of time-consciousness, unfolds before us and within us in such a flood that we are constantly making attentional selections from among the array of possibilities of what is given. What's more, we are "post-producing" what we are receiving in the moment of reception itself—editing "in camera," so to speak, which is to say, constructing and shaping in manifold ways what arrives, so that what arrives is always already a "production". And (therefore) an interpretation. All of these operations of reception, selection, production and interpretation, all of which also involve a return to, dredging up, recapitulation, rearrangement, reinterpretation and re-production of our accumulated stock of secondary retentions (of memories)—all of this occurs, to a very large extent, "behind the back of consciousness," without our being aware of it. And yet: sensitively, subtly, with potentially infinite complexity, infinite complication and in a limitless complicity between the "sender," the "receiver" and the multi-layered and supersaturated idiomatic milieu through which this multi-dimensional expression is conveyed.

Sometimes, however, this sensitive interpretive instrument goes awry. Precisely because it involves such a multiplicity of dimensions, where each of them involves a fine calibration, and where the synthesis of these dimensions is an operation that is mostly beyond description, let alone comprehension in the moment of reception/production—because of all of this, the "needle" of this instrument can start to go haywire. When it does so, it gives rise to the symptoms of the premorbid stage of psychosis: confusion, disorientation, loss of sense, a loss of *confidence* in one's ability to *make* sense or interpret *well*. From there, a struggle ensues, attempting to locate a new orientation, but when that struggle cannot make progress, behind the scenes there is the beginning of a "resetting" of that interpretive system, but in a kind of "default mode." As that faulty reinitializing of the interpretive system unfolds, one enters the state of uncanny tension of the prodromal stage.

What is the default mode of the interpretive system that allows us to orient ourselves in a cosmos of significance? All of a sudden, there is a crystallization, including in the sense of the crystalline freezing of what was hitherto liquid. All of a sudden, everything means one thing—every expression might seem to have great significance, but the significance of every expression proves to be identical. "All of these feelings I've been having are because of the signs I was picking up that there is a gigantic conspiracy going on, and it's all centred around me!"

Is this not the very tripartite process that occurs at a collective level when the crowd designates a scapegoat, and with all of those other reactive formations that amount to one or another form of collective psychosis, new forms of which seem to be emerging with highly disconcerting rapidity and variety (even if they all also seem somehow depressingly similar)? Post-truth, generalized distrust and suspicion, the susceptibility of just about anyone to falling under the sway of one or another species of conspiracy theory, the sense that one cannot find an authority with whom to reliably orient oneself: all of these socio-technically fuelled disorders and psychoses, which can befall individuals situated anywhere on the political spectrum, follow patterns that may have much to do with Schmitt's antithesis of friend and enemy, but all *also* resemble the premorbid, prodromal and apophanic stages of the onset of psychotic episodes in general and paranoid delusions in particular.

7. Resonance and Tension

What difference does it make if we examine such phenomena through this particular kind of lens? First, it is worth noting that this process of collective paranoia does not operate in the same way as those processes of the nervous system, as, for example, when my finger touches something very hot, causing the pain receptors in my finger to send signals along my arm, through my neck and into my brain, which responds by sending different signals back to my arm, my hand and my finger, stimulating muscle actions aimed at removing that finger from the source of the pain. This describes von Uexküll's "sensorimotor loop,"[19] but this "loop" is possible and necessary because of the linear, centralized character of the nervous system. But in the case of the psychosocial phenomena we are considering here, other terms are needed, because such processes are not best described as this kind of looping back and forth between centre and periphery.

The immune system offers terms that more closely conform to what occurs with this

19 Jakob von Uexküll, *A Foray into the World of Animals and Humans, with, A Theory of Meaning*, trans. Joseph. D. O'Neil (Minneapolis and London: University of Minnesota Press, 2010).

kind of mimetic contagion. Instead of loops of messages between centre and periphery, the immune system *resonates* through the body, as a spreading chain of antibodies. One might think: is this not to confuse the socially contagious character of certain forms of disease, or the spread of a virus or infection through a body, with the action of the system designed to defend against that contagion or infection? But this is the very ambiguity that characterizes the *psychosocial* immune reaction: to what degree the spread of such reactions is *itself* a sign of psychosocial disease (we might think of the xenophobic designation of scapegoats, for example), and to what extent a prophylaxis against a genuine threat (we might think of indigenous populations rising up against a colonial intruder, for example), has *something at least* to do with viewpoint. At what point does immune response shift, anaphylactically, so that it becomes a shock reaction whose rapid spread and crystallization becomes the very thing with the capacity to fundamentally threaten the organism itself (we might think of the rise of anti-Semitism leading to the fall of the Weimar Republic, for example)?

Resonance is possible only because there is tension. To be in a condition of tension is, for a physical system, to be in a situation where all of the elements are held within a mutually connected field of attraction and repulsion. In physical systems, this attraction and repulsion are the work of physical forces (in the physical systems with which we are mostly familiar, this tension is electromagnetic). In the noetic systems of exosomatic life, however, this attraction and repulsion are not a matter of electromagnetism, but nor is the attraction and repulsion here something that could be reduced to some primordial "antithesis" of friend and enemy.

Rather, what is at stake in the noetic tensions of exosomatic life involves a multi-dimensional and singularly complex question of the way in which the turns of all the idiomatic spirals greater than us and smaller than us meet in ways that either seem similar or dissimilar, fitted or unfitted, suitable or unsuitable, fruitful or sterile, or more generally, in Canguilhem's terms, *propulsive or repulsive*. The sensitivity of interpretation is a matter of negotiating the way in which these tensed possibilities are distributed across a heterogeneous field, and of negotiating and articulating them in terms of what these interactions, events and possibilities open up and what they close off. It is a sensitivity that inhabits this tension, a tension between individuals and groups of individuals, arising from the propulsive/repulsive diversity of their knowledge and desire.

This tensed diversity is what makes it possible for knowledge and desire to individuate, in ways that lead to conflicts and dissolutions, but also to singular resolutions that represent the individuation of knowledge and desire. And these resolutions amount to the production of new significance. To say that information is a kind of prodromal and protentive tension and resonance would be to say that it exists in a supersaturated field of possible meanings. And it would be to say that this is the condition of possibility of noetic diversity, but also that it is the condition of possibility of that supersensitivity that anaphylactically crystallizes into shock reactions.

8. War, Peace and Beyond

Why does this matter? It matters because today, algorithmic platforms utilize their immensely powerful informational strategies in a way that tends to eliminate that tension. The tension of noetic life always depends on the cultivation of highly sensitive, delicately balanced interpretive instruments that *always* work through a multiplicity of dimensions simultaneously. In other words, tension is always a matter of forms of knowledge and desire that must be cultivated, transmitted and transformed intergenerationally, where this transformation sometimes occurs very slowly (with the rhythm of linguistic evolution, for example) and sometimes very quickly (at the accelerating pace that takes us through childhoods shaped by cinema, then by television, then by the internet, then by Facebook, then Instagram, Snapchat, TikTok and whatever comes next, each successive epoch becoming more or less incomprehensible to the one that preceded it, and vice versa).

Tension is always a risk, precisely the risk that it will lead to supersensitivity, but tension is also productive: it is the tension between diverse viewpoints, the tension between the old and the young, or between men and women (seduction, for example, is a situation of tension, one that, at its best, can be electric, which is to say, a very short circuit), which forms the conditions in which what Canguilhem called propulsive constants can be followed, in which positive leaps can occur:

> There are two kinds of original modes of life. There are those which are stabilized in new constants but whose stability will not keep them from being eventually transcended again. These are normal constants with propulsive value. They are truly normal by virtue of their normativity. And there are those which will be stabilized in the form of constants, which the living being's every anxious effort will tend to preserve from every eventual disturbance. These are still normal constants but with repulsive value expressing the death of normativity in them. In this they are pathological, although they are normal as long as the living being is alive.[20]

20 Canguilhem, *The Normal and the Pathological*, 206.

The elimination of the tension of noetic and neganthropic life is a reduction of exosomatic life's multi-dimensional tension, leaving a form of "unlife"[21] that may still last for a long time, many of those it inhabits not *quite* knowing immediately or well that the efficient crystallization of frozen informational "repulsive" norms inevitably produces pathologies of suffering that eventually prove unbearable and unliveable. The destruction of the knowledgeable and desirable conditions of this tension and this resonance—between diverse viewpoints, between the old and the young, (and *especially*, in some way, even though this received the *least* attention from Stiegler) between men and women—leads either to the grey of flattened indifferentiation, or to war. Or to both at the same time. Today, we bear witness in a thousand ways to this collapse of tension, to the conflicts to which it leads, and to the wars which it is generating.

Today, the question of politics is above all a matter of knowing how to live well within a situation of unavoidable pressure. And yet in some way it is also a question of reinflating a form of pressure that has been lost, so that it can cope with the road ahead—and, we could say, of inflating it to a cosmic scale. It is thus a question of adopting all of the tensions that define us and confront us, so that we can resonate fruitfully *in and through* these tensions, and beyond the deflationary depressions of an all-too-anthropic universe. For exosomatic life, tensions are first and foremost a matter of being protentively and prodromally held out to the possibility and improbability of what's coming, its significance, and its pathologies. In this way, protentional tension forms the very conditions of possibility of attention and paying attention, and, without the knowledge and desire to live with such tensions and within them, and of (genuinely) apophanically transforming our relationship to them, we are bound to see a series of anaphylactic reactions to the efficient installation of repulsive informational constants, reactions that amount to the self-destruction of the psychosocial organism by itself, and by technically-induced means.

If politics can still be defined as the counter to war, then what it is also crucial to remember is that it is not exactly the case that peace is the *antithesis* of war. Rather, the condition of any lasting peace is precisely a matter of living in tension: peace can never mean frozen states of idyllic tranquillity, and can only mean metastable states of tension. Such a metastabilization requires the cultivation of the knowledge and desire to live well within a tension that is *never* completely stable, and which, if it *were* completely stable, would mean that the situation has regressed—that it has succumbed to entropy, and to anthropy. It can only be a matter, then, of something towards which we rise, towards which we raise ourselves, and the knowledge and desire this requires are irreducibly matters of interpretation and sensitivity.

21 See Ross, *Psychopolitical Anaphylaxis*, 162–64.

Today, we face an immense proletarianization of our interpretive and sensitive capacities. These capacities must be revived, at the scale both of the individual and the collective, and at a "cosmic" scale that exceeds them. Such an apophanic renewal of the *normativity* of exosomatic life can only be anchored to new propulsive values. This may well be something we should still understand as a question of establishing the conditions of peace, but only if the latter is defined as follows: peace involves the perpetually renewed cultivation of the capacity for living well in all kinds of resonant tension, within an extended critical situation that always threatens to mimetically catalyse into anaphylaxis, that is, into war.

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Human Aging and Entropy

Shannon Mussett

"No man who lives long can escape old age: it is an unavoidable and irreversible phenomenon."
Simone de Beauvoir

Abstract:
In this paper I argue that the contemporary pathologizing of old age is directly tied to the notion of uselessness, understood entropically as that which cannot contribute energy for useful work. The elderly are configured as socially useless and thus presumably threaten the health and longevity of the body politic. As a result, they are marginalized, ignored, and treated as waste to be jettisoned from the system. Because understanding bodies as machines able or unable to perform work accords with the second law of thermodynamics, the first half of this paper discusses entropy as both scientific law and philosophical concept and how it works to shape human aging as a societal danger. The second section explores the lived experience of aging and the pathologized position of social uselessness through Simone de Beauvoir's analysis of old age. As she herself ages, the place of senescence comes to play a more pronounced role in her philosophical inquiry. Writing about the lived experience of aging adds a vital dimension to the scientific and philosophical perspectives, as it foregrounds the various ways that entropy is felt: slowing, dissipating, and ultimately dying. While these should be viewed as part of the normal life cycle, they become markers of abjection which are judged harshly against the standard of social utility.

Keywords:
Entropy, Entropics, Age Studies, Old Age, Simone de Beauvoir

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In January 2023, *National Geographic* ran the story, "Living Longer and Better: How Science Could Change the Way We Age." The article follows several different scientists and companies racing to develop anti-aging medications and therapies. Rapamycin, metformin, and acarbose are among the numerous drugs tested in a blooming industry seeking to "hack the aging process itself by reprogramming old cells to a younger state."[1] Billions of dollars are currently flowing from Google's Calico Life Sciences, tech moguls, crypto millionaires, the Saudi royal family, and other entities devoted to various scientific endeavors striving to optimize human longevity. This accelerating trend in health care promises all of us prolonged life and mitigation of disability. The guiding myth peddles the idea that if enough dedication, money, and resources are thrown into the problem, humanity might just beat entropic inevitability yet.

The maximum lifespan for a human being tops out around 120–125 years. The race is on to increase the number of people able to reach that age and even to extend the maximum lifespan beyond it. On a more moderate scale, the anti-aging industry strives to make aging healthier and more comfortable as greater numbers of people experience longer lives without the expansion of mental and bodily enjoyment. However noble the easement of the pain of aging may be, there are many concerns about the motivations behind this quest and access to available treatments. Three issues remain largely unaddressed in these developments: 1) who benefits from these potential advancements? Clearly these pills and procedures will not be available to all human beings equally, 2) why would we seek to advance human aging in a time of obvious global climatic crisis and environmental decline? 3) a largely ignored problem, lies in the undercurrent of this frenzy: the pathologizing of aging as such. As Barbara Ehrenreich notes, in the 20th century, "medical science began to think of aging as a kind of disease as opposed to a normal stage of the life cycle."[2] If the hunt is on to find a cure to aging, then aging can only be seen as a sickness to treat and eradicate. This paper explores some of the considerations that must be taken into account to address this problem from an entropic perspective. The elderly serve as an important cross-section of many populations that suffer from the entropy-denying and entropy-accelerating practices rampant in late-stage capitalism. The elderly are forced to work longer, spend waning or nonexistent money for self-care (from the most banal cosmetics to the most extreme life-saving technologies and medicines) and are made invisible through

1 Fran Smith, "Living Longer and Better: How Science Could Change the Way We Age," *National Geographic*, January (2023): 42–43.

2 Barbara Ehrenreich, *Natural Causes: An Epidemic of Wellness, the Certainty of Dying, and Killing Ourselves to Live Longer* (New York: Twelve, 2018), 171.

marginalization.[3] Additionally, the affective experience of living decline is vital to being honest about what it means to be a person aware of inescapable waning and what is at stake in the profound anxiety surrounding an inevitable biological progression.

Entropy is a multivalent concept in scientific, philosophical, and literary registers. Human aging is a process that requires all these perspectives (and more) to fully explore its significance. While this paper cannot be an exhaustive treatment, it contributes to the modern critique of the shunning of senescence. I argue that the contemporary pathologizing of old age is directly tied to the notion of uselessness, understood entropically as that which cannot contribute energy for work. Populations that are unable to perform useful labor—and the elderly are quite possibly the largest group this affects—are configured as a threat to the health of the body politic. As a result, they are marginalized, ignored, and treated as so much waste to be jettisoned from the system. They become part of what Karyn Ball describes as, the "disheartened *precariat* running on empty [functioning] as the latest expendable product of asocial-individualism."[4] Because understanding bodies as machines able or unable to work coincides with the second law of thermodynamics, the first half of this paper discusses entropy as both scientific law and as philosophical idea, and how it shapes human aging as a societal danger. Once utility becomes coupled with health, and health with productivity, aging becomes a kind of sickness that threatens the smooth working of the machine. As such, old age is either something to ignore (as it will ultimately take care of itself) or something to remedy. This attitude, however, only exacerbates the precarity of those who are forced to live in society's shadow lands.

The second section takes up the lived experience of aging through Simone Beauvoir's analysis. While she only obliquely addresses the pathologizing of age, she provides an important voice in understanding how this happens through the othering of the elderly.[5] As she herself ages, the place of old age comes to play a more pronounced role in her philosophical inquiry. This last stage brings to the foreground the various ways that entropy is felt: slowing, dissipating, and ultimately dying. While all stages are normal in a full life cycle, old age is judged harshly and lived poorly against the standard of social utility.

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3 For rich discussions on the complexities of these issues and how they affect those in precarious positions, see, for example, Karen Ball, "Losing Steam After Marx and Freud," *Angelaki* 20, no. 3 (2015): 55–78; Jasbir K. Puar, "Coda: The Cost of Getting Better: Suicide, Sensation, Switchpoints," *GLQ: A Journal of Lesbian and Gay Studies* 18, no. 1 (2012): 149–158; and Lauren Berlant,"Slow Death (Sovereignty, Obesity, Lateral Agency)," *Critical Inquiry* 33, (2007): 754–80.

4 Ball, "Losing Steam," 69.

5 For a discussion of how Beauvoir's philosophy relates to the idea of pathologizing, see Shannon M. Mussett, "Simone de Beauvoir," in *The Oxford Handbook of Phenomenological Psychopathology*, Andrea Raballo, Matthew Broome, Anthony Vincent Fernandez, Paolo Fusar-Poli, René Rosfort, and Giovanni Stanghellini (Oxford: Oxford University Press, 2020).

Part One: Entropy is Inevitable

The discovery of the entropy law has had profound effects on multiple expressions of human knowing and self-understanding. Although the amount of energy in the universe remains constant, disorder increases over time, inexorably leading to what Boltzmann called, the "heat death" of the universe. Eric Zencey has argued that entropy functions as a contemporary root metaphor working its way into our interpretations of a vast array of economic, psychological, social, and natural phenomena. From a psychological point of view, it represents a "fourth" blow to humanity's narcissism (alongside Copernicus, Darwin, and Freud), while from an economic standpoint, it has contributed to the impossible demand for not just constant but accelerated growth.[6] Karl Marx and Friedrich Engels showed how the laboring body can be understood as a machine vulnerable to entropic decline. Sigmund Freud demonstrated how entropy functions as an unremitting drive toward stasis. Implicit, but not fully developed in all these treatments, is a description of the experience of living time entropically, specifically as a body/machine that breaks down and becomes socially useless.

In general, thermodynamics is the science of work understood in terms of heat and energy. The first law tells us that while matter and energy can neither be created nor destroyed (only changed), the second law informs us that heat ultimately moves from hotter to cooler temperatures, and that matter eventually moves from more complex to more homogenous states.[7] While the quantity of energy remains constant, its quality degrades from low-entropy (and therefore useful) to high entropy (and thus useless). This means that encountering ordered configurations of low entropy are rare in the universe and warrant careful consideration. Human beings fall squarely into this category.

In the mid-twentieth century, Claude Lévi-Strauss famously noted that anthropology would be better named "entropology" because of the terrifying and depressing tendency of humanity to reduce the diversity of flora, fauna, and cultures into degraded, homogenous sameness. More technologically advanced societies usher in this destructive force at a level of acceleration matching their supposed sophistication. The more culturally "developed," the greater the annihilation of diversity. This means our conceits of advancement are nothing more than perfections and accelerations of entropic dissolution. The science of entropy is not enough to critique this phenomenon. Science and philosophy must work

6 Eric Zencey, "Entropy as Root Metaphor," in *Beyond Two Cultures: Essays on Science, Technology, and Literature*, ed. Joseph W. Slade and Judith Yaross Lee (Ames: Iowa State University Press, 1990).

7 See Brian Greene, *Until the End of Time: Mind Matter, and Our Search for Meaning in an Evolving Universe* (New York: Vintage Books, 2020), 26.

together to understand why humanity not only functions in the natural order of entropic decay but increases it considerably to its own detriment.

Drew M. Dalton's recent article, "The Metaphysics of Speculative Materialism: Reckoning with the Fact of Entropy," takes speculative materialism to task for its general failure to account for the findings of contemporary empirical science. Dalton moves to correct this oversight in the development of a "new metaphysics of absolute reality upon which philosophy can reestablish its classical aim and projects"[8] by turning to the laws of thermodynamics, in particular, the entropy law, which he coins the "absolute law of existence." Entropy's lawfulness is uniquely absolute in the assertion of energy toward equilibrium, dissipation, and disorder. Pointing to the theory of Quantum Thermodynamics, Dalton notes that physics may very well be on the cusp of grasping the ever-elusive Grand Unified Theory. As such, it is best for any philosophy seeking to align itself with empirical science to be grounded in thermodynamics.[9]

Speaking directly to the phenomenon of life, a curious, perhaps surprising theory emerges. Life is often conceived as a peculiar manifestation of a struggle *against* entropy. Organisms maintain integrity *despite* the fact that matter constantly and relentlessly tends toward breakdown. Life, through this commonly applied interpretation, appears as almost miraculous islands of stability amidst the general tendency toward instability. However, contemporary biology has revealed that formulating life as anti-entropic is wrongheaded. In reality, the laws of thermodynamics reveal that that:

> the material function of living things is best defined as nothing more than dissipative catalysts within that system, little more than the effective agent of the transformation of relatively low entropic states (like matter) into relatively higher entropic states (like heat). We are, from this perspective, merely entropic machines: the most efficient way in which the universe can break down energy into its simplest form to be distributed evenly across the cosmos.[10]

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8 Drew M. Dalton, "The Metaphysics of Speculative Materialism: Reckoning with the Fact of Entropy," *Philosophy Today* 66, no. 4 (2022): 6.

9 This insight is what leads Dalton's call for speculative materialism to ground its insights in thermodynamic decay. This nihilating principle would be the ground of being itself, rather than its threat or denial.

10 Dalton, "Speculative Materialism," 11. Greene notes how life is one among many of the transient structures that form in the universal march toward greater entropy. "For all their majesty, these orderly arrangements are nature's workhorses, harnessing gravity and the nuclear forces to drive the cosmos toward realizing its entropy potential" Greene, *End of Time*, 59.

In other words, life is not anti-entropy, but rather, a particularly effective facilitator of it; an idea that harmonizes with Lévi-Strauss's theory of entropology but with less emphasis on the melancholy conclusions for humanity. While life is obviously at the mercy of disease, aging, and death, these very phenomena are the facilitators of entropic decay and catalyzers of life. Life emerges from decay which is "its *secret heart* and *ultimate essence*. Indeed, in this regard, entropic dissolution appears to be the *primal cause, motivating power, organizing structure*, and *eventual end* of all that we are."[11] Taken one step further, the harder we try to stave off entropic decline, the more we play into the thermodynamic movement toward heat death. Here is where I locate the convergence of aging labor, capitalism, and the entropy law. Life is indeed an effective facilitator of entropic decay and Dalton is correct that any contemporary philosophy that engages science must take this into account. Fighting against entropy—as we find in the ubiquitous anti-aging industry—is a losing battle. What's more, however, neglecting to take this fundamental law into account in the mindless push to use up all resources as fast and as wastefully as possible only hastens planetary demise which is unnecessary and clearly nihilistic. Where I want to redirect the conversation, however, is to emphasize that human society can think carefully about the ways in which we function as entropy machines. Because we inevitably use energy and produce waste does not necessitate that we diabolically accelerate it nor that we force vulnerable populations to shoulder the burdens of waste and loss while others remain relatively unscathed.

Clearly, it would behoove us then to take seriously the laws of thermodynamics when doing philosophical analyses. Strict philosophy of science or even materialism isn't necessarily required. However, acknowledging that entropy shows us on the macro and micro levels that useful energy is limited, systems require energy to maintain themselves, no system is fully self-perpetuating, and therefore all systems—at the largest cosmic to the smallest subatomic scale—will eventually decay. Entropy increase is inevitable, and the future will always be a state of higher entropy than the past. As Brian Greene explains, "the first law of thermodynamics declares that the quantity of energy is conserved over time, the second law declares that the quality of that energy deteriorates over time….the energy powering the future is of lower quality that that powering of the past. The future has higher entropy than the past."[12] This scientific law pertains to all life, even entropy-denying human beings. Ideally, foregrounding this truth would open ethical dimensions of responsiveness and care, especially with those most exposed populations who have the least access to support and are often positioned as human waste.

Anyone who lives long enough will undergo old age and disability. Entropy, as the

11 Dalton, "Speculative Materialism," 13.

12 Greene, *End of Time*, 34.

measure of the movement toward disorder and uniformity, is thus a necessary component to understanding the science of aging. Given that any organism exists in an open system (sharing energy and waste with its environment) aging will involve a complex exchange of energies that ultimately leads from a state of systemic and metabolic order toward the opposite state. A system defined in a thermodynamic sense "can be formulated as a collection of elements, or agents, constituting the system along with those elements that constitute the system boundary."[13] Thus aging must be viewed not only as the effects of thermodynamic movement toward equilibrium within the system of a body but also insofar as the body and its boundary relates to its surrounding environment in an open exchange of energy and waste. Senescence and death would be the ultimate breakdown of the system boundary and its surrounding environment. Gavin J. Andrews and Cameron Duff define organic aging in an open system "as the initial generation and later degeneration of its order."[14] The authors go on to detail the necessity of understanding aging on multiple scales, ranging from individual lifespans and biological changes in themselves and as they relate to the organic and material environment. Taking an approach that involves the human, organic, and inorganic world is crucial to understanding human aging "as a more-than-human performative production."[15] Entropy is therefore the primary theoretical foundation for any study of aging as living and non-living systems not only interrelate, but all move at varying rates from low to high entropy states. Any consideration of the effects of entropy on aging humans must therefore take into account increasing entropy in all dimensions of human life: economic, social, cultural, as well as technological, natural, and material. This means that singling out older people as energy drains and therefore uniquely problematic to the body politic is not only pernicious but scientifically unsupportable.

Cara New Daggett's recent work on energy humanities focuses on the "energetic turn" in contemporary western conceptions of labor. Using thermodynamics, and the entropy law in particular, Daggett argues that the unit of "energy" is a recent invention used to mark the shift toward *productivity* and *efficiency* as the sole registers of value in modern labor practices (and ultimately of all the Earth's resources). Just as Zencey argues that entropy emerged as the dominant root metaphor, Daggett traces the energy metaphor which promotes unlimited progress across all inorganic, organic, technological, and human embodied practices. Bodies, technology, and the very earth itself are organized as energy to be mined, exploited, and maximized. Regarding human labor, the energy

13 Atanu Chatterjee, Georgi Georgiev, and Germano Iannacchione, "Aging and Efficiency in Living Systems: Complexity, Adaptation, and Self-Organization," *Mechanisms of Ageing and Development* 163, (2017): 2.

14 Gavin J. Andrews and Cameron Duff, "Opening Out Ageing: On the Entropy of All Things," Transactions of the Institute of British Geographers 47, no. 3 (Sep 2022): 667 DOI: 10.1111/tran.12519

15 Andrews and Duff, "Opening Out Ageing," 673.

framework establishes overwork and underwork as social ills around which a great deal of capitalist anxiety congeals. Overwork is handled through the incessant emphasis on finding and maintaining energetic balances of energy input and output. Workers are understood as machines needing periodic energy tweaking and adjusting to maintain productivity. While overwork is a problem veiled under ethical concern, underwork is a far graver threat, "feared as a veritable scourge on civilization, and one that appeared much more intractable. Here were energy sinks, sites where energy sat unused or, worse, was frittered away, wasted."[16] Here is where we find not only the fears surrounding laziness, unfair distributions of resources, or social unrest, but also the obsession with how to force underperformers to increase their contributions to the social yield. The crux of the problem lies on how to increase energy output while contributing as little energy as possible in the equation. When dealing with young, able-bodied, and cognitively vigorous workers, this dilemma is less urgent as the social precarity of having to make a living carries its own punitive weight. But disabled, cognitively impaired, and older bodies are much harder to force into this form of energy accounting. To put it succinctly, old age poses a significant problem to the "preference for constant motion, action, dynamism, growth."[17]

The entropy of old age is inevitable and irreversible, yet it appears as the quintessential threat to progress and growth. This is why the aging laborer is the object of hyper-fixation. The ethical position of attention and care encourages us not to shun or ignore this inevitability, but to bring it into the fold of normalcy. This is not the custom in capitalist ideology which instead conceives of senescence as an abnormality. Old age is not understood as ineluctable or natural but rather fearful and potentially curable. The mythology of old age as a disease that medicine and technology can cure produces two particularly dangerous ideas. One centers around the belief that decrepitude be mollified or even reversed. This conviction emphasizes that cells can regenerate, systems can not only stave off breakdown, but they can actually *revert to younger states*. Chasing after these elusive elixirs of youth is of course the pastime of only those privileged with the time and material means to pursue them. Most humans will be necessarily shut off from the self-absorbed whims of this tiny elite. Yet, the neg-entropic ideology they promote spills over into the general sense that old age is a disorder, and one that only a select few will be able to reverse. The second idea is an offshoot of the first. Since cures are evasive, they must be protected from those who cannot and *should* not have access to them. These people fall in to the stereotype of what Jessica Bruder calls the "greedy geezer," a bogeyman who takes more than they should in terms of leisure and material wealth, "while draining the

16 Cara New Daggett, *The Birth of Energy: Fossil Fuels, Thermodynamics, and the Politics of Work* (Durham: Duke University Press, 2019), 96.

17 Daggett, *The Birth of Energy*, 18.

lifeblood from younger generations."[18] Whereas the ultra-privileged have the right and even duty to reverse the sickness of age, the rest are meant to suffer the inevitability of decline without so much as asking for access to resources lest they be viewed as robbing future generations of their scarce supplies.[19]

What benefits from this, is of course, capitalism, the great anti-entropic engine rooted in an ideology of infinite expansion without the production of unrecyclable waste. Instead of taking the lawfulness of entropy to heart as Dalton above suggests, we live in an age in which science, business, and medicine collude in the overt denial of this law. None of these assumptions are sustainable and all are ultimately obscene. As Greene reminds us, "we are all waging a relentless battle to resist the persistent accumulation of waste, the unstoppable rise of entropy. For us to survive, the environment must absorb and carry away all the waste, all the entropy, we generate."[20] However, in the system of the planet, utilizable energy and sustenance are limited, and waste can never be recycled completely without producing even more. Reversing the inevitability of decline and age therefore necessarily blows through scarce resources and produces more waste than it recuperates. If we paused and questioned our incessant judgment of humans as either useful or useless, these destructive practices could be mitigated. If we stopped producing senescence as an aberration, we could embrace the entropic inevitability of physical decline as normal and therefore worthy of care, time, attention, and shared resources. To facilitate movement in this direction, the lived experience of aging must be added to the discussion.

Part Two: Aging is Inevitable

There are multiple ways to take entropy into account when dealing with inevitable biological decline. Matter is neither created nor destroyed, but whether energy coalesces into relatively bounded structures such as stars, mountains, or bodies, or dissipates into homogeneity determines its value from a human perspective. Human aging is both a physical and a psychological experience. Physiologically, "with advancing age, bodily processes slow down, such as metabolic cycles, food absorption rate, respiration rate,

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18 Jessica Bruder, *Nomadland: Surviving America in the Twenty-First Century* (New York: W. W. Norton & Company, 2017), 67.

19 Teresa Ghilarducci notes that this view of the elderly plays right into the false consensus that old people should work as long as they can before retirement for their own benefit and for the good of society. Otherwise, the fear goes, they will take away resources from younger generations. Teresa Ghilarducci "Making Old People Work: Three False Assumptions Supporting the 'Working Longer Consensus,'" *Politics & Society* 49, no. 4 (2021): 562. Not only is there no evidence that the elderly are vampires on the young, Ghilarducci shows the many ways that social services across ages produces intergenerational health as the wealth is shared among rather than siphoned off by age groups.

20 Greene, *End of Time*, 42-43.

blood flow, etc. thereby reducing the action efficiency of the system as a whole."[21] There is no possibility of maintaining systemic integrity in perpetuity due to the constraints within and outside of a bodily system. Psychologically, these physical changes can be undergone through a variety of attitudes, many of which are contingent upon the situation of the aging individual.

All organisms die and aging is inevitable. If we live long enough, old age is inevitable too. Why, then, is it treated, as Beauvoir notes, "as a kind of shameful secret that … is unseemly to mention"?[22] Going one step farther, why is it understood as a kind of disease that can *and should* be cured? Where does the ground get primed for this conception of, what Beauvoir calls "that normal abnormality"?[23] As addressed in the previous section, science and philosophy are vital angles in understanding the phenomenon of human aging. But aging is also a lived experience, and one that varies widely depending on the time and place in which it is undergone. Beauvoir's existential analysis of the phenomenon of old age from both objective and subjective standpoints aids in teasing out the relationship between entropic thinking and the marginalization of those deemed socially useless. She maintains that no system of thought can ever adequately name and alleviate a problem unless it also takes into account how the problem is lived by those most directly affected by it. Old people under late-stage capitalism are cast aside the moment they no longer offer any form of use value, regardless of what they may have contributed earlier in life. This, for Beauvoir, is an unethical and unsustainable condition.

Life is an unstable system undergoing constant change and physical breakdown signals perceptible energy loss. Systemic balance is only temporarily achieved because organic matter is in constant flux. Age is, however, a particular kind of change: "an irreversible, unfavorable change, a decline."[24] As Beauvoir remarks, this assertion implies a value judgment regarding how we understand decline. Much like the vague horror evoked by the thought of universal heat death, "old age looms ahead like a calamity."[25] Even the mere thought of old age is existentially unsettling. Unlike the other animals for whom aging is less dramatic, our metamorphosis is, according to Beauvoir, a complete transformation. This is because we are self-aware of how this unidirectional process works. While the

21 Chatterjee, Georgiev, Iannacchione, "Aging and Efficiency," 4.

22 Simone de Beauvoir, *The Coming of Age*, trans. Patrick O'Brian (New York: W. W. Norton & Company, 1996), 1. I maintain the English translation of *La vieillesse* as *The Coming of Age*, in the footnotes, but refer to the book as *Old Age* in the paper as this is a more accurate translation.

23 Beauvoir, *The Coming of Age*, 286.

24 Beauvoir, *The Coming of Age*, 11; see also 37. Throughout the book Beauvoir is emphatic that "the word decline has no meaning except in relation to a given end—movement towards or rather from a goal" *The Coming of Age*, 86. In other words, there is nothing inherently repugnant about decline except insofar as it is socially categorized to be such.

25 Beauvoir, *The Coming of Age*, 5.

human body begins a kind of "retrograde" alteration at a relatively young age, such slackening is not necessarily a universally negative phenomenon. This is because for human beings, "the body itself is not in a purely natural state; it can compensate for loss, deterioration and failure by various adjustments and automatic responses, by practical and intellectual knowledge."[26] Where certain physical changes move toward slowing and cooling, entropics teaches that degradation in one system often lends energy to others. It is a gross oversimplification to assume that biological aging (rather than death) is a thorough and total systemic breakdown. Systems can borrow and lend energy to each other in direct, indirect, and novel ways.

Zencey explains that "in one of its more accessible guises, the second law of thermodynamics holds that energy spontaneously degrades from more useful to less useful forms, even if it accomplishes no work in the process."[27] What counts as work, of course, is of central concern. In capitalism, work is necessarily that which can be commodified—energy bought and sold to the highest bidder and paid for at the lowest cost. For a host of reasons, this discounts many of the activities that humans do to better themselves, their families, and their communities. As a result, most old people in these societies face aging with fear and despair over the very real possibilities of untreated physical ailments, poverty, and loneliness.[28] While these concerns are at the vanguard of Beauvoir's voicing of the shame surrounding aging, the underlying problem can be encapsulated by the pathologizing of old age through an overt denial of entropic decay.

Beauvoir studies aging as a decline and general slackening of energy on an existential and physical level most directly in *Old Age*, her last systematic philosophical treatment of an othered population. Like woman in *The Second Sex*, the old person is pushed to the margins of society—neither fully human, nor fully object. But this role provides no social utility and is thus unlike women who prop up patriarchal power. Woman's role is ambiguous—praised, feared, hated, and adored—but always useful. However, the old person is almost entirely shunned because they provide no clear use value. In fact, they are not only valueless but perceived as a sap on younger populations. As a result, old age fills us "with more aversion than death itself;" it is "old age, rather than death" that is life's

26 Beauvoir, *The Coming of Age*, 12. Beauvoir observes that with the industrial revolution and the rise of capitalism, old age suffers from profound discreditation. This is because "modern technocratic society thinks that knowledge does not accumulate with the years, but grows out of date. Age brings disqualification with it: age is not an advantage" Beauvoir, *The Coming of Age*, 210.

27 Eric Zencey "Some Brief Speculations on the Popularity of Entropy as Metaphor," in *The North American Review* 271, no. 3 (1986): 6.

28 The ways in which capitalism is deeply entwined with the abject othering of the aged was not lost on Beauvoir's analysis. It forms a central component of her discussion in *Old Age*.

real opposite.[29] In part, this is because the old person, significantly, *can no longer provide meaningful labor*, and thus becomes "a useless mouth to feed."[30]

The observation that old people are comprehended by society as useless due to their incapacity to provide socially exploitable labor is a primary theme of her play, *Useless Mouths*. There she observes the inclination to regard old age as one kind of disease that threatens the scarce resources of the common good. In the play, the socially useless are literally excised from society. Children, women, the infirm, and the elderly are cast out of the fictional medieval town of Vaucelles in a cruel attempt to extend dwindling rations until spring when reinforcements are anticipated. It is significant that the category of "useless mouths" is so broad in this play because it accentuates the overly narrow interpretation of utility based on a very particular kind of masculine intellectual and physical labor. Those who run the city and those who build the city are useful, all others are dehumanized to the point of murder by deprivation. One of the town elders declares that the "council has decided to get rid of the useless mouths. Tomorrow before sunset they will be driven into the ditches: the infirm, the old men, the children. The women."[31] Here the elderly appear as one category of many that fall outside of the parameters of social utility. As the useless mouths become increasingly dehumanized in the attempt to hoard resources for the benefit of a small set of men, the flaws of this homicidal logic become apparent. The town is surrounded, sealed off from the rest of the world. It therefore functions as a closed system with limited supplies of energy to sustain life. Entropic loss is a dominant threat throughout the story. The town elders reason that the most capable bodies should have access to shrinking rations because this increases the likelihood of the town's survival until spring. However, Beauvoir subtly challenges this rationale by showing that the able-bodied men who will be the beneficiaries of this fuel are instead the greatest producers of waste. The political leaders do nothing more than walk about, scheming and arguing. And the only workers present are devoted to the pointless task of completing a belfry that seems to never advance in progress. The failure to work within the confines of entropic loss only exacerbates it.[32]

Not only do the town leaders arbitrarily decide who and what counts as useful, but the

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29 Beauvoir, *The Coming of Age*, 539.

30 Beauvoir, *The Coming of Age*, 39.

31 Simone de Beavuoir, "The Useless Mouths," in *Simone de Beauvoir: "The Useless Mouths" and Other Literary Writings*, ed. Margaret A. Simons and Marybeth Timmerman (Urbana: University of Illinois Press, 2011), 56.

32 The role played by the belfry is further explored in Shannon M. Mussett, "Useless Mouths or Useful Labor? Simone de Beauvoir's Relevance to Modern Gray Labor Force Exploitation," in *Routledge Handbook of Contemporary Existentialism*, ed. Megan Altman, Hans Pedersen, and Kevin Aho (Milton Park: Routledge, 2024).

category of uselessness also becomes a kind of disease. One character even goes so far as to call the ill-fated populace "vermin" that should have been disposed of long before the time of crisis.[33] Here we see the very enactment of the marginalizing and pathologizing of the socially powerless. When this transformation of usefulness to waste is completed, they are no longer seen as human, but as parasites who threaten the social body. Consequently, it becomes morally permissible to dispose of them. Positioned as vermin, the only solution becomes to "cure" the hazard through eradication. The operation of scapegoating of those perceived as a threat remains a lifelong concern of Beauvoir's philosophy, politics, and ethics.

When Beauvoir turns to *Old Age*, her attitude has shifted toward the specific marginalization that the elderly experience. In *Useless Mouths*, those who are othered form a group far larger than the men in power who are willing to kill them. This gives them power to resist through their numbers. In *The Second Sex*, the category of Woman occupies the space of the absolute Other without reciprocity, yet women still compose roughly half of the human population. In *Old Age*, the elderly form a category smaller than the previous iterations. The old become "useless mouths" almost exclusively. In fact, Beauvoir employs this specific phrase throughout *Old Age* in the various ways she characterizes their plight.

To address the existentially lived dimensions of this appalling situation, Beauvoir provides not only philosophical and literary studies, but additionally chronicles her own experiences of aging. Seeking to join lived experience with philosophical observation, she illustrates that what it *feels* like to age is as important as systematically criticizing the ways a given society harms the elderly. Rooted in the phenomenological tradition, she describes human temporality as projection into the future. The past is meaningful only insofar as it shapes forthcoming possibilities. From an entropic standpoint, the ceaseless futural movement of being-toward-death encapsulates the embodied experience of time's arrow. To be human is to imagine oneself in the future and to configure the present toward the attainment of one's coming self in a unidirectional flow. As Beauvoir ages, she becomes progressively aware that she is entering a new landscape. When we are children, the future appears enormous and vast; in middle age, the future and past exert a kind of push and pull as we are drawn into the dynamic of recollection and working toward further self-development. Old age is significantly different than either of these life stages.

33 Beauvoir, "Useless Mouths," 47. As Liz Stanley and Catherine Naji observe, the pathologizing of the vulnerable and scapegoated other is directly tied to Beauvoir's experiences of living in Occupied Paris, bearing witness to the Nazi deportation and murder of thousands of her fellow citizens. Liz Stanley and Catherine Naji "'Introduction' to *The Useless Mouths*," in *Simone de Beauvoir: "The Useless Mouths" and Other Literary Writings*, ed. Margaret A. Simons and Marybeth Timmerman (Urbana: University of Illinois Press, 2011), 16.

Beauvoir writes of the struggle to confront the time after midlife in her autobiography, *The Coming of Age*. When we enter old age, the weight of the past pushes us forward into an ever-shrinking horizon. The future seems fixed "in that it is both short and closed. It is the more closed the shorter it is, and seems all the shorter for being the more closed."[34] This temporal reduction understandably induces anxiety. If life is defined by movement into an indefinite future, the shrinking of that future is often intensely disquieting. Yet, it is also the human condition. Ignoring, belittling, or fearing this inevitability only cheapens the fullness of finite life in all its temporal dimensions.

The observation of the shrinking future is even more pronounced in the preceding volume of her autobiography, *Hard Times*, which caused a "furious outcry" when she dared to discuss the taboo of growing older.[35] The world, Beauvoir discerns, becomes smaller, narrower, and more sharply finite as old age approaches: "to grow old is to set limits on oneself, to shrink. I have fought always not to let them label me; but I have not been able to prevent the years from enmeshing me."[36] Poignantly, she experiences this shrinking future very specifically as a crisis of work and social relevance. What had once been an orientation toward labor as what was yet to come, becomes a sense of lost possibilities and accomplishments fallen into a ceaselessly swelling past. While she does not specifically name her fear as that of becoming useless, the creative process is one tied to the supposed freedom of youth. All that remains is the ossification of aging and the experience of inevitable physical breakdown. Feeling the inescapability of the end looming, death haunts her waking and sleeping life. In fact, she writes (at 50, nonetheless) that "it has already begun. That is what I had never foreseen: it begins early and it erodes."[37] The experience of time not as future possibility, but as the erosion of form illuminates the entropic dimensions of aging. Instead of growth into complexity, Beauvoir describes age as breakdown and destruction, the movement from complex situations and possibilities into the habits and repetitions of the present. Beauvoir's experience directly connects to the way that entropy is often understood metaphorically as pessimistic, as a "convenient shorthand for articulating a sense that things are running downhill, falling apart, getting worse."[38] However, there is ultimately little value to denying the physical realities of aging. This is why Beauvoir is unafraid to write about them, and in so doing performs her

34 Beauvoir, *The Coming of Age*, 373. Later she describes the experience of old age as a "limited future and a frozen past" Beauvoir, *The Coming of Age*, 378.

35 Beauvoir, *The Coming of Age*, 1.

36 Simone de Beauvoir, *Hard Times: Force of Circumstance Vol. II: Hard Times*, trans. Richard Howard (New York: Paragon House, 1992), 377.

37 Beauvoir, *Hard Times*, 379.

38 Zencey, "Some Brief Speculations," 9.

rejection that her own labor would become useless.[39]

The marginalization of most elderly is not entirely arbitrary insofar as they age out of many activities and social contributions. However, Beauvoir emphatically argues that our understanding of human decline is only meaningful in a social context. While on a biological and physiological level, the body's systems succumb to deterioration, there is nothing in this that demands it be seen as a purely adverse condition except insofar as it is deemed as such by the society in which the old person lives. In short, there is nothing inherently *pathological* about aging.[40] Old age is not to be vilified or cured, it is to be respected and accepted as central to the fullness of human life.

The essential problem within this dangerous notion lies in the myriad ways capitalism functions as an anti-entropic machine—one that treats human beings as cogs, useful only insofar as they contribute to the continued generation of capital.[41] The experience of the aged is therefore often one in which they are either forced to be useful by working well beyond their capacities or desires, or to suffer lives of precarity and deprivation. In the final pages of *All Said and Done*, Beauvoir says that the letters she received from old people after the publication of *Old Age* "proved to me that their state was even darker and more wretched than my description."[42] In the end:

> What is so heart-breaking about the replies of old people who are asked whether they would rather go on working or retire is that the reasons they bring forward are always negative. If they would rather go on, it is out of fear of poverty; if they would rather stop, it is in order to look after their health; but in neither case do they look forward to that particular way of life with any kind of pleasure. They do not see either work or leisure as a form of self-fulfillment; neither the one nor the other is freely chosen.[43]

The shrinking future should not require that freedom is cruelly truncated or overtly

39 In the final volume of her autobiography, *All Said and Done*, Beauvoir writes that at a certain point, aging no longer affected her as a dramatic break with youth. She felt that the biggest cut came as she crossed the threshold between youth and middle age but as she grew older, the passage of time became more endurable. *All Said and Done*, trans. Patrick O'Brian (New York: Paragon House, 1993), 34.

40 In fact, Beauvoir explicitly divorces old age from disease. See, Beauvoir, *The Coming of Age*, 284.

41 To make this point, Beauvoir writes that "between youth and age there turns the machine, the crusher of men—of men who let themselves be crushed because it never even occurs to them that they can escape it" Beauvoir, *The Coming of Age*, 543.

42 Beauvoir, *All Said and Done*, 462. See also, 132–133.

43 Beauvoir, *The Coming of Age*, 274.

denied. There is no reason to cast the aged into the past, forcing them to be in some senses the living dead, or to push them to into the category of dependent object instead of independent subject. Entropy necessarily pushes *all* life toward demise, but there is nothing within this law that demands that the end be humiliating, painful, and fearful. And there is nothing in this law that says aging can *and should* be cured.

Conclusion

The modern pathologizing of old age emerges from the configuration of human bodies as machines oriented toward production, progress, and efficiency. The body conceived as a machine came to light at the same time as the discovery of thermodynamics. However, bodies as machines quickly turns into the formulation of human beings as nothing more than reserves of energy to do or not do useful work. If they are no longer capable of functioning in that way (or of buying their way out of the dilemma entirely) they become a threat to the body politic—to be fixed, silenced, or eradicated.

This paper has argued that piecing together the contemporary understanding of old age as a disease to be cured (rather than an inevitability inherent in all organic life) requires exploring the many ways that entropy operates on scientific, philosophical, and metaphorical registers. Science teaches us that entropy is a law and philosophy cannot and should not dismiss this. Critical engagement with the tendency toward systemic breakdown and organic death must be at the heart of any philosophy that engages the most toxic contemporary practices and hopes to offer new directions for human development. In addition to science and philosophy, the existential account of aging provides a necessary corrective to overly theorized, detached, and impersonal accounts. While Beauvoir does not directly formulate the challenge as treating old age as a disease to be cured, she provides an important reason as to how this came to be. Aside from the materially privileged who can try to evade wretchedness through access to cutting-edge health and medical technologies, leisure, and pleasure, most old people suffer their declining final years as "useless mouths," perceived to be drains on scarce resources while providing no social utility. But the ethical response to aging should not be one of fueling a fantasy of evading it through the myth of eternal life. Not only is this impossible from an entropic perspective but given limited energy, the more one system grows and thrives, the more others will be deprived and starved. Under capitalism, this then means that the wealthy and powerful will take energy and resources from the whole. Setting aside the vanity and self-absorption of individuals who think they have a right to live longer than is humanly necessary, there are the very real effects of taking disproportionate amounts of finite energy for the elite and off-putting waste into the human and natural environment. Not only is this unscrupulous, not only does it hasten planetary breakdown for everyone and everything, but it also necessarily produces populations such as the underprivileged elderly who shoulder the worst of the effects, particularly when they are no longer able to justify their existence through labor.

What would be truly radical in the face of these injustices would instead to become stewards of limited energy, sharing it responsibly among the various human and non-human systems that depend upon it.[44] The elderly occupy the future that awaits us all. A total reorientation toward this normal inevitability, a refusal to cast it as a sickness to be cured, and a redirection of resources and energy on the model of care rather than exploitation will work to make the future—for all of us—one that any of us would want.

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Dialectics of Entropy: Notes on the Topology of Time[1]

Attay Kremer

Abstract:

This paper is dedicated to sketching out, in broad outline, a system of metaphysics that takes the notion of entropy and the second law of thermodynamics as ontologically as possible. The 19th century saw a dramatic transformation in the basic categories of knowledge. Following the Industrial Revolution, both in metaphysics (dialectical materialism) and in physics (entropy and the second law of thermodynamics), the notions of time and matter became, as is argued here, intertwined. In this paper, I examine the notion of entropy so as to form a notion of a material, emergent temporality. Such a temporality is strongly non-linear and is unevenly distributed among material systems. The goal of this will be to show what the consequences of the Industrial Revolution have been on our conception of the form of time. Rather than the formal, linear time of Newtonian mechanics and Kant's transcendental idealism, I suggest that entropic time implies a world that is temporally non-orientable, relating back to itself in important ways. Taking some topological ideas from Deleuze's treatment of the third synthesis of time in *Difference and Repetition* (1969), as well as Žižek's concept of dialectical materialism from *Sex and the Failed Absolute* (2019), I will show how these disparate notions of material time bear on the topology.

Keywords:

Entropy, Dialectical Materialism, Time, Topology, Deleuze, Kant, Plato

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1. What's the Matter with Time?

The concept of entropy, which names in physics the tendency of matter to wear out and decay, has been a hot-button issue since its inception in the 19th century. With the Industrial Revolution and the prevalence of the heat engine, the temporal characteristics of matter came to the fore, as phenomena related to heat usually entail irreversible change—like burning a piece of paper—garnered more interest. Entropy is the concept aimed at capturing this irreversibility, and so, as I shall argue, the materialisation of time. While Newtonian physics concerned itself with the motions of bodies, it says nothing about changes *internal* to the constitution of those bodies. For Newtonian physics, gravitational dynamics, so-called celestial mechanics, was the main concern, and so it almost exclusively deals with motion in space. Such motions are reversible. In that theoretical frame, time is external to the moving bodies. The concept of entropy captures a temporality that is internal to material bodies. It theorizes changes in the quality of matter, rather than quantity and place. In doing so, thermodynamics breaks with the time-symmetry of Newtonian physics. Changes of quantity are reversible, and so show no affinity to a particular direction of time, while changes of quality can only go in one direction—qualities, thermodynamically speaking, cannot be changed back. Because Newton's laws were taken to be fundamental laws, this disparity raised a serious *aporia*: how can a direction of time emerge from laws that make no directional distinctions?[2]

This foundational problem for theoretical physics results from a change of metaphysical perspective about the relationship between time and matter. What brings about the question regarding the origin of the direction of time is a change in the role of time in the order of the world. With the development of thermodynamics, time could no longer be understood as something purely formal and external to matter—what is sometimes called mathematical time. Rather, thermodynamics forces an understanding of time as something that inheres in the principles of matter itself. From an entropic viewpoint, it is not that matter moves in accordance with the form of time, as it did in Newtonian physics, but that matter itself is temporal. It is not that matter changes in time, but that time changes matter.

The goal of this paper is to explicate some of the metaphysics I take to be implicit in this rejoining of the concepts of time and matter. The classical view that divorces time and

2 This question was first put forward by Lord Kelvin, to which he also suggested a solution, in W. Thomson, "The Kinetic Theory of the Dissipation of Energy," *Nature* IX, (1874): 441–444. Then again, by Loschmidt, as a paradox, meant as an argument against the work of Ludwig Boltzmann on statistical mechanics, in the *Umkehreinwand* paper. For a contemporary discussion of these problems, see David Z. Albert, *Time and Chance* (MA: Harvard University Press, 2000) and TY., Wu,"Boltzmann's *H*-theorem and the Loschmidt and the Zermelo paradoxes," *Int J Theor Phys* 14, (1975): 289–294.

matter is radically transformed in the wake of the Industrial Revolution. In the realm of the concepts of physics, this is most manifest in the notion of entropy, as I will flesh out in what follows. The basic notions of our understanding of the world were drastically revised at the time of the Industrial Revolution and the development of thermodynamics. In this paper, I would like to develop some intimations of the systematic metaphysics that might be implied by the entropic physics that resulted from the Industrial Revolution. The idea that the Industrial Revolution might have had a profound impact on these primary notions (time and matter) is rooted in Sohn-Rethel's thoroughly Marxist notion of a real abstraction, with which he seeks to capture the role of the mode of production in shaping the fundamental categories of thought.[3] He writes:

> Our explanation thus argues that the categories are historical by origin and social by nature. For they themselves effect the social synthesis on the basis of commodity production in such a way that the cognitive faculty they articulate is an *a priori* social capacity of the mind; although it bears the exactly contrary appearance, that of obeying the principle of the *ego cogito*… Our theory is directly concerned only with the questions of form.[4]

What Sohn-Rethel takes up in this quote, and continues to develop throughout *Manuel and Intellectual Labour: A Critique of Epistemology*, is the determination of the fundamental forms of thought, or categories, by the social forms of production. It is, properly construed, perhaps the most radical materialist inversion of the idea of the categories, traditionally understood to determine the objects of thinking. For Sohn-Rethel, the categories are not only a conceptual framework that shapes our thinking about objects but are also in themselves determined by the objects of thinking. The social forms of production are at work in the categories of thought—they form the very way we conceive of the world around us. In this spirit, the goal of this paper will be to trace out the consequences of one change that occurred in our fundamental categories, namely the profound interdependence of matter and time revealed in the second law of thermodynamics. Guided by the concept of entropy, I will sketch out, in contradistinction with the early modern, or classical view,[5] of Newton and Kant, the new constraints placed on our notions of time and matter. While I take the historical event to be of supreme importance, the essay will focus on the more systematic or conceptual aspects.

The primary question being: what are time and matter when they are thought to be

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3 Here and in the rest of this section, unlike most of the paper, I use "categories" in the broad, vaguely Aristotlean sense, rather than the particular sense in which Kant employs the term.

4 Sohn-Rethel, *Intellectual and Manuel Labour: A Critique of Epistemology*, trans. Martin Sohn-Rethel (Leiden and Boston: Brill, 1978), 4–7.

5 I use the term "classical" as in "classical physics," not in the historical sense of the "classical era."

intrinsically intertwined? I hope to show that the change in physical categories not only has radical metaphysical consequences, but that they lead us in the direction of dialectical materialism. Not merely because its sister framework, historical materialism, provides, as in Sohn-Rethel, a sense of the challenge at hand, but much more importantly, because dialectical materialism is *the* metaphysics in which time and matter are insistently thought as mutually immanent. The main bulk of the paper will be dedicated to the description of the change between the classical and entropic viewpoints, and the final section will seek, by reference to Žižek's unique brand of dialectical materialism, to relate the entropic view developed with dialectical materialism. This paper aims to sketch out a path, hopefully novel, of thinking about time in light of entropy.

1. The Classical View: Immaterial Time

To get a sense of the radical change in our conceptual framework, as well as to begin to feel out the figure of the new metaphysics that that change might imply, we should begin with the classical view. While Newton was perhaps the first to explicitly put forward the canonical view of classical physics, I will take Kant to be exemplary of it, as his transcendental philosophy has as one of its foremost goals the justification of Newtonian physics by metaphysical considerations. As he declares in the *Metaphysical Foundations,* explaining the need for that book: "*Properly* so-called natural science presupposes, in the first place, metaphysics of nature."[6] Because we are here most concerned with the metaphysical consequences, Kant is the most inviting figure to turn to. So let us give an account of the relationship between time and matter in the critical philosophy.

Kant's theory of cognition is divided into the regulative and the constitutive. The regulative is what we associate with reason, and so too with purposiveness and moral consideration. The constitutive part of cognition in Kant's system, namely that cooperation of cognitive faculties that is required to make judgement regarding objects of possible experience, is the understanding and the intuition (mediated by the imagination). The first is general and conceptual, while the latter is particular and sensuous. The intuition is responsible for making possible the reception of objects in perception, while the understanding is the minimal conceptual cargo that is necessary for ordering these objects in judgment. Time, introduced early on in the "Transcendental Aesthetic" where the roles and operations

6 Kant, *Metaphysical Foundations*, trans. Michael Friedman (Cambridge, UK: Cambridge University Press, 2004), 5. While this text is not one of the three Critiques, it is a crucial explication of the first Critique, the main goal of which is to justify a concept of experience rich enough for the foundations of science. For a thorough, profound and scholarly exposition of this text and its role in Kant's oeuvre, see Friedman, *The Construction of Nature: A Reading of the Metaphysical Foundations of Natural Science* (Cambridge, UK: Cambridge University Press. 2013), 1–33.

of the intuition are first laid out, belongs to the domain of the intuition. As a form of sensibility, time is not intrinsic to phenomena, but part of the frame in which phenomena may appear. Together with space, it gives us the shape or outline of what it means for something to be phenomenal, to appear, but it is in itself independent of these phenomena. In the "Metaphysical Exposition of Time," Kant writes:

> Time is a necessary presentation that underlies all intuitions. As regards appearances in general, we cannot annul time itself, though we can quite readily remove appearances from time. Hence time is given a priori. All actuality of appearances is possible only in time. Appearances, one and all, may go away; but time itself (as the universal condition of their possibility) cannot be annulled.[7]

In repeatedly stressing that time cannot be annulled, while the appearances in time—those that appear simultaneously or successively—can be, Kant is positing the independence of the "stuff" of appearance from the form of time to which they conform. For Kant, time is a property of cognition, indeed the form of its sensible faculty, not of things, so that it would by necessity be outside of what appears. Still, what appears has the form of time, it takes part in time and so is constrained by the form of time. There is thus a disconnect between matter and time, or between the form and stuff of appearances. This view is uniquely modern, distinguished from the time of somebody like Plato, who considered time to be a product of the regular motion of the stars.[8] The regularity of the world, for Kant, is not productive of time, but a product of time. Time itself cannot be learned from experience, for to see simultaneity or succession, things would already have to be either simultaneous or successive. It is thus outside the world and formative of it. In that, Kant echoes Newton, who writes in a famous Scholium of the *Principia Mathematica*: "Absolute space, in its own nature, without regard to anything external, always remains similar and immovable."[9]

But what is it that time is divorced from? I used the term "stuff of appearance," but what is it that we mean? I do not mean to refer to some mass of unformed sense data, or raw

7 Kant, *Critique of Pure Reason*. trans. Werner S. Pluhar (Indianapolis and Cambridge: Hackett Publishing Company, Inc. 1996), A31/B46.

8 This is, of course, not meant to be a scholarly conclusion regarding Plato. This view is put forward in *Timaeus*, whose namesake says "the wanderings of these five planets, which are bewilderingly many and amazingly complex, do constitute time." Plato. *Timaeus and Critias*, trans. Robin Waterfield (Oxford: Oxford University Press. 2008), 39d.

9 Isaac Newton, *Mathematical Principles of Natural Philosophy and his System of the World*. trans. Andrew Motte, rev. Florian Cajori (Berkeley, Los Angeles, London: University of California Press, 1974), Bk. 1.

sensation. It is unclear whether we can ever speak of pure, unformed matter, both for Kant and in principle. Rather, I mean to refer to those concepts applicable to phenomena which bring them closer to what we call matter. Matter is substantive, it is always in a network of causal relations, and so on. Such properties are not consequences—at least not direct consequences—of the form of time. Rather, they are concepts that shape our thinking in general, to the extent that it applies to objects of experience. What makes appearances "material," is a family of categories that is applicable to them and makes them conformant to something recognisable as matter. The project of the *Metaphysical Foundations* is very much directed at showing how the categories of the understanding, when explicated properly, imbue appearances with the material properties necessary for the physical sciences.

What is important for me here is that we have two senses in which time and matter are decoupled: First, because time is a form of sensibility and is so principally independent of appearances. Second, because the material properties of appearances are a product of a different faculty of cognition. They do not appear in sensibility as such but result from the synthesis of the understanding. I take Kant to be saying that what is material about matter is not gained in sensation. Or, that properly speaking, nothing "feels like matter." Rather, something seems material to us because of the way in which we put those feelings together. Something appears material because it is thought materially. It must be conceived in a community of mutual effect, where it causes motion and its motions are caused by something else, and it must endure these changes, in order for it to seem like matter. We find this need for mutual effect reflected in the fact that Kant takes mechanics to be an explication of the categories of relation.[10] This is in contradistinction with time, which is immediately given to us in all things. We cannot, in mere sensation, feel that something is material, but we cannot fail to feel, in mere sensation, that something is temporal, that it conforms to the form of time.

Expressive of different faculties of cognition, time and matter are conceptually decoupled. They are independent. Not only that, but there is a clear hierarchy—time outranks matter. Time is truly outside the world of things, and, in a crucial sense, governs it. To see this, we should briefly recall the schematism.[11] While it is true that the understanding and the intuition are heterogeneous, they must come together in determinative judgement, which always subsumes a particular under a concept ("*this* is a *chair*"). Thus, there is something

10 Kant, *Metaphysical Foundations*, 75–92.

11 This is a famously difficult and dense part of the first *Critique*. For commentary, see Martin Heidegger, *Kant and the Problem of Metaphysics*. trans. James S. Churchill (Bloomington: Indiana University Press, 1965), 93–113, and Béatrice Longuenesse, *Kant and the Capacity to Judge: Sensibility and Discursivity in the Transcendental Analytic of the Critique of Pure Reason*, trans. Charles T. Wolfe (Princeton and Oxford: Princeton University Press. 2000), 243–274.

of a common ground to them, or at least a faculty of cognition responsible for bridging the gap between the two. As Kant develops it, what mediates between the sensible and the conceptual is the imagination, guided by the form of time. Concepts are synthesised in time—that is, they are taken to apply only to the extent that they unite multiple sequential experiences—and particulars always take part in the form of time. Thus, time is not only sensible but also responsible for relating the sensible and the conceptual. For our purposes, it means that the materiality of things expresses itself in time. Not only are those things temporal, but *their temporality is the condition of their materiality*. Simply put, matter would not be matter if it could not *move* like matter. Thus, while matter and time belong to different faculties and have different origins, matter is subordinate to time, and materiality can only be made manifest because of the form of time. Note that the ontological primacy of time is a curiosity of Kant's transcendentalism, and not shared by Newton or classical physics generally. So, for Kant, formal time is ontologically prior, while in the classical frame more generally, the two are simply independent.

Kant's view is Newtonian, or belongs to classical physics, in the sense that it takes time to be almost a purely mathematical thing. It is the indifferent and overarching order of matter and its events. Time and matter belong to different realms—one is an essential formal condition of experience, and the other is a name for some cluster of properties. The crucial point here is that this divorce of time and matter makes irreversible change foreign to this conceptual framework. Irreversible change takes matter to be a measure of time, to cohabitate with it and, in an important sense, condition it. As long as the two are divorced, and time has the upper hand, all change is change of place, locomotion, because time can never really "enter into" matter. This clean conceptual divide is challenged by phenomena related to heat. Thermodynamic phenomena require that time be more internal to things than their form, they require that the materiality of things intermix with their temporality. If entropy—a decay that is internal to matter—is the origin of the arrow of time, time must be, in some sense, a product of materiality. So, we should formulate more clearly how the notion of entropy, together with the second law of thermodynamics, challenges the classical view.

2. Introducing the Second Law

Entropy is a notoriously elusive concept. While much has been written about it, its uncanny sprawl makes it difficult to capture. To conceive of entropy properly is to tie together phenomenological thermodynamics, statistical mechanics and information theory, and in so doing also simplify that common insight into a simple, conceptual language. Seeing as I would like to say something meaningful about entropy and do not possess such penetrating insight, I should stick to a particular aspect of the second law of thermodynamics. If, as I presented it, the framework of classical physics is one in which temporality is the condition of materiality, the second law is an inversion. I suggest that the second law pushes us to say that materiality is the condition of temporality.

In its first and most primitive appearance, entropy—originally called "transformational content" [*Verwandlungsinhalt*] – is defined by the following equation:

$$dS = \int \frac{\delta Q}{T}$$

where is an element of heat given off by a body, T is that body's absolute temperature, and dS is the change of entropy. In 1862, Rudolf Clausius put down that formulation, hypothesising that in reversible processes , while in irreversible processes .[12] Meaning that a system out of thermodynamic equilibrium will tend towards maximum entropy. Three years later, he coined the name entropy, from the Greek en-trope, meaning "to be in direction" (literally, "in-direction"). The thought behind the name was that matter itself had a directional character. Phenomena of heat reveal a content of matter that is transformational by nature and forces things into the order of time. That order of time is one shaped and formed from that transformational content. Entropy puts things into the order of time because we can always say that some time has passed by saying that the entropy has increased. That increase is the measure of irreversibility.

Foregoing for the moment epistemological questions, and questions pertaining to the correct, scientific interpretation of these ideas, let us dwell a moment on the consequences of the notion that guided Clausius here. It seemed that energy dissipation appeared not to be a coincidental thing but pointed to something essential to matter. All matter, it seemed, is perishable by necessity. The brilliance in the name "entropy" is that it indulges

12 Clausius, "Ueber verschiedene *für die* Anwendung bequeme Formen der Hauptgleichungen der mechanischen Wärmetheorie," *Annalen der Physik und Chemie* 125, no7 (1865): 353–400. 390: "Sucht man für *S* einen bezeichnenden Namen, so könnte man, ähnlich wie von der Gröſse *U* gesagt ist, sie sey der *Wärme- und Werkinhalt* des Körpers, von der Gröſse *S* sagen, sie sey der *Verwandlungsinhalt* des Körpers. Da ich es aber für besser halte, die Namen derartiger für die Wissenschaft wichtiger Gröſsen aus den alten Sprachen zu entnehmen, damit sie unverändert in allen neuen Sprachen angewandt werden können, so schlage ich vor, die Gröſse *S* nach dem griechischen Worte ἡ τροπή, die Verwandlung, die *Entropie* des Körpers zu nennen. Das Wort *Entropie* habei ich absichtlich dem Worte *Energie* möglichst ähnlich gebildet, denn die beiden Gröſsen, welche durch diese Worte benannt werden sollen, sind ihren physikalischen Bedeutungen nach einander so nahe verwandt, daſs eine gewisse Gleichartigkeit in der Benennung mir zweckmäſsig zu seyn scheint."

in a rather unexpected twist. We could have said that all matter is perishable because temporality is the condition of all matter, to begin with. That all things exist in time, so must pass away. But in terming the quantity of dissipating energy "entropy"—calling it "what puts things in direction"—Clausius pushed in the opposite direction. Instead, he invites us to consider that *materiality is the condition of temporality*, that the fact that the order of time in one direction rather than the other is not a property of the transcendental constitution of phenomena, but a formal feature that emerges immanently from matter. It is a property of matter that puts us in a direction, not a directionality that makes materiality into a property.

The crucial theoretical point not to be missed is that the entropic worldview is the materialisation of time. To take the concept of entropy to heart, to place it in the centre of our field of concepts, is to understand time as a feature of matter. The metaphysical challenge at hand is that of thinking of time as belonging properly to matter, without discarding its formal nature. True, it is an immanent rather than a transcendental notion of time. Still, we should not thereby disregard the fact that succession and simultaneity are not in and of themselves content. It would be too quick and too easy to disregard form altogether in taking time to be immanent. What is at stake is understanding time as a form that emerges from matter, rather than one imposed on it from without (by a transcendental subject, for example). Time would thus not be conceived as linear, not a straight line of events, with strict and simple past, present and future.[13] For time to belong to matter, it must be local and non-uniform, just as matter itself is.

Speaking of entropy in somewhat essentialist terms may invite the sense that this directionality that belongs to matter is uniform. Namely, that all things tend uniformly to expenditure and decay. This is, however, not so. There are cases in which the entropy of systems decreases. If we put work into a system, we may decrease entropy—or increase the inverse quantity, sometimes called negentropy. The decrease of entropy is a common feature in cooling systems, and much more interestingly, in living systems, and was, in fact, first coined by Schrödinger in *What is Life?* in the attempt to explain life as a physical phenomenon.[14] Entropy is, mathematically speaking, a non-uniform scalar field, a function that varies from place to place, increasing and decreasing at different rates at different times and places, in different systems. Every system, every part and every mechanism has a different entropy and a different rate—and direction—of the change in

13 Of course, the theory of relativity, both general and special, have undermined the usual notion of linear time. What I have in mind for the metaphysics of thermodynamics here is somewhat different, as will be shown.

14 Schrödinger made use of "negative entropy", which Léon Brillouin abbreviated to "negentropy." Schrödinger's idea was that "What an organism feeds upon is negative entropy." See Erwin Schrödinger, *What is Life? and Mind and Matter* (Cambridge, UK: Cambridge University Press, 1992), 47.

that entropy. This is because matter itself is profoundly heterogeneous. A living system is an essentially different kind of matter—organic—from a dead body, a steam engine or a planet. If time is, as suggested, a formal directionality that emerges from and exists immanently in matter, we must take time to be unevenly distributed, paced differently and directed differently in different places.

So, while we would like to retain something of the formal in the description of material—or entropic—time, the main characteristics of formality must be discarded: uniformity and homogeneity, that all things that have a particular form are in some obvious sense identical. If time can no longer be understood as external to phenomena, but must instead be construed as internal to them, it must be as variable and non-uniform as the phenomena themselves. Time then emerges as a peculiar and particular feature, a quirk of every specifiable bit of matter, rather than a universal and homogenous thing.

Think of that oft-quoted William Gibson line, "The future is already here—it's just unevenly distributed."[15] To my mind, it captures exactly what it means to think entropically or to think of time materially. Time is not dissimilar to, as the line well suggests, an aether-like substance filling space, or capital, distributed across the socius, flowing from one place to another. The future may be imported and exported, time can be slowed down or accelerated. What this implies is the express opposite of the quote given above, from Kant's "Metaphysical Exposition of Time." Under the eye of entropy, we should say that if appearances (matter) are annulled, so is time, and that where there is no matter there is no time. In that sense, *time matters*. And so, it is nothing without matter. What is more, there is matter without time. Matter *can* be in perfect equilibrium, perhaps completely static and unchanging, having reached a state of maximal entropy. In that case it would be, *de facto*, outside of time. But time can never be outside of matter. Kant's metaphysical exposition is fully inverted. And so, the question is raised: What is the form of material time?

3. Time Reformed

What is at stake in the form of material time is a form that emerges out of heterogeneous matter. That is, it is the question of how form might be wrought out from matter rather than applied to matter. In this regard, the view that Kant and Newton take falls into generally Aristotlean lines. It is a hylomorphic view of time. Time is the form of phenomena in that there is the matter of appearances, and there is, from a separate ontological origin, their form. Form and matter are, on such a view, simultaneous and independent of one

15 *The Economist*, December 4, 2003.

another. As the classic Aristotlean example goes, there is wood and there is the form of the cabin. The wood exists independently of the cabin and the idea of the cabin exists, as a form, independently of the wood in the mind of the cabin-maker.[16] In insisting on understanding time as internal to matter and emergent from it, we are forced out of this Aristotlean picture. What we are after is a genetic notion of time. Or, an account of how temporality originates from materiality—how matter is generative of time.

The ontological problematic of generation—the problem of ontogenesis—has a rich history, dating back to Anaximander, and has, in modern philosophy, had its most fruitful examination in Simondon and Deleuze. For both, standard ontology—what may be broadly cast as an Aristotlean or hylomorphic tradition—goes astray in thinking of form and matter as separate things brought together in the constitution of an individual thing, e.g., a wooden cabin. Rather, to account for individuals one must account for the processes of individuation, wherein form and matter are indistinguishably involved. That is, the process by which something becomes what it is, is inexorably tied to a formation that is internal to its matter. The hylomorphic model puts forward the following image: a craftsperson approaches some material with an idea of what can be done with it, and after a process of labour, forces that idea on the material. From the viewpoint of ontogenesis, the craftsperson's labour has a dialogical aspect, a mutual choreography, wherein the craftsperson responds to the matter, trying to unveil forms and potentials hidden in it. Whatever the craftsperson attempts to do is immediately responded to by the matter—some things it allows and others it does, some things are possible, but still very difficult to achieve, and so on. There is an interplay between form and matter. For Simondon, the model for this is crystallization, a process where matter is transformed, given new form, but not by external imposing.[17] Rather, it is an actualisation of something that exists potentially in the matter and comes to light from within.

While Simondon's work on ontogenesis is geared towards questions of technology and information—following the broadly post-metaphysical line of questioning opened up by

16 Take, as an example of this, a beautiful passage from *Metaphysics* Λ: "The causes which initiate change <are causes> inasmuch as they have come to be previously, while the things which are causes in the sense of formula exist simultaneously. For it is when the human being is healthy that health also exists, and the shape of the bronze sphere exists at the same time as the bronze sphere. Whether something remains afterwards too has to be considered, since in some cases nothing prevents it; for example whether the soul is of such a sort–not all soul but intellect… [as in] the case of the arts as well: for the medical art is the formula of health." Aristotle, *Metaphysics* Λ. trans. Lindsay Judson (Oxford: Clarendon Press, 2019), 1070a21-30.

17 For his introduction to the notion of ontogenesis, see Gilbert Simondon, *Individuation in Light of Notions of Form and Information*. trans. Taylor Adkins (Minneapolis: University of Minnesota Press, 2020), 1–10.

cybernetics[18]—it does not address something like the categories of time, space, causality, etc. Deleuze, picking up on Simondon's cue, sees in that notion of ontogenesis a path towards a reconsideration of traditional metaphysical categories. His work is not so much a reconsideration of Aristotle's view of art [*techne*], but an attempt to invert Kant's entire transcendental project. For him, what is required by the project of ontogenesis is a retelling of Kant's critical philosophy from the viewpoint of its genesis.[19] Not in justified ordinary experience, but in examining the radical and problematic experience from which ordinary experience might emerge. It is from this point that his overarching transcendental empiricism and immanent metaphysics begin.

Keeping this in mind, it should be obvious that in order to approach the question of time after entropy, we must follow along the lines of the ontogenetic project. The metaphysical groundwork for this new notion of time, the appropriate, proverbial "flipping" of Kant on his head, is most lucidly undertaken by Deleuze. There is, however, an absolutely crucial difference. Ontogenesis is concerned with coming into being. It is concerned with how forms come into being through their matters. But the concept of entropy, which guides this proposed reconsideration of the notion of time, is a concept of decay, of passing out of being, rather than coming into it. What is at stake in entropy is not so much the viewpoint of genesis, as it is the viewpoint of decay. Time emerges as intrinsic to matter precisely in that matter decays in and of itself. That is, the emergence of the form of time is not in the genesis of the individual but is rather manifest in its death.[20] Thus, what we aim to extract from Deleuze's project, for our purposes here, is a notion of how form can be inextricably internal to matter. The difference we would like to draw is that this inextricability is a fact of decay, rather than generation.

To treat Deleuze's ontogenesis fairly requires that one tarry with it carefully and quite possibly for the duration of several chapters of a book, especially if one, as I do, intends to adopt something of Deleuze's without taking his framework as is. So, what I would like

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18 On the relationship between cybernetics and metaphysics, see Hui, Yuk. *Why Cybernetics Now?* in *Cybernetics for the 21st Century, Vol1: Epistemological Reconstruction.* ed. Yuk Hui (Hong Kong: Hanart Press, 2024) and Jean-Pierre Dupuy, *On the Origins of Cognitive Science: The Mechanisation of the Mind*, trans. M. B. DeBevoise (Cambridge, MA: The MIT Press, 2009), 15–22.

19 This is how Deleuze interprets the third *Critique*, and in light of that *Critique*, the very sense of the term "critique." As he takes it, the third *Critique* asks about the problem of the genesis of the relationship between the faculties of cognition and reveals in that that all critique is a matter of genesis. See Gilles Deleuze, *Desert Islands and Other Texts, 1953–1974* (New York and Los Angeles: Semiotext(e), 2004), 56–71. As well as, Joe Hughes, *Deleuze's Difference and Repetition* (London and New York: Continuum International Publishing Group, 2009), 1–7.

20 This is, in a sense, already an intimation of the dialectical approach to the matter. Dialectics may be broadly and crudely characterised as that dynamic mode of thinking in which something's death shows its truth.

to do now is present something of a sketch of Deleuze's view, in broad outline, in order to clarify what it means for form to emerge in this context. The common portrayal of Deleuze as a philosopher of difference hits the mark exactly here. Formal and universal features are liable to emerge from pure, immanent content because immanent content is ontologically prior to identity, and is therefore difference as such. What we have been thinking about as matter should be, on this Deleuzian approach, a field of pure differences—sheer heterogeneity. It is not to be thought of as a homogenous mess, as we sometimes intuitively do, because such an image of thought implies that every bit of it is in a sense identical to every other. That would be a primary assumption of form—the form of identity. If form is truly to be considered posterior to matter, pure matter must be understood to be everywhere heterogenous, other to itself. We cannot speak of this heterogeneity as something universal, in the sense that all differences are in some sense of the same kind, but rather of that pure difference as repeating throughout matter. Two differences are not of the same kind because both are in some sense a difference, but rather we sense each is a repetition of another. One difference seems to recall and re-enact the other difference. Just as two actors playing Hamlet, or for that matter, two productions of Hamlet, recall each other—neither seeming in principle prior to the other—so too, one difference recalls another.[21]

Difference and repetition, the eponymous concepts of Deleuze's masterwork, are brought together in thinking of form as something internal to content. The main idea is that the unity that one associates with form is derived not from notion of identity, a oneness which is presumably manifest to an external observer, but is in itself an expression of internal difference. Something sticks together by demarcating itself from its environment and by differentiation of its internal parts. While Deleuze's manner of thinking is abstract enough to accommodate potentially everything under this frame, it is, for Simondon, always modelled on the organism and the machine. So, for example, we can speak of an organism being unified, being *an* organism, because it is doubly differentiated—both from its milieux, its surroundings, and is host to the differentiation of organs. Its unity is primordially difference: the difference of its parts and its difference from the world. From the genetic viewpoint, the unity is articulated in the doubled difference, rather than those differences being comparative articulations of a prior unity.

Keeping this metaphysical frame in mind, let us look at how this notion of self-otherness as primary ontogenetic difference might be an active agent in forming time. In the so-called third synthesis of time, a key moment of the "Repetition for Itself" chapter of *Difference and Repetition*, Deleuze addresses precisely that problem. There he recalls one of four poetic formulae he used to introduce Kant's philosophy: Rimbaud's "I is another."

21 Deleuze, *Difference and Repetition*, 9–11.

He suggests that Kant's transcendental view of time results from a fundamental split between the ego, or the empirical self, and the I, or the transcendental self. Time emerges as what mediates the active, determining I and the passive, determined ego. He writes:

> The I and the Ego are thus separated by the line of time which relates them to each other, but under the condition of a fundamental difference… I am separated from myself by the form of time, and nevertheless I am one, because the *I* necessarily affects this form by carrying out its synthesis and because the Ego is necessarily affected as content in this form… the determined ego represents determination as an Other… It is the thread of time.[22]

The crucial theoretical point here is that Kant's linear and formal time doesn't have to be accepted as simply given by and to transcendental subjectivity. Paying particular attention to the relationship, in Kant's own system, between the ego and the I, we are able to glean a genetic condition for time as an empty form. A split, a mediated split between active and passive is, on Deleuze's account, the genetic condition of empty form. It is an inversion of Kant: beginning with the split in the self, rather than the conditions of sensibility, and taking these not be consequences of those conditions of sensibility, but vice versa. The split self conditions the possibility of forms of sense. It is, I suggest, exactly the twist required to cash out the metaphysical debts of entropy. Before translating these ideas from the split internal to the subject into the split internal to matter, let us say a little more about how this split leads to a linear, empty form of time.

Deleuze contrasts Hamlet's "time is out of joint" with the common Greek idea—explicitly addressed both in Plato's *Timaeus* and Aristotle's *Metaphysics XII*—that time is subordinated to the circular motions of celestial bodies. The time of the Greeks is neither formal nor transcendental, it belongs to the world of phenomena. It is the regularity of the planets, that in its turn produces the regularity of seasons, that is responsible for the order of time. There, time is joint to the world. It is bound to it. "The joint," Deleuze writes, "is what ensures the subordination of time to… [that] which it measures."[23] On the other hand, Kant's time is out of joint in the sense that it is "freed from the events which made up its content, its relation to movement is overturned."[24] Formal time, undetermined by events, is a temporality that cannot bring one back to the starting point. It is not, as with the Greeks, a time of pure repetition, of eternal recurrence, but a time of progression and detachment. So, we ask: what is it that might not allow the world to return and fold

22 Giles Deleuze, *Kant's Critical Philosophy: The Doctrine of the Faculties*. trans. Hugh Tomlinson and Barbara Habberiam (London: Athlone Press, 1984), viii–ix.

23 Deleuze, *Difference and Repetition*, 88.

24 Deleuze, *Difference and Repetition*, 88.

back in on itself? Well, on Deleuze's view, it is an internal split. Something that becomes self-differentiated cannot return, cannot be seasonal, but must, in that movement of self-differentiation, detach itself from the world in which it started. Formal time is a time of self-othering because it is self-othering that disallows the eternal return of the same—everything must return otherwise—things are forced to move forward.

How, then, are we to conceive of this with regard to matter itself, rather than subjectivity? This is a difficult question. Implied here is a dramatic change in perspective. Not merely a materialist turn, but a materialism of replacement. The question implies that subjectivity, in all its twists, turns, hopes and dreams, may be substituted, by some formal analogy, for completely material systems. Questions about the relationship between matter and subjectivity are varied, and I do not fain to hope that anything I can say here is definitive. Still, in service of the line of thought that I have started to develop here, I would like to describe that material analogy, setting aside the critical, open questions involved in it. So, if the split between the I and the ego is to be formulated in material terms, we need to find for ourselves a sense in which a material system is both active and passive or is both conditioned and conditioning. I mentioned earlier that a material body must be constituted by a doubly articulated differentiation. An internal differentiation between organs and an external differentiation from its milieu. The internal differentiation is, to my mind, promising for this formal analogy. That is, because the organs or parts of the body are related to it as active parts on a passive, constituted background and because the body itself is related to its milieu as an active agent in a passive world, it seems that we may be able to think of the body, and the environment, as an empirical self, an ego—a representation of material system, in a sense, its trace—on the one hand, of the parts, and the body, as an active transcendental self, an I that might determine its own representation in its world.

On such a view, material systems, just as the transcendental subject, are always in the dual business of constituting and being constituted, conditioning and being conditioned. This double activity leads, in every material system, to a private form of time. Each system and each part—which, of course, taken by itself, can be thought of as its own system—involves a split between active and passive. Thus, in mediating between these two sides, for each system, there must also emerge a form of time. That form would invariably be proper to that system and only to it. Each mediation requires a form, and so two systems that do not relate to each other in any way, could not be said to share a form of time. The proper nature of the materially emergent form of time is not, as for both Kant and Deleuze, singular and universal, because it is not constituted by an observer seemingly external to things. Rather, it is that each difference in the material world is, by definition, mediated temporally, and so must retain for itself a private time. There is no form of time but form*s* of time. The crucial difference between the transcendental approach and the material approach is that for matter, time must always be said in the plural. The heterogeneity of matter should be construed as producing a heterogenous family of times, a unique form and duration for each system.[25]

In the material context, this self-othering, which for Deleuze is a condition of genesis, is rather a condition of decay. The manifestation of difference in the ontogenetic framework is the manifestation of the primal stuff of individuation, and so what is in principle responsible for things being as they are, for their forms, actualities and capacities. However, in matter, differences make themselves most apparent in decay, where the constituent parts of a material body come apart, and the body diffuses into its environment. On the statistical interpretation of entropy, the notion of decay is understood to be the tendency to become like a gas—diffuse, decomposed. When things decay, their structures disappear, they dissolve into their building blocks. Formal time, by which we can tell that something moves forward in time, is, on the entropic view, correlated with decomposition rather than generation.

In the fifth chapter of *Difference and Repetition*, Deleuze writes about this characteristic of entropy, that it is an extensive quantity prefigured by an internal, pure difference. It belongs to the direction of space and time, just as pressure and heat, or even "the high and the low, the right and the left, the figure and the ground;" but it is an extension that manifests itself from out of an intensive quantity, out of the pure energy of pure difference. He writes: "entropy is an extensive factor but, unlike all other extensive factors, it is an extension or 'explication' which is implicated as such in intensity, which does not exist outside the implication except as implicated." As an "implicated extension," entropy intrinsically hints at the possibility of general movement, of the space time in which things in general move, beyond the particular difference from which it emerges. In that sense, it is expressive of the difference that makes the difference for the forms of extensive quantities. In his words, "[entropy] has the function of *making possible* the general movement by which that which is implicated explicates itself or is extended."[26]

4. A Dialectical Rejoinder

In the duration of this paper, I told two parallel stories regarding the nature of time, both ending with a rough sketch of a material time. First, a story that belongs to the history of physics, from Newton to Clausius, where the turn away from the regular motion of the stars to the internal dynamics of heat brought about the need to conceive

25 In this regard, there are *entropies* rather than entropy, as I discussed in the previous section. Entropy is a vastly varied field, differing drastically from system to system.

26 Deleuze, *Difference and Repetition,* 229.

of a material property that might order events. Then, a philosophical story from Kant's formal, transcendental time, to Deleuze's genetic viewpoint, wherein time emerges from a movement of self-othering. An important difference between these two accounts is that in the philosophical one, we find an earlier position—that of the Greeks. When I speak of inverting the classical view, it is crucial to note that it is, in itself, already an inverted view. One may recover a Kantian form of time by inverting a Platonic form of time, by detaching time from the motions of the planets and insisting on its belonging to a subject and so independent from the world. The question is thus raised: Is the material time I have been trying to describe here simply a return to Plato? Is the suggested view simply a temporality regulated by matter, as in the case of the celestial bodies?

The answer, of course, is no. We should insist that this double inversion of Plato in fact leaves us as far as we have ever been from Plato. It is in that sense that the demand and search for a notion of a material time that I have tried to develop here is dialectical. We have taken up a dialectical view of time in the sense that each description of time given is not abstractly negated by the view that comes after it, but diverges from it in a particular, concrete way. Platonic time is not simply negated, but its particular aspect, its being bound to phenomena, is negated. So, both Platonic time and Kantian time are regular. Then, what is negated in Kantian time is not its mediation of a constitutive split, but its ready-made nature. We related time back to matter in a specific way: by insisting on viewing time as emergent from matter. Thus, the entropic time I would like to suggest here is not Platonic in that it is not subordinate to regular phenomena, but emergent from all material systems and thus strongly non-regular. In this sense, I argue that we should say that entropy is a dialectical conception of time—a concept of time that strongly negates both Platonic time and Kantian time in particular and concrete ways.

An important consequence of the strong non-regularity of emergent material time is that it does not allow us to think of the world as temporally oriented. It does not have a single direction of time. If, as the second law as I presented it, implies identifying the direction of time with an increase in entropy, it follows that the decrease of entropy is tantamount to going back in time.[27] And if entropy, like all material properties, is heterogenous and variable, it is surely conceivable—and indeed it is very much the case—that some systems have decreasing entropy and some have increasing entropy. The arrow of time would thus be unevenly distributed—some places going back and some forward. In mathematical terms, the inability to fix, universally, a direction on some manifold is called non-orientability. And if we follow what I sketched out, we cannot fix a universal temporal direction to the world, and so may call it temporally non-orientable. In rejoining time to

27 Nick Land develops the idea that increase in entropy might be thought of as going into the future. See Nick Land, *Templexity: Disordered Loops through Shanghai Time* (Urbanatomy Electronic, Kindle Edition, 2014).

phenomena, we have rejoined it slightly askew, unevenly, as one does when constructing a Möbius strip.[28]

While this description holds for a local view of systems, there is still the matter of the universe as a whole, or of global entropy. The question of global entropy is crucial but cannot be fully taken up here. I hope to discuss this point in depth elsewhere. For the time being, let me say that the question of a global or universal direction is dependent on our capacity to speak of the universe as a totality. So to speak, to view it from God's viewpoint. For any real, physical observer can only measure entropy for quasi-isolated systems, and never for the whole of the universe. It is exclusively from a divine perspective that one can make sense of global entropy. Any notion of universal or global entropy is predicated on a totality. Reichenbach, for example, argues that there is universal increasing entropy because whenever we include a system's surroundings, we see increasing entropy. His argumentation is subtle and multifaceted, but his account necessarily relies on the potential existence of an overarching whole. The idea that we could always, and therefore infinitely expand our view. While scientifically sound, this is a philosophically problematic approach.[29] As there are good reasons to argue against the idea of the universe as a whole (as a closed system). Bergson makes a similar argument against totalisation in his *Creative Evolution*. For him, the concepts of mathematical physics are predicated on closing and isolating systems, and the open nature of the universe provides a profound conceptual difficulty for their generalisation.[30] Another argument, more in line with Kant, is that empirical concepts are only valid within possible experience, and the whole is experience is not itself an experience – one cannot speak of the whole of the universe empirically, only of partial manifestations.[31] Thus, it is not false but metaphysically imprudent to speak of universal entropy. If the view of time as emergent from local material difference that I proposed here carries any weight, we should make more of the partiality that belongs to particular observers than to the attempts, however successful, to universalise the products of that partiality.

By way of conclusion, I would like to indicate how this view of time, following something suggested by the notion of entropy, does relate to dialectical materialism. In my introduction, I referred to Sohn-Rethel's unique brand of historical materialism—a view

28 The Möbius strip may be constructed, heuristically, by taking a strip, cutting it at some point, turning one end 180 degrees and reattaching. This construction is non-orientable in that going around it left turns to right, up to down and vice versa.

29 See Hans Reichenbach, *The Direction of Time*, ed. Maria Reichenbach (Berkeley, Los Angeles, London: University of California Press, 1971), 125–135, and 133 especially.

30 See Henri Bergson, *The Creative Evolution*, trans. Arthur Mitchell (New York: Random House, 1944), 18–27.

31 See Kant's discussion of the first Antinomy: Kant, *Critique of Pure Reason*, A426/B454-A434/B462.

on which changes to the mode of production induce changes to the most fundamental categories of thinking. In that reference, I also implied that we may view entropic physics and dialectical materialism to be sister world-views, both being changes to the fundamental categories of thinking, induced by the Industrial Revolution, as a change in the mode of production. To restate, in a slightly more substantial way, the sense in which these are sister world-views, let me compare the view developed here with that of Žižek's in *Sex and the Failed Absolute.* The notion of an emergent, material time that I indicated in this paper is remarkably close to the definition of dialectical materialism that Žižek develops in that book. The position proposed here is of a materialist view of time, that understands the world as temporally non-orientable. Žižek's view was put together in an attempt to rescue a notion of historical progress that refuses the naive Enlightenment view of a steady trend toward the perfection of mankind. For Žižek, the dialectical materialist must be committed to viewing the world as a non-orientable surface, in which the progress of history is not linear and universal but moves at different paces and in different directions in different regions and times.

In his introduction, Žižek gives four theses that define his idea of dialectical materialism. The latter two are, as I understand it, reflected in the entropic view of time I argued for here:

> 1. "progress is always localized, the overall picture is that of a circular movement of repetition, where what is today 'reactionary' can appear tomorrow as the ultimate resort of radical change."[32]
>
> 2. "antagonism [is] the constitutive contradiction of an entity with itself: things come to be out of their own impossibility, the external… is always the externalisation of their immanent self-blockage and inconsistency."[33]

I hope that this view of time as local, non-linear and materially emergent, speculative as it is, might help to illuminate, to some extent, what is revolutionary about the Industrial Revolution: Perhaps, that it forces us out of an orderly and ideally regulated world, to a world dominated by a kind of chaos—not in the abstract sense of disorder, but in the sense of a fluid and heterogenous order, one manifest in the phenomena of genesis and decay, rather than stable existence.

32 Slavoj Žižek, *Sex and the Failed Absolute* (London: Bloomsbury Academic, 2020), 4.
33 Žižek, *Sex and the Failed Absolute*, 5.

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TECHNOPHANY
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Affirming Entropy

Ashley Woodward

Abstract:
This paper challenges the frequent demonisation of entropy in philosophies of technology which attempt to draw a "naturalised" axiology from thermodynamics, information theory, and related sciences. Such philosophies include Wiener's cybernetics, Stiegler's neganthropology, and Floridi's information ethics, in each of which entropy designates the *evil* which must be fought in the name of life, information, or some other notion of "the good." The perspective the paper develops to argue the case is Nietzschean. Nietzsche himself rejected the consequences of the Second Law, but I wish to argue that it is possible to *affirm* entropy, for Nietzschean reasons.

First, the paper argues that the reason Nietzsche rejected the Second Law is that it provides consolation for the pessimist (an argument made by von Hartmann). Eternal return should be affirmed because it is the *more difficult* position, and so provides the ultimate existential test. However, metaphysical and existential reasons must give way to the more recent scientific evidence, especially the dating of the universe, which undermines Nietzsche's argument against heat death. While this is alone sufficient reason to affirm entropy, the position is supported by two further classes of reasons. First, the oppositions which have supported the traditional ascription of values to negentropy and entropy can be challenged; and 2) entropy can be seen as consonant with the characteristics of existence which Nietzsche sought to affirm, especially *becoming*.

Keywords:
Entropy; Thermodynamics; Philosophy of Technology; Nietzsche; Eternal Return; Value; Life

 Corresponding author: Ashley Woodward, a.z.woodward@dundee.ac.uk

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Introduction

Contra long-prevailing wisdoms, *entropy should be affirmed.* The aim of this paper is to argue the case. Since William Thomson (Lord Kelvin) drew the consequences of the Second Law of thermodynamics—the tendency of entropy to increase in closed systems—to the cosmic level of the "heat death" of the universe, entropy itself has frequently been cursed as a veritable force of evil. Numerous scientists and philosophers have demonised entropy, using it as an inspiration for naturalising values and construing it as the general antagonistic principle against which everything valued as "good" contends. Entropy has typically been characterised as disorder, disorganisation, dispersal, dissolution, and death. The Second Law has been interpreted to mean the inevitable triumph of entropy over order, organisation, creativity, change, civilisation, progress, life, and so on. In short, entropy has very frequently been understood as the naturalised equivalent of the theological notion of evil, and has been denounced and negated as such. This tendency has been significantly evident in philosophies of technology. In what follows, I will adopt a Nietzschean framework through which to argue that this construal of entropy as evil is deeply problematic and wrongheaded, and that entropy should instead be affirmed.

Section one presents a summary survey of a number of prominent positions that "demonise" entropy, in order to demonstrate that the position I am arguing against is not a mere phantasm, but a real position that has frequently been explicitly adopted in influential scientific and philosophical literature. After charting the appearance of entropy and its negative construal in early thermodynamic theory, I focus on some contemporary philosophers of technology and the pedigree they themselves cite: Bernard Stiegler and Luciano Floridi are taken as prominent representatives, and Norbert Wiener and Erwin Schrödinger as key influences.[1]

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1 A recent publication, Drew M. Dalton's *The Matter of Evil: From Speculative Realism to Ethical Pessimism* (Evanston, Ill: Northwestern University Press, 2024), has argued for an understanding of entropy as an objective evil, and situated pessimists such as Arthur Schopenhauer, Philipp Mainländer, and E.M. Cioran as contributing to a tradition which supports this. Such philosophers reason that existence is evil because the inevitability of decay means that the striving of life is fundamentally bound to suffering and death. It would further the general argument mounted against the construal of entropy as evil to engage with this work, but such a task is beyond the scope of this paper. First, because my focus here is on entropy, and while Dalton (as have others) associates the metaphysical principle of decay to be found in these pessimists with entropy, they do not explicitly engage with it themselves. Second, the thinkers I primarily take issue with here are not pessimists, but rather "negentropy optimists": they do not deny the value of existence, but rather establish a fairly conventional "naturalised" ethic of good and evil on the basis of negentropy and entropy. In such a naturalised schema entropy is taken as a force of evil, but only as an oppositional principle which allows the establishment of a positive value of existence in negentropic terms. A technological criterion seems to govern how these thinkers understand the "evil" implications of entropy: it is not suffering that is problematic for them,

Section two tackles Nietzsche's own treatment of entropy and the Second Law. This is an important step in my argument, because it has become fairly well known in the secondary literature that Nietzsche himself actually rejected the consequences of the Second Law, along with the idea of any final state of the universe. Arguably, however, the reasons *why* he rejected those consequences has not been well understood, and my aim here is to clarify this issue. This will then pave the way for a "Nietzschean" affirmation of entropy, against the letter of his texts but in the spirit of his philosophy.

Section three compares Nietzsche's arguments with more recent relevant scientific data, demonstrating that we have much stronger reason to accept entropy today on scientific grounds than he did in the nineteenth century. Section four critically deconstructs some of the main oppositions which have upheld the moral privileging of negentropy over entropy, and section five argues that entropy is in fact close in many ways to Nietzsche's preferred cosmology, especially in its aspect of becoming. The argument of the paper leads to the conclusion that if we are to affirm *existence* in a Nietzschean fashion in light of our currently available scientific and philosophical understanding, then *entropy* should in fact be affirmed.

1. Entropy Demonised

> The Second Law is all about entropy increasing, which is just a technical way of saying that things get worse.
>
> —Peter Atkins[2]

> *Enter* MEPHISTOPHELES.
>
> —Goethe, *Faust*

1.1 Thomson's "Heat Death"

> [W]e must admire the sagacity of Thomson, who, in the letters of a long-known little mathematical formula, which only speaks of heat, volume, and pressure of bodies, was able to discern consequences which threatened the universe, though certainly after an infinite period of time, with eternal death.
>
> —Hermann von Helmholtz[3]

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but rather a final state of the universe in which there is no more energy available to do work, i.e., the machinery of the cosmos will eventually break down in "heat death."

2 *Order and Disorder*, Episode 1: *Energy*, BBC, 2012.

3 "On the Interaction of Natural Forces," in *Science and Culture: Popular and Philosophical Essays*, ed. David Cahan (Chicago and London: University of Chicago Press, 1995), 30.

Rudolf Clausius introduced the term "entropy" in 1865[4], to describe dispersed or "spread out" energy that is no longer useful for doing work. How did it come to pass that this notion came to be vilified and associated with theological and moral notions of evil? Here we need to point to the closely associated Second Law of thermodynamics. Early formulations by Thomson and Clausius simply describe this law in terms of heat flowing from a higher temperature body to a lower temperature body and never *vice versa*, something of which it is not obvious we ought to be afraid.[5]

The idea that there might be something deeply worrying about entropy was introduced with William Thomson's 1852 lecture "On a Universal Tendency in Nature to the Dissipation of Mechanical Energy."[6] Here he briefly concludes, from the Second Law, that

> 1. There is at present in the material world a universal tendency to the dissipation of mechanical energy.
> 2. Any *restoration* of mechanical energy, without more than an equivalent of dissipation, is impossible […]
> 3. Within a finite period of time past, the earth must have been, and within a finite period of time to come the earth must again be, unfit for the habitation of man as at present constituted […].[7]

Here Thomson draws out the implications of the Second Law already implied by Sadi Carnot's pioneering work in thermodynamics, and states, without further comment, the consequence that the earth must be at some time in the future uninhabitable to human beings in their current form. He did not himself use the term "heat death" (which originated with Ludwig Boltzmann) but was credited with the idea by latter commentators (see the comment by Helmholtz which heads this section).

With reference to Carnot and Thomson, Hermann von Helmholtz then expanded the consequences of the Second Law to encompass the entire universe in his 1854 lecture "On the Interaction of Natural Forces":

4 Rudolf Clausius, "On Several Convenient Forms of the Fundamental Equations of the Mechanical Theory of Heat," in *The Mechanical Theory of Heat*, ed. T. Archer Hirst (London: John Van Voorst, 1867).

5 Thomson, for example formulated it as follows: "It is impossible, by means of inanimate material agency, to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of the surrounding objects." "On the Dynamical Theory of Heat, with Numerical Results from Mr. Joule's Equivalent of a Thermal Unit, and M. Regnault's Observations on Steam," [1851] in *Mathematical and Physical Papers 1.* (Cambridge: Cambridge University Press, 2011), 179.

6 Thomson, "On a Universal Tendency in Nature," in *Mathematical and Physical Papers 1* (Cambridge: Cambridge University Press, 2011).

7 Thomson, "On a Universal Tendency in Nature," 514.

> [T]he first portion of the store of force, the unchangeable heat, is augmented by every natural process, while the second portion, mechanical, electrical, and chemical force, must be diminished; so that if the universe be delivered over to the undisturbed action of its physical processes, all force will finally pass into the form of heat, and all heat come into a state of equilibrium. Then all possibility of a further change would be at an end, and the complete cessation of all natural processes must set in. The life of men, animals, and plants could not of course continue […] In short, the universe from that time forward would be condemned to a state of eternal rest.[8]

The idea was again stated, in a way that became more popular and influential, by Clausius in his 1867 lecture *Über den zweiten Hauptsatz der mechanischen Wärmetheorie* [On the Second Principle of the Mechanistic Theory of Heat]. Clausius describes "heat death" in terms of a "limiting state" of maximised entropy, which he presents as an inexorable, if distant, fate:

> Although the current state of the world is still far from reaching this limiting state, and the approach to it happens so slowly that all the time periods we consider as historical times are only short spans compared to the immense durations required for significant transformations in the world, it remains an important outcome that a natural law has been discovered which conclusively suggests that not everything in the world is cyclical, but rather it continually changes its state in a certain sense and tends towards a limiting state.[9]

These scientific presentations of entropy and the consequences of the Second Law tend to remain rather neutral in their tone. Yet Helmholtz intimates its profoundly disturbing potential when he asks, "Shall we terrify ourselves by this thought?" and concludes stoically that "[a]s each of us singly must endure the thought of his death, the race must endure the same."[10] The attachment of a distinctly negative value to entropy emerges more clearly in later developments.

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8 Hermann von Helmholtz, "On the Interaction of Natural Forces," in *Science and Culture: Popular and Philosophical Essays*, ed. David Cahan (Chicago and London: University of Chicago Press, 1995), 30.

9 Clausius, *Über den zweiten Hauptsatz der mechanischen Wärmetheorie* (Braunschweig: Vieweg, 1867), 17.

10 Helmholtz, "On the Interaction of Natural Forces," 41–2, 43.

1.2 Schrodinger's Life

In February 1943, the physicist Erwin Schrödinger gave a series of lectures at Trinity College, Dublin, on the topic *What is Life?* The short book based on these lectures became one of the most influential popular science books of the twentieth century. Here Schrödinger explains life in a way which opposes it to entropy. Life is that which *resists* entropy, slowing down the action of the Second Law. What distinguishes living things from inert matter is their tendency to go on doing things, to resist the inert state that comes with thermal equilibrium.[11] Living beings avoid, or at least postpone, this decay by *metabolising* food that they take in from their environment. Schrödinger specifies that the Greek root of the term "metabolism" means change or exchange.[12] Organisms retain the capacity to go on *changing* by *exchanging* with their environment.

In answer to the question of *what* exactly organisms take in from their environment (as food), Schrödinger rejects prevailing answers in terms of matter or energy and proposes that what organisms feed on is "negative entropy." He explains:

> What then is that precious something contained in our food which keeps us from death? That is easily answered. Every process, event, happening - call it what you will; in a word, everything that is going on in Nature means an increase of the entropy of the part of the world where it is going on. Thus a living organism continually increases its entropy - or, as you may say, produces positive entropy - and thus tends to approach the dangerous state of maximum entropy, which is death. It can only keep aloof from it, i.e. alive, by continually drawing from its environment negative entropy - which is something very positive as we shall immediately see. What an organism feeds upon is negative entropy.[13]

After introducing the term "negative entropy," Schrödinger suggests that it can be replaced with the term *order*.[14] Entropy itself is then equated with disorder, or chaos. Life is a process through which living beings compensate for the entropy they produce by "sucking orderliness" from their environment.[15] In a later note addressing criticisms of his term "negative entropy," he suggests that if his sole audience were physicists, he would have used the term "free energy" instead.[16] As it is, Schrödinger"s work was very influential in introducing the idea of life as associated with a "negative entropy" (later

11 Erwin Schrödinger, *What is Life?* (1944) (Cambridge: Cambridge University Press, 1967), 68.
12 Schrödinger, *What is Life?* 70.
13 Schrödinger, *What is Life?* 71.
14 Schrödinger, *What is Life?* 73.
15 Schrödinger, *What is Life?* 73.
16 Schrödinger, *What is Life?* 74.

shortened to "negentropy" by Léon Brouillon)[17] and equating entropy with disorder and death. After Schrödinger, if we fear death, then we may believe we need to fear entropy.

1.3 Wiener's Cybernetics

In his development of the transdisciplinary science of cybernetics, Norbert Wiener contextualises the analogy it makes between living beings and machines in a larger physics and metaphysics of order and disorder (entropy). The analogy itself, which is exemplified by automata, is based on the idea of information as the means of communication and control in systems of all kinds, including living beings and machines. Wiener, along with Claude Shannon, developed a mathematical theory of information which follows the statistical mechanics developed in the nineteenth century for thermodynamics. The *probabilistic* nature of information allows basically the same equation to be used to measure information as that which has become known as "Boltzmann's principle," which measures entropy in thermodynamics.[18] Wiener explains:

> The notion of the amount of information attaches itself very naturally to a classical notion in statistical mechanics: that of *entropy*. Just as the amount of information in a system is a measure of its degree of organization, so the entropy of a system is a measure of its degree of disorganization; and the one is simply the negative of the other.[19]

In Wiener's cybernetics, information and all systems which use it to increase order can be understood in terms of negative entropy, while disorder is understood as entropy.

Similarly to Schrödinger's understanding of life, Wiener understands living beings as increasing order in local systems, despite the inevitable increase of disorder in the more global systems of which they are a part, and he extends this notion of "anti-entropic" processes[20] to machines insofar as they are able to increase order:

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17 Léon Brillouin, "Negentropy Principle of Information," *Journal of Applied Physics* 24, no. 9 (1953): 1152–1163.

18 In fact developed in its final form by Max Planck, but so associated with Boltzmann that it is inscribed on his tombstone. The equation for the principle is $S = k \log W$, where S stands for entropy, k is a constant ("Boltzmann's constant," also first stated explicitly by Planck), and W, the number of microstates in a system.

19 Norbert Wiener, *Cybernetics*, 2nd Ed. (Cambridge, Mass: MIT Press, 2019), 17.

20 Norbert Wiener, *The Human Use of Human Beings: Cybernetics and Society*, 2nd Edition (London: Free Association Books, 1989), 32.

> The machine, like the living organism, is, as I have said, a device which locally and temporarily seems to resist the general tendency for the increase of entropy. By its ability to make decisions it can produce around it a local zone of organization in a world whose general tendency is to run down.[21]

It is in this context that Wiener names entropy as the "arch-enemy"[22] of the cause of order, of progress and civilization, not only in a local and temporary sense, but because of the heat death that the Second Law predicts. The Second Law will mean that order is ultimately destined to disorder, life to death, and Wiener characterises entropy as a "devil."[23] Drawing on theological traditions, he argues that this devil has an Augustinian nature rather than a Manichean one. This means that entropy/evil is not to be understood as a substantial counter-tendency to good (the Manichean "heresy"), but rather as simply a lack, privation, or negation of good, as Augustine contends. Entropy is then simply a lack of order. Wiener furthermore names this devil Mephistopheles, referencing characteristics ascribed to him in Goethe's *Faust*, suggesting that he is not a fully independent and unlimited force of evil, but only a deprivation of good.[24] Wiener conceives his project of cybernetics as part of the broader struggle against entropy (understood as disorder or disorganisation), which he theorises by drawing analogies with theology, explicitly demonising entropy in the process.

1.4 Stiegler's Negathropology

Far from the diabolical character of entropy having disappeared from more recent literature, its profile seems to have been raised. This is evident in the work of Bernard Stiegler, who, in the years before his recent and untimely death, identified entropy as the negative value in his own original philosophy. This philosophy encompasses a global metaphysics of systems and individuals ("organology"), with a particular emphasis on how things "individuate," or become what they are. Stiegler is concerned with human individuals in their psychological and affective constitution, technologies, societies in general, and the earth with its manifold economic, political, and environmental problems. Stiegler's "organology," or "neganthropology," is a kind of energetic systems theory, in which negentropy is identified as the general "good," and entropy the general "evil." In this,

21 Wiener, *Human Use*, 34.
22 Wiener, *Human Use*, 34.
23 Wiener, *Human Use*, 34.
24 Wiener, *Human Use,* 35.

Stiegler is influenced by earlier scientists and philosophers such as Schrödinger, Alfred J. Lotka, and Nicholas Georgescu-Roegen,[25] but his thinking is also subtly complexified by the influence of Nietzsche.

Stiegler describes the individuation process in general in terms of tendencies which are contrary, but "composing" rather than simply opposing in an antagonistic sense. Inspired by Nietzsche, Freud, and others, he identifies this "compositional" way of thinking as present in early Greek thinking, prior to the imposition of metaphysical, oppositional thinking (with Socrates, Plato, and Aristotle). It is, for example, present in Heraclitus's "unity of opposites," and it is this mode of non-oppositional thought which inspired Nietzsche's thinking, first of the complex, productive intertwining of Apollonian and Dionysian tendencies, and then in thinking "beyond good and evil," understood to be moral oppositions isomorphic to metaphysical ones. Stiegler associates this compositional mode as essential to healthy individuation processes and to life itself.

However, Stiegler reintroduces evil, and entropy as a principle of evil (or simply negative value), in order to explain what goes wrong with individuation processes. Even though "disindividuation," and entropy in some sense, are essential to healthy individuation processes, they can shift out of balance with their opposing tendency and become dominant, leading to the destruction of the healthy individual. One way Stiegler explains this is with recourse to the double nature of *Eris*, the goddess of discord, indicated by Hesiod at the beginning of *Works and Days*, to which Nietzsche drew attention in his early essay "Homer's Contest." One of the natures of *Eris* is as the goddess of competition, who motivates the accomplishment of great deeds. This is a healthy and productive kind of agonism, strife, or discord. However, this very same tendency can transform into its worst aspects, in which it becomes the other *Eris*, the goddess of war and destruction.[26] Applying this principle to thermodynamic ideas, Stiegler acknowledges that metastability, the state of potential energy necessary for further individuation, is a state between order and disorder, containing them both in tension. But disindividuation is then associated

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25 Georgescu-Roegen's work in economics established a position known as "entropy pessimism," which further demonises entropy. In short, he argues that the Earth's resources are finite, and do not support any economic model of infinite growth. While aspects of his understanding of physics have been challenged (he believed the Second Law can be applied to physical matter in the same way as to energy, which is not the scientific orthodoxy), his basic position of "entropy pessimism" continues to be influential in environmental circles, as well as being an important influence on Stiegler's philosophy. See Nicholas Georgescu-Roegen, *The Entropy Law and the Economic Process* (Cambridge, Mass: Harvard University Press, 1971).

26 See Stiegler, *The Decadence of Industrial Democracies*, trans. Daniel Ross (Cambridge: Polity, 2011), 50–53 (section 5. "The worst and the best in the epoch of nihilism as questions of war and class struggle") and *Acting Out*, trans. David Barison (Stanford: Stanford University Press, 2008), 73–75 (the section "The question of evil and the thought of tendencies").

with the tendency to disorder, or entropy, which can break away from this productive interaction, become dominant, and simply destructive.

While Stiegler warns against "diabolising" the tendency against which one fights,[27] in his later works his polemical rhetoric hardly holds back from presenting "entropy" as the general, overwhelming problem, the principle of evil and diabolism itself. This is encapsulated in his coining of the term "Neganthropology"—which is in part drawn from "negentropy," the opposite of entropy—to indicate all that we must fight for in order to overcome the destructive tendencies he sees as characteristic of the Anthropocene (which he also calls the "Entropocene"[28]) and threatening the human race with extinction in multiple ways. According to Stiegler, with entropy:

> the question of evil resurfaces, and it does so macrocosmologically—and not morally—after the Nietzschean attempt to leap (*Sprung*) beyond good and evil, and as the threat from within the biosphere to the biosphere itself.[29]

1.5 Floridi's Information Ethics

Neither is the demonisation of entropy restricted to the "literary" dramatisations of the continental philosophical tradition. Luciano Floridi does not hesitate to explicitly identify entropy and evil in his account of ethics within the systematic exposition of his philosophy of information.[30] He more lately regrets the choice of the term "entropy," but only because of the confusion it his caused his readers in relation to the way the term is used in thermodynamics and Shannon's information theory.[31] He in fact doubles down on the metaphorical association of entropy with evil in its theological dimensions, broadly following Wiener. In order to distinguish it from thermodynamics and information theory, Floridi clarifies that entropy in Information Ethics (IE) doesn't refer to energy (thermodynamics) or formal syntax (information theory), but to the degradation of information in its *semantic* or *ontological* dimension: that is, it concerns information *content* (meaning, or being). In order to further clarify what he means, Floridi proposes to call this *metaphysical entropy*, which he explains as follows:

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27 Stiegler, *Acting Out*, 73–4.

28 See Stiegler, "Capitalism as Epistēmē and Entropocene," in *The Neganthropocene*, ed. and trans. Daniel Ross (London: Open Humanities Press, 2018).

29 Stiegler, *Neganthropocene*, 196.

30 Floridi now describes himself as a "former" analytic philosopher and positions his own philosophy of information beyond the divide. Yet his work remains rooted in this tradition and continues to display many of its norms.

31 Luciano Floridi, *The Ethics of Information* (Oxford: Oxford University Press, 2013), 65–66.

> Metaphysical entropy refers to any kind of destruction or corruption of entities understood as informational objects (mind, not just of semantic information, or messages), that is, any form of impoverishment of Being.[32]

Floridi proposes that a fundamental positive value be accorded to any and all information, such that any informational entity has a minimal value (i.e., is considered "good") in its simple existence. Any degradation of information is then construed as an ethical *evil*. In a move reminiscent of Wiener, he then suggests that evil has only a negative, or privative, meaning: Being is good, and Non-Being, or nothingness, is evil. Entropy, as the degradation of information, is thus considered evil in informational terms.

This thesis, Floridi says, follows the classical notion of evil as *privatio boni*: only good has substantial reality, and evil is simply the negation, destruction, or corruption of a positive good.[33] Again following Wiener (knowingly or not), Floridi quotes Goethe's Mephistopheles in support of the "negative" character of evil as Non-Being:

> I am the Spirit, that ever denies!
> And rightly so; for everything that comes into being, deserves to perish;
> since it were better if nothing had come forth.
> Thus is everything that you call Sin,
> Destruction, in short, Evil,
> my proper Element.[34]

Floridi develops his notion of entropy as evil by specifying four ethical principles of IE, the first three of which give us normative statements regarding entropy:

> 0 entropy ought not to be caused in the infosphere (null law)
> 1 entropy ought to be prevented in the infosphere
> 2 entropy ought to be removed from the infosphere
> 3 the flourishing of informational entities as well as the whole infosphere ought to be promoted by preserving, cultivating, and enriching their well-being.[35]

It would be hard to imagine a much more explicit "demonisation" of entropy than Floridi's evocation of its Mephistophelean character, his bald characterisation of entropy *as* evil, and

32 Floridi, *Ethics of Information*, 67.
33 Floridi, *Ethics of Information*, 67.
34 Goethe, *Faust*, I, 1338–44. Floridi's translation; see: *Ethics of Information*, 67.
35 Floridi, *Ethics of Information*, 71.

its normative ethical proscription.[36] Yet we can see Floridi's position as a condensation of multiple tendencies towards the demonisation of entropy, and while he develops a unique "informational" notion of entropy, its characterisation as evil draws on many precursors who, as we have seen, have established this metaphysical, moral, and affective association.

2. The Case of Nietzsche

The above examples of the "demonisation" of entropy may be thought of—whether or not this appears consciously in the writers concerned—as instances of *naturalising values*. Nietzsche sets out the project for a naturalisation of values when he examines the inadequacy of the current state of values in nineteenth century Europe. God was dead; the transcendent source of values had been seriously placed in question. However, Nietzsche complained, the values prevailing in European culture continued, as if by inertia, to be the "highest values" inherited from the Christian and metaphysical traditions. The project Nietzsche then sets out is to "naturalize" values by finding a new basis for them *in nature*, rather than in some transcendent supernatural source. In *Gay Science* 109, he writes:

> When will all these shadows of God cease to darken our minds? When will we complete our de-deification of nature? When may we begin to "*naturalize*" humanity in terms of a pure, newly discovered, newly redeemed nature?

For Nietzsche, science—the study of nature—is a major source of inspiration for the discovery of new principles of value. For example, he claims to find "the will to power" everywhere in living things and was partially inspired in this idea by Boscovitch's theory of the atom.[37]

Stiegler clearly announces the way that entropy can be understood to have played a role in the naturalisation of values:

> Emerging from thermodynamics about thirty years after the advent of industrial

36 In addition to the sections of *The Ethics of Information* cited, see Floridi, Luciano and J.W. Sanders, "Entropy as Evil in Information Ethics," *Etica & Politica* 1, no. 2 (1999) <http://www2.units.it/etica/1999_2/index.html>.

37 Z:II "Self-Overcoming." On Nietzsche and Boscovitch, see for example Greg Whitlock, "Roger J. Boscovitch and Friedrich Nietzsche: A Re-Examination," in *Nietzsche, Epistemology and Philosophy of Science*, ed. Babette E. Babich (Dordrecht: Springer, 1999).

technology […] the theory of entropy succeeds in redefining the question of *value*.[38]

Nietzsche engaged with the ideas of thermodynamics and entropy, and notably he rejected the Second Law, or at least its apparent implication of heat death.[39] In a recent article, Joel White argues that this rejection was motivated by a kind of *ressentiment* against the idea of heat death.[40] He summarises his interpretation as follows:

> Nietzsche's hatred for the so-called "metaphysical" and will to overcome nihilism determine a resentful attitude towards entropic death that ultimately takes refuge in the *deus ex machina* of perpetual motion. It is hard to think of anything more counter to Nietzsche's own criticisms of the history of metaphysics than the use of perpetual motion as the means of energetically conditioning the eternal return. The affirmation of the eternal return as an affirmation that seeks the transvaluation of values is affirmed not for itself but for "ulterior motives," ones that begin and end in ressentiment, for it is not a yes-saying but a no-saying to heat death by any means necessary, metaphysical, or not. For what could be more reactive than the foolhardiness of those that continue to believe in ideas such [as] *perpetuum mobile*, the law of identity in mechanical form, despite it being both practically and theoretically disproved?[41]

I do not believe *ressentiment* against the idea of heat death is a fair characterisation of Nietzsche's reasons for rejecting it. To see why, let us first consider the argument itself, then its context.

Nietzsche rejected heat death (without naming it as such) in so far as it implies a final

38 Bernard Stiegler, *Automatic Society 1: The Future of Work*, trans. Daniel Ross (Cambridge: Polity Press, 2016), 10.

39 A great deal of credit must be given to Paolo D'Iorio for advancing our understanding of Nietzsche's idea of the eternal return by painstakingly reconstructing the context of the scientific and philosophical debates around the Second Law from which they emerged. See Paolo D'Iorio, "Eternal Return: Genesis and Interpretation," trans. Frank Chouraqui, *The Agonist* 3, no.1 (2010): 1–43. Stiegler discusses Nietzsche and entropy, and D'Iorio's interpretation specifically, in *L'immense régression*, section 55: "Nietzsche et la mauvaise nouvelle de l'entropie" [Nietzsche and the Bad News of Entropy], 408–416 [digital edition].

40 Joel White, "How Does One Cosmotheoretically Respond to the Heat Death of the Universe?" *Open Philosophy* 6, no. 1 (2023): 2022–0233. Despite the point of disagreement regarding the interpretation of Nietzsche that follows in the text above, my conclusion at the end of this analysis is the same as White's: given its persistent scientific status, the consequences of the Second Law cannot simply be denied on "metaphysical" grounds, which can easily appear as flimsy as imaginative wish-fulfilment when placed against the (at least relatively) firm edifice of scientific evidence.

41 White, "How Does One Cosmotheoretically Respond."

state. The argument draws on multiple authors in these debates, and their philosophical and scientific heritage, but most significantly on Schopenhauer's argument *a parte ante* ("from the part before") for the impossibility of an infinite time having already passed before the present moment.[42] Nietzsche presents the argument as follows:

> If the world could in any way become rigid, dry, dead, *nothing*, or if it could reach a state of equilibrium, or if it had any kind of goal that involved duration, immutability, the once-and-for-all (in short, speaking metaphysically: if becoming *could* resolve itself into being or into nothingness, then this state must have been reached. But it has not been reached. From which it follows—[43]

The sentence breaks off, but clearly what follows is that a final state is not possible. If it were, it would already have been reached since there has already been an infinite time in which to accomplish such a state. Nietzsche then builds his "cosmological" argument for the eternal return on this basis, adding the idea of a definite quantity of force to that of infinite time: given this, every possible combination of force must repeat an infinite number of times (eternally return).[44] He suggests that this is demanded by the First Law of thermodynamics, that of the conservation of energy.[45]

Nietzsche's choice of eternal return over heat death needs to be understood in the context of *pessimism*, the Schopenhaurian philosophy which initially attracted him but which he spent the rest of his intellectual life trying to overcome. The image of existence that Nietzsche seeks to affirm is in many respects precisely the image that plunged Schopenhauer into pessimism, and which the latter thought needed to be "negated" or "denied." For example, Schopenhauer writes: "Eternal becoming, endless flux belong to the revelation of the essential nature of the will."[46] For Schopenhauer, the will is the fundamental nature of reality, and its character consists in a restless drive that can never be satiated. The will determines human life as essentially incapable of fulfilment, fluctuating between suffering and boredom. The "eternal becoming and endless flux" which characterise the will are, here, reasons for pessimism. A "heat death" of the universe would remove these reasons, resulting in a kind of consolation from this deepest of pessimistic views. D'Iorio

42 Again, this has been meticulously reconstructed by D'Iorio. See D'Iorio, "Eternal Return."

43 WP 1066. Here and following I quote from *The Will to Power*, despite its notorious unreliability, because many of the relevant passages are not yet available in more reliable English translations. In the few cases where there are alternatives available, I have also cited them, but have selected all quoted text from *The Will to Power* for the sake of consistency and clarity.

44 WP 1066.

45 WP 1063/WLN 5[54].

46 Arthur Schopenhauer, *The World as Will and Representation*, vol 1, trans. E.F.J. Payne (New York: Dover, 1966), 164 (section 29).

explains very clearly why the pessimist is consoled by the thought of heat death:

> interpreting Schopenhauer's concept of will as a "not being able to not will," as an eternal willing creating an infinite process in the past and in the future, would lead one to despair, because this would suppress the possibility of a liberation from the senseless impulse of the will.[47]

Schopenhauer, who died in 1860, did not significantly engage the philosophical debates on thermodynamics, which became popular in Germany only after Clausius' 1867 lecture *Über den zweiten Hauptsatz der mechanischen Wärmetheorie* [On the Second Principle of the Mechanistic Theory of Heat].[48] But the pessimistic position was prominently represented in these debates by Schopenhauer's follower Eduard von Hartmann. In the latter's 1869 book *Philosophy of the Unconscious*, he argues that the absence of pain is the best possible happiness.[49] This position led him into debates about heat death, where his aim was to argue in favour of its reality, because for him it constituted an ultimate liberation from suffering. What he wanted to avoid was precisely the notion of an eternal return, where the cycle of life might start again, and with it the pain of existence.

In light of this pessimist context, Nietzsche's thesis of eternal return then appears as what it is: a challenge to the pessimist thesis, which deprives the pessimist of their hope for a final "liberation" from existence. In Nietzsche's words: "Everything becomes and recurs eternally—escape is impossible!"[50] Against White's interpretation, I would emphasise that Nietzsche's aim with the eternal return is not to present a comforting idea to ward off an unpalatable one, but precisely the opposite: the eternal return is designed to present life in such a way that there is *the greatest difficulty* in affirming it. This is what Nietzsche means, for example, in characterising the thought of eternal return as "*the heaviest burden*"[51] and "the *hardest* idea."[52] In characterising Nietzsche's position as reactive and motivated by *ressentiment*, White misses this aspect. If Nietzsche found heat death an abhorrent thought that he felt *ressentiment* towards, then that would in fact have been reason to *prefer* it over

47 D'Iorio, "Eternal Return," 23.

48 Clausius, *Über den zweiten Hauptsatz*. The importance of this lecture is noted by D'Iorio, "Eternal Return," 40.

49 Eduard von Hartmann, *Philosophy of the Unconscious*, trans. William Chatterton Coupland (London and New York: Routledge, 2014). See for example the section "Nature of the Problem" in chapter XIII, where Hartmann asserts that someone who, on the point of death, had the chance to live their life over again, would most likely prefer non-existence. (D'Iorio highlights the relevance of this thought experiment to Nietzsche's eternal return.)

50 WP 1058.

51 GS 341.

52 WP 1059.

the hypothesis of eternal return for the role it is intended to play as an existential "test." As Pierre Klossowski has emphasised, the idea of the eternal return acts as a "selective doctrine," which establishes the difference between "higher types" (those who can affirm it) and the rest of humanity (those who cannot).[53] For Nietzsche, "the eternal return" is "the highest formula of affirmation that can possibly be attained."[54] My contention, in short, is that Nietzsche was not concerned that the Second Law was *too nihilistic*, but that it was *not nihilistic enough* to present the ultimate test—because the thought of ultimate annihilation is exactly what is comforting to pessimists like Schopenhauer or Hartmann. Nietzsche affirmed eternal return *because it is the more difficult position to affirm*, and it thus achieves the highest affirmation. The thought of Eternity is a *terrible test*; it should in fact be *easier* to affirm heat death. Uncovering Nietzsche's specific motivations for rejecting heat death then clears the way for a Nietzschean affirmation of entropy. In the following, I will presents reasons why we might believe not just that this is possible, but necessary.

3. The Scientific Spirit

Nietzsche's relation to science, and to purported "scientific facts," is a complex and contested matter, but the presence of a certain privileging of the "scientific spirit" over the "religious" or "metaphysical" in his works is well-attested. In general, he wished to pursue and accentuate "the recently attained preponderance of the scientific spirit over the religious."[55] In this scientific spirit, then, to interpret Nietzsche's philosophy according to its own guiding lights we should place his views on entropy and heat death in the context of the scientific knowledge of his time and compare it to our own.

Now, Nietzsche's argument is that *all things being equal* with respect to scientific evidence, we can argue the merits or demerits of various cosmological models on the basis of speculative metaphysical arguments, combined with value judgements. This, I think, can be read from the note published as *The Will to Power* 1066, in which Thomson's and Düring's views on heat death are discussed, and where he presents the argument about infinite time *a parte ante* as follows:

> Nothing can prevent me from reckoning backward from this moment and saying "I shall never reach the end"; just as I can reckon forward from the same moment into the infinite.

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53 Pierre Klossowski, *Nietzsche and the Vicious Circle*, trans. Daniel W. Smith (Chicago: University of Chicago Press, 1997), chapter 6: "The Vicious Circle as a Selective Doctrine."

54 EH "Books" Z.

55 WP 1062/UF 36[15].

With respect to value judgements, he notes that wherever he has found the argument for a finite time prior to the present moment, "every time it was determined by other ulterior considerations (—mostly theological, in favour of the *creator spiritus*)." He then continues to elaborate the argument *a parte ante*, in a passage already quoted above, and makes the important point:

> This is the *sole certainty* we have in our hands to serve as a corrective to a great host of world hypotheses *possible* in themselves. If, e.g., the mechanistic theory cannot avoid the consequence, drawn for it by William Thomson, of leading to a final state, then the mechanistic theory stands refuted.[56]

In short, this is a metaphysical and logical argument made in the context of a lack of *scientific* evidence which would decide between various "world hypotheses." However, we now have much more scientific evidence, giving weight to a certain hypothesis (or class of hypotheses). Here, I would point to two important issues: first, there is the weight of the general acceptance of the Second Law itself. Second, there is the dating of the universe, which is the single most important development in cosmology since Nietzsche's time, and gives significant privilege to certain "world hypotheses," while diminishing the plausibility of others (or, more strongly put, falsifying them). We are no longer in the same situation with respect to "a great host of world hypotheses possible in themselves."

Both of these issues are to some degree still open to debate, but are nevertheless compelling in making certain contrary hypotheses appear very unlikely. While some scientists are still not entirely convinced,[57] for the most part today the scientific consensus seems to be in step with the sentiments Arthur Stanley Eddington famously expressed in 1927:

> The law that entropy always increases—the second law of thermodynamics—holds, I think, the supreme position among the laws of Nature. If someone points out to you that your pet theory of the universe is in disagreement with Maxwell's equations—then so much the worse for Maxwell's equations. If it is found to be contradicted by observation—well, these experimentalists do bungle things sometimes. But if your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation.[58]

56 WP 1066; emphasis added.

57 See for example Roger Penrose, *The Road to Reality* (New York: Vintage, 2005), 692, and Sabine Hoffenfelder, "I Don"t Believe the 2nd Law of Thermodynamics (The Most Uplifting Video I'll Ever Make)," YouTube, 2023.

58 Arthur Stanley Eddington, *The Nature of the Physical World* (Cambridge: Cambridge University Press, 1929), 74.

The great breakthrough in dating the universe was made by astronomical observations combined with spectrum analysis, and published by Edwin Hubble in 1929.[59] This supported a model of the universe as expanding, and hence implied a point and a time from which it began to expand (an "origin"). Today there is what some believe to be a "crisis" in cosmology, because two different methods of dating the universe—by measuring cosmic background microwave radiation, and by measuring distances between observable astronomical phenomena (stars and galaxies)—give us different results (18.8 and 14.5 billion years, respectively).[60] Nevertheless, they both point to an origin, so whichever turns out to be more accurate, together they stand against the hypotheses of an infinite past. This evidence supports the Second Law of thermodynamics, and for us today, reverses Nietzsche's available argumentation. While he could hold (perhaps quite plausibly) that the argument of infinite time *a parte ante* decides against the Second Law, today the combined weight of the Second Law and the dating of the universe means we should rather say that because of these, we can know that an infinite time has *not* elapsed prior to the present moment.[61] Nietzsche's "sole certainty" for choosing between cosmological hypotheses is no longer tenable, and in the interests of the scientific spirit we should reject any hypotheses which contradict the weight of current evidence, including Nietzsche's own.

4. Beyond Good and Evil

I take the above scientific considerations to be sufficient reason to affirm entropy. To do so is in keeping with a Nietzschean "scientific spirit," which compels us to reassess Nietzsche's own conclusions in light of the evidence we now have available concerning cosmology. In this and the following section, however, I will further consolidate the argument by respectively 1) "deconstructing" the oppositions which have stabilised the attachment of the values of "good" and "evil" to negentropy and entropy; and 2) argue that from the perspective of Nietzsche's own interpretive attempts to naturalise values, we have good reasons to affirm entropy as consonant with his vision.

59 Edwin Hubble, "A Relation between Distance and Radial Velocity among Extra-Galactic Nebulae," *Proceedings of the National Academy of Sciences* 15, no. 3 (1929): 168–173.

60 E. Di Valentino, A. Melchiorri, and J. Silk, "Planck Evidence for a Closed Universe and a Possible Crisis for Cosmology," *Nature Astronomy* 4, no.2 (2019): 196–203.

61 As Paul Davies, for example, writes: "The fact that the universe has not yet so died—that is, it is still in a state of less-than-maximum entropy—implies that it cannot have endured for all eternity." *The Mind of God* (London: Penguin, 1992), 47.

4.1 Beyond Order and Chaos

On the basis of the common characterisation of negentropy as order and entropy as disorder, we can see a co-implication, rather than opposition, of these tendencies in both "traditional" equilibrium thermodynamics, and the more recent science of far-from-equilibrium systems. While, as I have emphasised, entropy has often been demonised, scientists have also not uncommonly presented it as what *makes possible* negentropic order. The production and maintenance of order *always* comes at the cost of entropy production. And the relations between these have long been described in terms of open, "coupled systems." While the Second Law dictates that entropy always tends to increase in *closed* systems, the creation and maintenance of order is possible in an *open* system when it channels the entropy it produces into a larger system with which it is in communication.[62] (An oft-repeated example is a fridge, which maintains a temperature lower than its environment by channelling the heat it produces into that environment.) The production of local order in coupled systems does not contravene the Second Law, because the overall entropy in the coupled systems—and in the universe as a whole—still increases. Another way of seeing this point is to say that it is the process of the dissipation of energy itself which can be "harnessed" to create order.[63] Negentropic order and entropic disorder are then co-implicated processes, and from this point of view it makes little sense to positively value negentropy and negatively value entropy in an exclusive manner, as though we would be "better off" without the latter.

An even deeper complication and co-implication has been introduced by far-from-equilibrium thermodynamics. This area, pioneered by Ilya Prigogine, challenges the exclusive attachment of order to negentropy and disorder to entropy by having identified "dissipative structures," in which order surprisingly emerges from entropic processes, contravening Boltzmann's principle. Boltzmann formulated thermodynamics in terms of heat understood as atomic agitation, and the probabilities of the distribution of these atoms: entropy is then understood as tending to increase because there are many more probable states of "disorder" than of order, and thermal agitation encourages the disordering of physical arrangements. With dissipative structures, however, we have highly improbable states of order arising from processes involving a high degree of dissipation (entropy). An example here is Bénard convection cells, where the dissipated state of energy in the agitated atoms of a heated fluid spontaneously give rise to ordered patterns. In the words

62 These terms are sometimes used with different meanings in the scientific literature. Here I am using "closed" system to mean a system in which neither energy nor matter is exchanged with an outside, and "open" system to mean one in which both can be exchanged. (Sometimes the term "isolated" system is used in place of this meaning of "closed" system, while the term "closed" is used to refer to a system which is open to exchanges of energy, but not of matter.)

63 *Order and Disorder*, Episode 1: *Energy*, BBC, 2012.

of the English translation of Prigogine and Isabelle's Stenger's popular book on the topic, nature is capable of producing "order out of chaos."[64]

Interestingly, this close relation between order and chaos is nothing radically new, neither in thermodynamics nor in mythology, religion, and philosophy. [65] The features of the latter which the former seems to invoke were already noted by Helmholtz, who was in fact the first to evoke the demon Mephistopheles in conjuring the concept of entropy, but in a distinctly less diabolical aspect than the later manifestations we have already encountered:

> [I]n what close coincidence the results of science here stand with the earlier legends of the human family, and the forebodings of poetic fancy. The cosmogony of ancient nations generally commences with chaos and darkness. Thus for example Mephistopheles says:-
>
> > Part of the Part am I, once All, in primal night,
> > Part of the Darkness which brought forth the Light,
> > The haughty Light, which now disputes the space,
> > And claims of Mother Night her ancient place.[66]

Both the science and the myth suggest that entropy, as a principle of chaos, is entwined with rather than opposed to negentropic order. The key point is that the close connections between negentropy and entropy in both traditional and far-from-equilibrium thermodynamics challenge the simple association of the values of "good" and "evil" (or simply "bad," "worse," etc.) to each respectively.

4.2 Beyond Life and Death

> Consumed by lust, O Man, do not forget: you—are the stone, the desert,
> you are death . . .
>
> —Nietzsche, "The Desert Grows," *Dithyrambs of Dionysus*

64 Ilya Prigogine and Isabelle Stengers, *Order out of Chaos* (London: Flamingo, 1985). For the Bénard convection example, see page 142.

65 On order and chaos in ancient Greek mythology and philosophy, see Shannon M. Mussett, *Entropic Philosophy: Chaos, Breakdown, and Creation* (Lanham: Rowman & Littlefield, 2022), chapter 2.

66 Helmholtz, "On the Interaction of Natural Forces," 34–35.

A further case may be made for challenging the oppositional logic which informs the thought of entropy in the context of *life*. As we have seen, Schrödinger was highly influential in characterising life as a negentropic process, and correspondingly associating entropy with death. Now, despite his affirmation of "life" in an *existential* sense, Nietzsche is wary of any oppositional vitalism, of the kind that Schrödinger seems to endorse. For example, in Nietzsche's writings we find the following:

> Let us beware of saying that death is opposed to life. The living is merely a type of what is dead, and a very rare type.[67]

This is a complex point, since what Nietzsche would seem to be opposed to is the kind of vitalism which retains theological and anthropomorphic resonances in proposing something unique and perhaps "supernatural" that distinguishes living from unliving matter.[68] Certainly, Schrödinger's theory of life is no nineteenth-century vitalism of this kind.

The complexities of Nietzsche's views on life, compared with more recent theories, are not something I can do justice to here. Nevertheless, whatever Nietzsche might have meant by "life," it is highly implausible that he meant "order," or something else seemingly cognate with the notion of negentropy. This can hardly be what he meant by identifying his "message" with the Dionysian. If we had to characterise Nietzsche's position in terms of the oppositional choice the negentropic theory of life gives us, affirming life for Nietzsche means to a much larger extent affirming disorder, and even affirming death, than affirming something like "life as order." In light of the points about the revaluation of destruction, chaos, and so on we noted above, the *challenge* Nietzsche sets us with the injunction to affirm life is much better expressed with the affirmation of entropy.

Moreover, Nietzsche privileged "life" in an existential sense which is not reducible to a concern for the preservation of the biological organism. This is quite evident in his comments that beings with a high degree of will to power are concerned only to express that power, even at the potential cost of their own continued existence. For example, he writes:

> To wish to preserve oneself is a sign of distress, of a limitation of the truly basic life-instinct, which aims at the expansion of power and in so doing often enough

67 GS 109.

68 On Nietzsche's dissatisfaction with both mechanism and vitalism, see Christoph Cox, *Nietzsche: Naturalism and Interpretation* (Berkeley: University of California Press, 1999), section 5.2.5.

> risks and sacrifices self-preservation.[69]

Nietzsche also puts this message into the mouth of Zarathustra, who proclaims of the will to power:

> I would rather perish than renounce this one thing; and truly, wherever there is decline and the falling of leaves, behold, there life sacrifices itself—for power![70]

Since, as we have noted, all energetic processes tend towards dissipation (entropy production), life-affirming expressions of will to power could well be understood as consonant with entropic processes leading to the complete dissipation of the forces constituting the organism (death).

4.3 Beyond Order and Disorder

We have so far deconstructed the *opposition* between entropy and negentropy, understood as order and disorder. Arguably, it is the characterisation of these physical principles as "order" and "disorder" which have so readily allowed evaluative associations and judgements to be made concerning them. Helmholtz was among the earliest to explicitly make this association, calling entropy "disorder" (*Unordnung*) in 1882,[71] and it subsequently taken up by Boltzmann and became widespread in both scientific and popular discourse. More recently, however, this association has been questioned, and some scientists are preferring to stick to terms such as "dissipation," "dispersal," and "spread" to characterise entropy. The notions of order and disorder have increasingly become recognised as subjective judgements, with limited clear applications in mathematical and physical description. Georges Chapoutier has argued that while disorder may be rigorously defined according to a statistical analysis of particles in particular cases, such as the theory of gases, there is no reason to think that this holds for more complex phenomena, and no way to quantitatively distinguish more ordered from less ordered systems in most cases.[72] Even more radically, Frank L. Lambert has waged a campaign (with some success) to have the description of entropy as disorder removed from textbooks. He cites the fact that this

69 GS 349.

70 Z:II "Self-Overcoming."

71 Helmholtz, "Ueber Die Thermodynamik Chemischer Vorgange," [On the Thermodynamics of Chemical Processes] in *Wissenschaftliche Abhandlungen*, vol. 2 (Leipzig: Barth, 1833), 972.

72 See Georges Chapouthier, "Information, structure and forme dans la pensée de Raymond Ruyer," *Revue Philosophique de la France et de l'Étranger* 203, no. 1 (2013): 21-23 and Jean-Jacques Matras and Georges Chapouthier, "La néguentropie: un artefact," *Fundamenta Scientiae* 5, (1984): 141–151.

formulation was influentially used by Boltzmann prior to quantum mechanics, when he did not have a valid way to quantitatively calculate microstates, and when the existence of atoms was not widely accepted. Consequently, Boltzmann had to focus on systems at a "macro" level, and this made his metaphoric description of entropy as "disorder" a more plausible way to grasp the concept intuitively at the time (1898) than we have a right to sustain today. In short, Lambert unequivocally asserts:

> Entropy is not disorder. Entropy is not a measure of disorder or chaos. Entropy is not a driving force. Energy's diffusion, dissipation, or dispersion in a final state compared to an initial state is the driving force in chemistry. Entropy is the index of that dispersal within a system and between the system and its surroundings.[73]

Order and disorder are largely aesthetic and practical judgements, made from a subjective, human perspective. It is these judgements to which moral values are then attached, according to human aims, interests, and feelings of pleasure and pain. The difficulty in ascribing judgements of order and disorder in an objective sense may be given with a simple example, which is sometimes seen in the literature: whether milk poured into coffee increases or decreases order in the universe depends on what we value as "ordered": the milk, or the cup of coffee. The dangerous "subterfuge" of entropy and negentropy is that they then seem to provide an objective "grounding" for such values and seem to accord with a naturalisation of values. It was precisely on such a point that Nietzsche remained suspicious of science and considered that it was still in need of philosophical critique: science continues to be inflected with many metaphysical notions.[74] These include the tendency to anthropomorphise—to see human traits and interests that we have "projected" into the world, and to imagine that they are objectively intrinsic to it. Following the old "highest values," we still tend to see the true, the good, and the beautiful in the world—they unconsciously filter our impressions and understanding. Writing of the cosmos, Nietzsche insists that "[n]one of our aesthetic and moral judgments apply to it."[75] The recent move away from ascriptions of order and disorder in thermodynamics can be seen in this Nietzschean light as a welcome move in breaking with anthropomorphism and aesthetic and ethical images of the universe. It can be understood as heading in the direction of a fuller "de-deification" of nature and preparing the way for a more intellectually honest appraisal of nature, on the basis of which a naturalisation of values, "beyond good and evil," might proceed.

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73 Frank L. Lambert, "Disorder - A Cracked Crutch for Supporting Entropy Discussions," *Journal of Chemical Education* 79, no. 2 (Feb 2002), 187. See also Evguenii I. Kozliak and Frank L. Lambert, " "Order-to-Disorder" for Entropy Change? Consider the Numbers!" *The Chemical Educator* 10 (2005), 24-25.

74 Nietzsche describes these metaphysical aspects still present in science as making it the latest avatar of the ascetic ideal in GM III.

75 GS 109.

5. Revaluing Values

Having critically questioned the way metaphysical values have been ascribed in thermodynamic concepts, I would like to turn finally to the question of revaluing values, of naturalising values on the basis of a de-deified nature. We may, I believe, take Nietzsche's attempts in this direction as provisional—as he was self-consciously aware, he was a product of his own time, and could only pave the way for such a revaluation. It is possible that some of the points raised above, such as the dissociation of entropy and disorder, already point towards a nature more de-deified than Nietzsche was able to think. Nevertheless, we can add grist to the mill of the argument that entropy should be affirmed if we consider what Nietzsche believed it *is* about existence that needs to be affirmed, and see entropy as expressing many of the same aspects.

While they are often used as short-hand terms for each other and run together in the literature and popular discussion, entropy (as we have noted) is the name for energy in a dissipated, spread-out, or "disordered" state, and the Second Law concerns the tendency of entropy to *increase*.[76] As we have seen, Nietzsche's criticisms revolve around the Second Law implying a final state. If, however, we take entropy on its own terms, there is abundant reason to associate it with notions that Nietzsche sought to positively revalue and affirm in his philosophy, in contrast to the Christian-Platonic tendency to devalue them: entropy may be understood as a principle closely associated with destruction, chaos, disorder, the irrational, the Dionysian, transformation, and becoming. Let me briefly outline a number of these associations.

First, we can see such associations in Nietzsche's cosmology. We can find the basis for the cosmology he prefers and affirms in his lectures on the Pre-Platonic philosophers from 1872–76.[77] This cosmology is essentially Heraclitus's, which Nietzsche interprets as a superior alternative to the image of existence presented by Anaximander ("the first pessimist."[78]) For Anaximander, the cosmos is characterised by Becoming and Passing Away: the fact of Becoming is presented as constituting an "injustice," which must be atoned for by Passing Away. (We can see here intimations of the Christian view of existence as guilty, and in need of redemption, and of Platonic metaphysics which devalues Becoming.) It is in fact Anaximander's condemnation of existence we encountered

76 Clausius's statement of the Second Law in the same paper in which he coined the term entropy is: "*The entropy of the universe tends to a maximum*" ("On Several Convenient Forms," 365), and in a widely used contemporary thermodynamics textbook we find one statement of this law as simply "Entropy tends to increase." (Daniel V. Schroeder, *An Introduction to Thermal Physics* (Oxford: Oxford University Press, 2021), 76).

77 Friedrich Nietzsche, *The Pre-Platonic Philosophers*, trans. and ed. Greg Whitlock (Urbana and Chicago: University of Illinois Press, 2006).

78 Nietzsche, *The Pre-Platonic Philosophers*, 37.

above, put by Goethe into Mephistopheles's mouth: "everything that comes into being, deserves to perish." For Nietzsche, Heraclitus's cosmology is superior because existence is portrayed as "innocent," with both Becoming and Passing Away presented as part of the same essential process of creation and destruction, likened to the play of a child, building sand castles at the beach and then smashing them for sheer pleasure.[79]

For Heraclitus, the process of Becoming and Passing Away is eternal, and the cosmos has no end which will not then spontaneously produce another beginning. This is indicated in several of the Fragments:

> 30. This ordered universe (cosmos), which is the same for all, was not created by any one of the gods or of mankind, but it was ever and is and shall be ever-living Fire, kindled in measure and quenched in measure.[80]
>
> 103. Beginning and end are general in the circumference of the circle.[81]

Among many other indications, the following unpublished note from May–June 1888 clearly demonstrates that Nietzsche was still informed by these Pre-Platonic notions while developing his late thoughts on cosmology using the notions of will to power and eternal return:

> *The new world-conception.*— The world exists; it is not something that becomes, not something that passes away. Or rather: it becomes, it passes away, but it has never begun to become and never ceased from passing away—it maintains itself in both.[82]

Thought in terms of Anaximander's metaphysics, entropy may be understood as the Passing Away, and heat death can be understood as the ultimate "recompense" for coming into being in the first place. This resonates with Hartmann's pessimistic argument for an end state to the universe, which he hopes will not begin again. Nietzsche, however, preferred the Heraclitean view because it presents Becoming as innocent.

Like the idea of Passing Away, entropy might be understood as a principle of destruction.

79 Nietzsche writes: "The Passing Away (ψθορα) is in no way a punishment. Thus Heraclitus presents a cosmodicy over against his great predecessor, the teacher of the injustice of the world." *Pre-Platonic Philosophers*, 63. For Nietzsche's riff on Heraclitus's theme of children's play, see BT 114.

80 In Kathleen Freeman (ed.), *Ancilla to the Presocratic Philosophers* (Cambridge, Mass.: Harvard University Press, 1948), 40.

81 *Ancilla to the Presocratic Philosophers*, 46.

82 WP 1066.

Now, destruction is a feature of existence that Nietzsche sought to revalue, believing that it needs to be affirmed as necessary, and as having a desirable (as well as a nihilistic) manifestation:

> The desire for destruction, for change and for becoming can be the expression of an overflowing energy pregnant with the future (my term for this is, as is known, "Dionysian").[83]

Nietzsche even presents himself and his work (in "thermal" terms!) as self-destructive and world-destructive:

> Yes, I know whence I have sprung!
> Insatiable as a flame
> I burn and consume myself!
> Whatever I seize hold on becomes light,
> whatever I leave, ashes:
> certainly I am a flame.[84]

Destruction is a necessary part of the process of change, and in a similar way entropy may be understood as an essential aspect of becoming. Entropy is a principle of process, change, and transformation, and thus the becoming that Nietzsche sought to affirm over the nihilism of static Being.[85] This association of entropy with transformation is strikingly indicated by Clausius's explanation of his coining of the term:

> [A]s I hold it to be better to borrow terms for important magnitudes from the ancient languages, so that they may be adopted unchanged in all modern languages,

83 GS 370.

84 R.J. Hollingdale's translation of the poem *"Ecce Homo"* in *The Gay Science*, put (back) into verse form here following Nietzsche's German original. Hollingdale, "Introduction," in *Dithyrambs of Dionysus*, trans. R. J. Hollingdale (London: Anvil Press, 1984), 10.

85 Gilles Deleuze emphasises this: "What nihilism condemns and tries to deny is not so much Being, for we have known for some time that Being resembles Nothingness like a brother. It is, rather, multiplicity; it is, rather, becoming. Nihilism considers becoming as something that *must* atone and must be reabsorbed into Being, and the multiple as something unjust that must be judged and reabsorbed into the One. Becoming and multiplicity are guilty - such is the first and the last word of nihilism." *Pure Immanence*, trans. Anne Boyman (New York: Zone Books, 2001), 84.

> I propose to call the magnitude S the entropy of the body, from the Greek word τροπή, transformation.[86]

From this point of view, to denounce entropy as the "curse" of the universe would be the very gesture of nihilism, negating the value of immanent existence because of its character as change, transformation, and becoming.

Conclusion

As we have known since Popper, even our best science should always be considered falsifiable and revisable. Moreover, as we have known since Hume, values (*oughts*) don't simply follow from facts (*is*'s). We "naturalise values," we stay true to the meaning of the earth, by following the best science of our times, recognising that we are *interpreting* not only the values on which we base the supposed facts, but the facts themselves. This is no excuse for denying the most plausible interpretations, and if, as seems to be the case today, we are largely constrained to admit the likelihood (if not certainty) of entropy, the Second Law, and their consequences, then we should certainly be able to affirm them. In the current scientific context, naturalism and life-affirmation decide in favour of affirming, rather than denying or decrying, entropy.

Philosophies of technology seem to have been particularly tempted by the naturalisation of values which valorises negentropy and demonises entropy. This is perhaps understandable insofar as the laws of thermodynamics emerged from the close study of the technology of the steam engine (rather than from initial observations of nature). If we care about naturalisation with an existential dimension, however, in philosophy of technology as in all philosophy we should make an effort to let go of the "naturalisation" of evil as entropy, which is an importation from the theological tradition. Instead, we should embrace the spirit of Nietzsche's philosophy, rather than the letter of Nietzsche's text, in *affirming* entropy. In doing so, it is helpful to emphasise those aspects of entropy which resonate with Nietzsche's ontology of becoming. We should affirm entropy, because it is becoming itself, life itself, and the consequences of the Second Law should be affirmed just as death must be tragically affirmed as a part of life. We will advance a long way in banishing the shadows of the dead God when we stop imagining demons in the very fabric of nature and learn how to live with it rather than imagining it as an adversary. And this, in a tragic spirit, involves affirming things that are difficult, things we are tempted to deny. It is high time that, in this spirit, we learn to affirm entropy.

86 Clausius, *The Mechanical Theory of Heat*, 357.

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Towards a New Industrial Revolution? Entropy and its Challenges

Bernard Stiegler, Maël Montevil, Victor Chaix and Marie Chollat-Namy

Translated by Joel White

Introduction

Below is a podcast and transcript of the interview concerning the 1st chapter of the book Bifurquer: Il n'y a pas d'alternative [Bifurcate: There is No Alternative] *on the scientific, technological, and political stakes of the notion of entropy. The discussion took place between Bernard Stiegler, Maël Montévil, Marie Chollat-Namy, and Victor Chaix, on the 1st of July 2020.*

More than four years ago, at the initiative of Bernard Stiegler and myself, Victor Chaix, the Association of the Friends of the Thunberg Generation (AAGT) held and recorded a discussion on the book *Bifurquer: Il n'y a pas d'alternative*, published a month earlier by Les Liens qui Libèrent.

This interview was intended to be the first of a long series on each chapter of the book. Between its main authors—members of the Internation scientific network—and young activists of the Association, in order to have an intergenerational dialogue and transmission, confrontation.

The book *Bifurquer* then served as a theoretical and scientific basis for the reflections and activities of the young Association, launched at the dawn of the year 2020. The aim of the interview was to highlight the political and economic issues at stake, in particular, through dialogue and collective reflection on the book's major theses. More broadly, we wanted to shed light on the key concepts of the book, using the format of an open discussion.

That's how Bernard Stiegler, Maël Montévil, Marie Chollat Namy, and I came together on the premises of the Institut de Recherche et d'Innovation and the Association, on this July afternoon, with the invaluable technical support of Riwad Salim and Giacomo Gilmozzi for the recording.

 Corresponding author: Victor Chaix, vchaix98@gmail.com

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Bernard Stiegler was president of both organisations at the time. He had edited the book *Bifurquer* alongside the Internation collective, which he had set up two years earlier. Maël Montévil, a researcher in theoretical biology, was a member of this interdisciplinary and international collective, as well as one of the main writers of the chapter we were going to cover in the book. He was also a PhD student under the supervision of Giuseppe Longo, who also contributed to the chapter and has taken the responsibility of president of the Association.

Marie Chollat-Namy and I were members of the Association, students of the life sciences and humanities respectively, and we were both activists in the ecologist civil disobedience movement, Extinction Rebellion.

It was our last meeting and discussion with Bernard Stiegler, before his death on 5 August 2020. We believe that his words are still relevant today, as is the philosophical, scientific, technological, and political project that he pursued during his final years.

After an overview of the current and historical epistemological framework of entropy by Maël Montévil, Bernard Stiegler continues the introduction by placing it in the context of the scientific and political project of the Internation collective. The discussion then continues with contributions and questions from Marie Chollat-Namy and myself. From Elon Musk to a sustainable and desirable political economy, from the imperative of efficiency to that of information theory, from the organisation of the living to the functioning of computers: the discussion was rich and sometimes difficult.

It comes at a time of intense reflection by Bernard Stiegler and the AAGT, around the Archipel Des Vivants project, which is intended to provide a concrete follow-up to the proposals in the book *Bifurquer* to set up "laboratory territories," as well as around the theme of theoretical computer science, on which the philosopher was working in spring 2020 and planning future events and publications.

Our approach to this dialogue is to not separate the scientific from the political, in the sense that one informs and orientates the other. Entropy, as much as it comes from thermodynamics, was a notion to investigate in its consequences for the living, as well as for our industrial economy and our relation to information technologies. For Bernard Stiegler, entropy was an understudied notion, as much by researchers of different disciplines and domains (beyond thermodynamics) as by the educational system. This discussion was as such a way to compensate for this "repression" of entropy, which he deplored to be mainly absent in spheres of knowledge and scientific circles, as much as in discourse by youth movements on climate and social justice.

Round Table

Maël Montévil: Today, we're going to give an overview of the first chapter of *Bifurcate: There is No Alternative*, which deals with science, anti-entropy, and exosomatisation.

Ever since Newton and the Industrial Revolution, science has played a central role in organising both society and production. The way in which it does this depends on the particular epistemology that constitutes it. The first epistemology that constitutes the relation between society and production is the classical epistemology that stems from Newton. This is a very specific epistemology in which equilibria are spontaneous and the world is fundamentally conservative. Nothing is lost, nothing is created, energy is conserved, and the laws remain the same as time advances. So, everything is very conservative. This epistemology was applied to economics, for example, with the idea that the balance of payments between states (Hume's idea) stabilizes spontaneously. And so, in this epistemological framework, there is no need for reflection: equilibrium is spontaneous and optimal.

With the industrial revolution, this type of conception was applied to the design of machines, machines that functioned spontaneously, spontaneously producing what had to be produced. In this situation, the worker becomes a proletarian in the sense that he loses his knowledge, because that knowledge is passed on to the machine, the knowledge that makes it possible to produce what we want to produce. However, with the industrial revolution came a scientific revolution: thermodynamics and the introduction of the concept of entropy. Thermodynamics was absolutely necessary to understand thermal machines, firstly steam engines, and involves entropy, which is a quantity that can only increase in an isolated system.

Increasing in an isolated system means that it defines a time arrow. There is a before and an after. And the laws are no longer the same if time is reversed. This scientific framework led to cosmological questions, i.e. the increase in entropy gave rise to the prospect of the thermal death of the universe. In other words, the idea that the universe is heading towards a gradual degradation until a situation where nothing can really happen. But the question of entropy has been very little integrated into economic concepts, which are still dominated by the concept of equilibrium and therefore a loosely Newtonian framework.

In mainstream biology, the question of entropy has not really been taken into account, although certain theorists, starting with Schrödinger, have considered it. The question that Schrödinger poses is how it is that living beings remain in a configuration of low entropy? If we look closely at the second law of thermodynamics, this is not a contradiction. Such a situation is possible because there are flows with the outside world. Entropy can only increase in an isolated system. In an open system, entropy can remain low or even decrease—if entropy is rejected on the surroundings.

However, the concept of entropy and low entropy is not sufficient to understand living organisms. Another industrial evolution has been initiated by the concept of information, which has two faces: on the one hand, computational information in the sense of calculation, as in mathematical logic, and information theory in the sense of Shannon, which describes the faithful transmission of the written message, for example. These frameworks radically changed the way society was organized, with the idea that intellectual activity would ultimately be information processing, by analogy with the computer and the transmission of information.

This has led to a second wave of proletarianisation, i.e. a loss of knowledge, in the sense that certain activities that used to be done by humans are now done by information processing systems, but also in the sense that the way in which humans now work tends to imitate these information processing systems. It's not the information processing systems or devices that replace humans because they would be equivalent, instead the two converge leading to the possibility of substitution. And this wave of proletarianisation is also taking place through the development of consumerism—consumer capitalism—where it's not just producers who are being proletarianised, who are losing their knowledge, but also consumers as such who undergo this process, whose activity is prescribed by marketing.

So, why is this informational framework inadequate for understanding living beings and then for understanding what we need to do in the face of the current crisis? In fact, this notion of information, which in a sense echoes Schrödinger's idea that living beings are characterised by a particularly low entropy (in the physical sense), is far too imprecise an idea. In other words, the entropy of living beings is certainly low, but living beings are also organised. In other words, the way in which they are configured enables them to survive; to reproduce and also to generate novelties that will become how their bodies then function.

So, by analogy with information theory, entropy alone does not describe the meaning of messages, it just describes the transmission of messages that have already been written. This means that a message that makes no sense can contain just as much information as a message that does make sense. As a result, a text written by a five-year-old, or even typed by a five-year-old, contains as much information as a play by Shakespeare.

Bernard Stiegler: According to this vision …

M.M.: According to information theory. But with this idea, I think, that information theory is basically designed to transmit, for example, a written text. And therefore, to transmit it faithfully. That's its problem. Its problem is not knowing in what way this text contributes to the fact that society functions, for example.

B.S.: In very concrete terms, this leads to the compression of messages, whether text messages or sound messages, image messages. Hence, this image compression then can, by eliminating a great deal of redundancy, transmit complex images across twisted copper wires.

M.M.: The counterpart of information is noise. Shannon's original work was on noise: how to transmit a message faithfully across a noisy channel. So, noise makes absolutely no sense, it can't play a positive role. Whereas in Darwin's biology, random variation allows, or at least contributes to, the emergence of biological organisations. So, it's not an adequate framework, it's a framework that isn't sufficient, but which can sometimes be operational. In other words, it can be deployed, but that doesn't mean it contributes to understanding. It allows you to make calculations.

To go further, I'd like to talk a little about the concept of anti-entropy, which we introduced with Francis Bailly and Giuseppe Longo. The idea is not to stay with physics entropy and its derivates, but to add another distinct quantity, even if it is linked to entropy, which is used precisely to describe biological organisation as such. The counterpart of entropy is the production of anti-entropy, in other words the production of novelty. With the idea that in the Anthropocene, many processes destroy anti-entropy, or even prevent the production of anti-entropy, i.e. the production of functional novelty.

B.S.: So, this work, which we started exploring a few years ago, first with Giuseppe Longo, six or seven years ago—that's how it started—was very much linked to the problems of automation. They led us, along with Maël who has just spoken and a number of other people, whom I won't mention here but who are signatories to this book or who helped write it, to take up questions that were opened up by Alfred Lotka in 1945. Earlier, in fact: as early as the 1920s, after Lotka had begun to approach these questions, let's say, in particular this idea of the evolution of human beings that would be different from that of animals, and therefore not subject to Darwinian natural selection. Lotka summarised this in a very short text, 20 or 25 pages long, which was read and commented on by Nicolas Georgescu-Roegen. Both were mathematicians who had emigrated to the United States. Both were interested in biology, but Georgescu-Roegen was an economist and Lotka a biologist. Georgescu-Roegen popularised a concept called the bio-economy, which in my opinion is based on a misunderstanding.

I'd like to repeat, rephrase, and summarise what Maël has just said. We say ... when I say "we," in this book *Bifurquer*, it's also a project—it's a book, but this book is a weapon with which to carry out a project. Well, a weapon, that's perhaps a bit aggressive. A tool, let's say, to carry out a project. And this project is to launch what we call "laboratory territories," which will experiment with development that is, let's say, sustainable, if not sustainable and compatible with a multi-level distributed economy.

The nano-economy is the domestic economy—when I do my shopping, I'm in the nano-economy, I save as much as possible, I try to buy the best products as cheaply as possible. If I'm a member of the "Thunberg generation," I try to come on a scooter or by bike rather than by metro, or even by taxi, etc. [laughs]. It's local, and it meets Schrödinger, because Erwin Schrödinger posited that the negentropy that living organisms generate [is temporary and local].

That's not exactly what Maël thinks either, because we're not completely in sync on everything. There are things we haven't fully explored to the end. But I'm one of those who believes that applying the word negentropy to physics is not acceptable. That the word negentropy should be limited to living things. Because otherwise we confuse order and disorder on the one hand, and entropy and negentropy on the other. And if we do that, we give credence to a vision of the generation of order through noise that comes from physics, i.e. Ilya Prigogine's dissipative structures, and which in my opinion brings nothing at all to biology. That's not to say that it doesn't do anything for biology, but ... I think it can be misleading.

I say this for a very specific reason: it's because Schrödinger, on the other hand, coined the concept of negative entropy, which was later transformed into "negentropy" by Brillouin. Schrödinger states very precisely that this negative entropy can only occur on a local scale. So, it cannot be separated from an organisation's relationship with its environment. A gypsy tribe that was at the heart of Bohemia 50 years ago and is now in Seine-Saint-Denis must surely have changed a lot.

This locality is conditioned by the surrounding environment. This is extremely important. It's extremely important because we're starting to find issues linked to the Anthropocene, to global warming, to disturbances generated by what I call anthropy [pronounced as "entropy" in French], with an "a" and an "h". It takes up the concept of anthropogenic forcing of the G.I.E.C. (which, translated into French, is "forçage anthropique") and it also takes up a certain definition by geographers of what we call anthropised environments, i.e. environments inhabited by human beings, which impose models of the human, of the anthropos, and that's anthropic with an "a" and an "h." [pronounced as "entropic" in French].

So, where Lotka is very important is that he has shown that all human beings are equipped with artificial organs. Without artificial organs, they cannot live. He's not the first to say this, Rousseau and Herder were already saying it, so it's not new at all. What is completely new, however, is that he, as a biologist, says: firstly, biology is a question linked to entropy, it's inseparable, and secondly, in human beings, the fight against entropy, i.e. the reduction of entropy, is also an increase in entropy, which can become uncontrollable. Why does it get out of control? Well, because, to take an example, one can increase the speed at which people move around with planes or cars.

The entropic cost of these goods is becoming unsustainable on the scale of the biosphere, which is a locality where, at a given moment, all the effects of the biosphere's locality are consolidated.

There is a very, very big problem here, and this problem has been called the Anthropocene since 2000, but the first person to describe it, in my opinion, was Vernadsky in 1926. Because we always talk about the Anthropocene era, and Vernadsky described the Anthropocene era, although this is not what he called it: he called it the technosphere. Obviously, if we cross Vernadsky with Lotka (in fact, in 1926 Vernadsky wrote, "Just look at what Lotka is doing, because this guy is going to say some important things," I'd like to stress that he said the same thing about Alfred Whitehead too), then the question facing human beings is one where they need to optimise their potential for neguanthropy with an "a" and an "h" [pronounced as "negentropic" in French], in other words, to fight against anthropism in the sense of anthropisation [pronounced as "entropisation" in French]. In other words, to minimise its entropic effects.

Why is this so? Because these organs, as Socrates said, are pharmaka. In other words, they are multi-purpose. You can use a book, for example, as Socrates wrote in the 5th century BC, to demonstrate a mathematical theorem, and this is how book culture began, in fact, as early as the 7th century BC, but books can also be used to dogmatise young Athenians and get them to do stupid things, to cultivate their thirst for power. In the same way, you can use a computer to increase your profits in a totally disproportionate way—I would remind you that the sophists were also people who wanted to increase their profits. At least, that's what Plato says.

Of course, computers can do amazing things: they can fight entropy, even anthropy with an "a" and an "h". But on one condition: that we prescribe what Lotka calls knowledge. Because what Lotka is saying is that the function of knowledge in human beings is to reduce entropy and increase negentropy. And even to make possible what Bailly, Longo and Montévil have called anti-entropy, but here I say it with an "a" and an "h", that is anti-anthropy.

What is anti-anthropy with an "a" and an "h," as opposed to neguanthropy with an "a" and an "h"? Neguanthropy with an "a" and an "h" is the educational institution, the family institution—everything that constitutes frameworks that are maintained, conserved and reproduced. And that makes anti-anthropy possible: the adolescent's revolt against his father, the slightly insolent pupil who will perhaps become Arthur Rimbaud or Charles Baudelaire, or I don't know who, Albert Einstein (you should know that Einstein was considered not to be a very good pupil, and that he was rejected, and 15 years later it was said that he was the greatest genius in the history of humanity, which is quite an excessive claim by the way).

So, what we're saying today is that we need to try and develop an economy; an economy—and here I come back to what Maël was saying earlier—that revalues knowledge and fights against proletarianisation. Why does it enhance knowledge and combat proletarianisation? Because Lotka says that only knowledge can reduce entropy. From there, we say: we need to deproletarianise economic activities, the activities of what we call producers, but also consumers, because consumers, as [Maël] said, are also proletarianised. For example, through marketing and all sorts of things, we can lead them to behave in an entropic way against themselves, without them realising the impact on their health, on their own wallet economy, and so on. And so, for us, this means that we need to produce a kind of new industrial revolution.

Maël began by saying that the industrial revolution of the 19th century was based on Newton (in fact, it began at the end of the 18th century). Hume was a Newtonian. All these people thought that Newton was the culmination of science, at that time, that's what they thought. They thought that, at last, we have achieved physics. That's what Kant said. In our opinion, this led to a kind of repression of thermodynamic entropy in the nineteenth century. Knowing that, of course, what is quite delicious in a way, and somewhat paradoxical, is that it was industrial development that made thermodynamic theory possible. It was through the observation of artificial organs, which Lotka calls exosomatic, that we discovered that entropy could be increased enormously. So, it was by starting with human activity that we then returned to the laws of physics. It's not by starting from physics. This is extremely important.

Then, as you said, Maël, in the twentieth century—for reasons that are still open to discussion, and which Mathieu Triclot has clarified in a really important book—information theory developed in the wake of computer science, even if it wasn't initially designed to solve computer science problems, but telecommunication problems, and therefore problems of optimising signal communication ("signal processing," as it's called in engineering). This led to a notion of entropy and negentropy, which is not at all bounded, because if we compare the different protagonists of this notion who were in dialogue and worked together, they do not agree on what entropy and negentropy mean (Wiener and Shannon do not have the same vision of things).

This vision, which we will call computational—because Shannon's vision is that we can optimise, through calculation, the limitation of redundancy, the limitation of noise and be able, for example, to compress the signal—well, this is what will become theoretical computer science, combined also with the visions which posit that the computer is a Turing machine. In other words, a computational machine capable of any type of calculation. The combination of these two things will produce a theory of entropy in the twentieth century which seems to us to be highly problematic, and which will also generate a great deal of confusion. Because it all started in the '40s (late '40s early '50s), and it was linked to intelligence.

Today we are told that the "great singularity" will mean that in 10-, 15-, or 20-years' time, computers will tell us how to solve the new mathematical theorems. I find this totally fanciful.

Dan Ross's book analyses this model in some detail, drawing on the work of Mirowski, who has done a great deal of work on information in economic models, particularly the neo-liberal model (especially through Herbert Simon and Friedrich von Hayek). This model—that everything can be transformed into information, that all knowledge can be transformed into information, and that all information can be calculated—is going to be imposed on every activity today. Medicine, transport, cooking ... everything! Bringing up children ... Absolutely everything.

We maintain that this model is extremely dangerous. Because it assumes that everything is calculable, it overlooks incalculabilities that are in fact inevitable. Personally, I think that the pandemic we are currently experiencing is a typical case of this. When you think you can calculate everything, you think you can get rid of masks, you think you can cut hospital beds: there are a lot of things that you can do. Similarly, you can reduce the budget of the Ministry of Social Affairs, and then, why not, the Ministry of Education, etc., and the army too. And yes, this includes the army too because they want to replace soldiers with killer robots (in addition to all the enormous ethical and other problems, such as the preservation of justice, that may arise). This is totally false.

Decision cannot be reduced to calculation—Immanuel Kant explained why. This is what

Whitehead later reiterated, based on mathematics and physics, and not just philosophy: decision is what always goes beyond calculation. And for a very precise reason: it's because human beings transform the world, not just interpret it, as Karl Marx said. When we transform it, we introduce an incalculable. This incalculable can be called Pablo Picasso, Albert Einstein, or Greta Thunberg. What we're arguing today is that all these issues require us to rethink the industrial economy.

What has just happened through the pandemic, the confinement and the economic catastrophe that all this engenders (which is colossal, and the extent of the catastrophe has not yet been gauged at all—no one has yet gauged it, because we don't really know how it's going to materialise, because it's global, so we can no longer separate China, Japan, North America, Europe, Africa, etc) this catastrophe is a catastrophe generated by proletarianisation. And we say that the theory of information and all those things have produced processes that should not be ignored, and which are sometimes extremely effective.

This technological efficiency means, for example, that a number of things can be robotised, tasks can be eliminated, or tertiary services can be replaced by consumer behaviour that is "cookised"—with cookies that ultimately trigger stock replenishment operations, or all sorts of things of that kind, all of which means that, for example, the OECD says that in the next 20 years, 16.6% of jobs in France will disappear. So there's a very, very significant reduction in employment.

That was before the COVID crisis. And we say that if you want to make people solvent, you have to redistribute productivity goods. And the question is: what criteria? We say that it's not enough to redistribute, for example, through a universal income, even if we're not against a universal income as long as it's not one that immiserates, as long as it's not lower than the minimum social benefits already offered, which is what, unfortunately, those who revendicate it are actually advocating... and above all we say that we need to pay for knowledge outside of the workplace. In other words, more and more people are going to produce knowledge outside their working hours, as the intermittent entertainers do.

Why do you want to do this? Because when you're not working, you're in anti-entropy. When you're employed, you're in neganthropy with an "a" and an "h". In other words, you're serving a system, you're maintaining the system, and that's fine. But what will produce knowledge is anti-anthropy with an "a" and an "h". This is the thesis that Marie will soon be defending, for example, introducing things that didn't exist before, in other words what we call novelty. From there, we need to try and rethink (this is what we develop in Chapter 3 of *Bifurquer*, in great depth) the accounting models, the qualification and quantification of value and wealth. To put in place a working method, which we call contributory research, so that all kinds of stakeholders—today we are starting to work with farmers, fishermen, and people involved in tourism too, in an island context that is across a group of islands—so that all these stakeholders can optimise their activities, for themselves, for their own interests. And not against the planet, and by integrating the whole question of entropy, which we call sustainability.

I'll finish by saying that we're all—well, more or less—very impressed by Google. Firstly, in the 20 years that Google has been around, I've been amazed by its advances. Even Amazon, which I detest. I hold Google in high esteem because I use it every day. Amazon is becoming more complicated. But in any case, I have great admiration for this structure. I have great contempt for Facebook because I think it's extremely trivial and beastly. But what I'm saying is that if it's growing, it's because it's efficient. And if we ever decide to ignore this effectiveness, the efficiency of these technologies, for example, by saying that we're going to defend French-style public services, and that we don't want this efficiency, then the French-style public service will collapse. We have to make this efficiency our own. And to make it your own, you have to criticise it. In other words, we have to point out its limits.

It's an efficiency that neglects what Aristotle, or even Immanuel Kant, called finalities. And that's not what we call finality today. That's the language of telos, with the Greeks, dating back to the fourth century, with Aristotle. We now call it sustainability. There is finality in living things. It was Kant who first understood this: in what is known as the Third Critique, the Critique of Judgement, Kant understood that living beings embody a finality. And that is very, very important.

A catastrophe occurred with what is known as neo-Darwinism, which led us to believe that we could eliminate the question of finality, that all these stochastic processes of natural selection could allow us to dispense with this question. But this is not true. What is true is that, like Jacques Monod, we have to try to do without finality, because at the beginning finality was God, in Aristotle as in Kant. So, let's try to do without God, without a transcendent finality such as that ... and they try to find such a finality in probabilistic computational models. Monod said: let's look at the organism as a teleonomic system. But it's not just a teleonomic system. In other words, there is a consolidation at the level of the biosphere which means that, at a given moment, the human being is not simply an organism, but an exorganism. They have to engage in politics, they have to engage in economics, they have to produce works of art. They have to bring up their children in a way that no one else can. And that is absolutely singular and it's a singularity of purpose that can't be reduced to teleonomy. So we need to reinvest in this question of finalities, and finalities are what are produced in knowledge.

When I say "knowledge," let's be clear: for us, knowledge doesn't necessarily mean passing a thesis, a competitive examination, or an *agrégation*. Knowledge is knowing how to cook, how to cultivate a garden, how to bring up a child, how to take a car apart and put it back together again. It's all this very empirical knowledge. And it's also knowing how to live together. In other words, what we call cultures. Knowing how to be hospitable, all that ... And hospitality, I don't know, in Morocco is not at all the same as in China. But there is hospitality in all civilisations, just not in the same way. And we're not very hospitable.

If we're not very hospitable, it's not because we're bad people, it's because we've destroyed the knowledge that used to be passed on. Like knowledge of commensality, for example: we no longer know how to eat together. If you read Zola's *Germinal*, you'll see that they still know what hospitality is. This is also the theme of another novel that has been turned into a very famous film, called *Babette's Feast*. So that's what knowledge is, it's something fundamentally generous and in science it's the same, the great mathematicians are generous. They don't defend their little careers, ...

M.M.: Great chefs too, by the way...

B.S.: And great chefs too, of course, when they're not overly mediatised and proletarianised, like scientists, for that matter.

Victor Chaix: It seems obvious to me that we need to rethink the current economy, which is totally ill-adapted to the challenges of the Anthropocene. As is well described in chapter 1 of the book *Bifurquer*. Nevertheless, in relation to what [Bernard] just said, in relation to the fight against entropy, it seems to me that in its physical sense, there seems to be a limit. Given that entropy can only increase in an isolated system, in its purely thermodynamic and physical conception, what does it mean to fight entropy economically if it is bound to increase thermodynamically?

B.S.: It means making sure that the human species lasts as long as possible. It will disappear anyway. You need to know that. It will disappear like the sun disappears (the cooling of the sun: Hubert Reeves became very famous for this in *Patience dans l'azur*). So, your question is very important.

Elon Musk says: we have to leave. We have to get off the Earth. He doesn't say why, but it's because some people in Silicon Valley are building themselves floating islands 22 kilometres off the coast, because they're outside American law, they don't pay tax, etc. That's Peter Thiel. They say: we have to leave, we have to move to Oceania, and so on. In any case, people are all going to kill each other, they're all going to die of COVID, and so on. That's really what a number of people (not all) are saying, and it's been written down.

Musk is more likeable than that, I think. I like him because he's depressive! [laughs] So, like all depressives, he's cyclothymic. So, one minute he's saying we need to conquer Mars, and the next he's on TV saying: I'm getting high because ... well! And his shares plummet [laughs] and his shareholders say, "he's completely out of his depth." But he's brilliant. He says, we've got to get off the Earth. He says the same thing as Hubert Reeves. Hubert Reeves says: at some point we have to migrate. And to colonise the Moon (there's a project in China attempting to do this), and then Mars and much further afield too. And that will take thousands of years. But on our scale, on the scale of evolution, it's a very short time.

Why do I say this? It's because this question of non-sustainability, in the very long term—not only on Earth but in the solar system—is a scientific question. It's not at all a rant by a fortune-teller or whatever. It's not a doomsday prediction or anything. That wasn't the case until thermodynamics. I pointed out that this was the cause, in my opinion, of Friedrich Nietzsche's nervous breakdown. When he discovered Thompson's positions, he had a breakdown that lasted 2 or 3 years, and he cured himself by writing Thus Spoke Zarathustra.

What I'm saying is that we have to stop being in denial. We criticise Trump for being in denial, we criticise the boomers for being in denial. And we're right, but we shouldn't be in denial ourselves. Entropy is increasing, and at some point, we must also have the modesty to know that we can hardly anticipate more than a few decades. Anticipating in the sense of making decisions and trying to build things. That's what I mean by that. Not theoretical models, because theoretical models are always just theoretical models. They are never practical models. They can feed them but...

For me, the big political economy question is between those who say: "There are those who say, as we do, and I say this very specifically to Elon Musk: "you won't actually leave Earth because your rocket depends on the ground segment anyway." And before a rocket can do without a ground segment ... The ground segment is the name given in the space industry to the Cape Canaveral base.

We worked with the C.E.A. [French Atomic Energy Commission] on the ground segment, and before we can do without a ground segment ... [laughs] it's not going to happen any time soon! It might be possible once we've colonised the Moon or Mars. I'm not ruling those things out at all. I'm neither for nor against it, but I don't rule it out a priori. On the other hand, we do maintain that if we don't reinvent a sustainable economy ... but sustainable means for a certain period of time. Not eternal. Eternal is ... you have to go to the Pope for that. Or an Imam or whoever, but... [after all] why not, because having the ability to eternalise concepts can help people to do very good things. I've got nothing against it, at all, religious models, which help people to live. But scientifically, man will disappear from planet Earth and very probably from the universe as a whole.

If there is anything left to inherit from man—and from living beings, I would say, more generally—then I have no idea what it will be. There are, of course, then the transhumanists, who are trying to talk about hyper, hyper-acceleration—you could even call it archi-acceleration—in other words, much more than hyper-acceleration. What for? To take control of the exosomatisation on Earth, if need be, and not at all elsewhere, in fact. That's marketing. Very ambitious, a little delirious at times, in my opinion, but it's essentially marketing.

So, to come back to your question, which is a fundamental question, and a difficult one ... we have to mourn the loss of eternity. That's definitive. Arthur Rimbaud already said it, and it's nothing new. In any case, in physics. As for theology and all that, I leave that to people to sort out. But I have a lot of discussions with theologians. To make an economy, an economy that would be an economy of sustainability, and to ensure that there will still be human beings on Earth in 10,000 years' time and living beings, etc., well then, we need to build an economy of neguanthropy, but neguanthropy will never eliminate entropy.

Then there's a movement called the extropians, who claim that man can escape entropy. That, for me, is totally crazy. I don't know what you think [Maël]? It's a model that has developed in astrophysics: there have been astrophysicists who have fuelled this discourse to some extent. But for me it's completely fanciful.

M.M.: There's one thing I'd like to add—this is just one example of physical entropy, but it's related to another neguentropy, which is interesting because it's also relatively simple—and that's the question of minerals. This is dealt with a little in the book. Because, for example, we talk about peak production for minerals, but in fact minerals such as copper, phosphate, etc., are fundamentally conserved. So, they cannot be destroyed. They are destroyed, but in the very long term, with the increase in entropy, but that's hundreds of billions of years away. So, they are preserved.

What does it mean when production peaks? It means that there are pockets where they are concentrated. Therefore, it's feasible to extract them, but in fact these pockets don't appear spontaneously, because spontaneously it's the maximum of entropy and therefore the maximum of dispersion. They appear thanks to the movement of volcanoes, the Earth's geological movements. This is what will lead, quite accidentally, to concentrations of these minerals in certain places. Which we come to exploit, which we come to reconcentrate again, every time we produce entropy on Earth.

The Earth's movements also produce entropy. But it also produces concentrations like this. So we concentrate them even more, we use them to make things. And the question is: what happens next? If we disperse them completely in the environment, we increase entropy. Given the distribution of these elements on Earth, we'll very quickly find ourselves having to generate an enormous amount of entropy in order to have more of them, to extract areas where they're less concentrated, and so on. So the idea, as we all know, is to interpret these processes in terms of entropy so that they don't disperse. The aim of recycling is to prevent the dispersal of ores in particular. So this is a good example of how it works. Bearing in mind that the extent of the concentration of these ores, for example, the concentration of rare earth, etc., depends on a perspective that comes from the objects we are trying to produce, so it's relative. It's a question of perspective. The relevance of the low entropy of these minerals is entirely a question of perspective. So is the relevance of their dispersion.

Marie Chollat-Namy: You talked about the current framework, which is based on a Newtonian vision governed by calculation and at the same time poses a lot of danger, but on the other hand it also has a very effective function, which has succeeded in producing everything we know at the moment: the telephone, all that... Now, faced with the problem raised by the Anthropocene and the ecological crisis, wouldn't something effective, like this vision, be effective, precisely, in combating the ecological crisis, and in this case, would there be forms of calculation that could combat this crisis?

M.M.: So, this efficiency is analysed, albeit very schematically, in two dimensions. One dimension is that it is effective, but because it produces an enormous amount of entropy. So, its effectiveness comes from its destructive nature. Facebook, for example, falls into this category. And there's another dimension, where efficiency can be hijacked to be anti-entropic. So, the idea is to divert it, to mobilise it for this purpose.

B.S.: In other words, to criticise it. Immanuel Kant is considered to be the founder of modernity-modernity, if I can put it that way. Because we say that there is Descartes who founded modernity, who made Newton possible and all that. And then there's Kant, who built the epistemological framework of modernity, let's say industrial modernity, the modernity we're going to know, in which we're still more or less. And what does Immanuel Kant say? He says that criticising doesn't mean denouncing at all, it means stating the limits. There are limits, and Newtonian physics also has limits.

I often use an example when I talk to journalists about these issues. I often say: look, every aircraft has to be certified. It's important to know this, if you want to put all the scientific bodies in the air. As a result, there are no crashes—well, there are still some, but given the number of aircraft flying, it's absolutely incredible that there are so few accidents (although with drones, it's starting to get very complicated). But why is it like this? Firstly, because of certification, and secondly, international civil aviation legislation is extremely precise and extremely restrictive.

When you produce a new model of aircraft, it has to be certified. Boeing, you have heard, had a problematic certification. It's a bit like the Lancet affair ... it's extremely serious because it discredits the certification bodies. And in principle these bodies are very serious, they are engineers and physicists (I'm talking about aircraft). For medicines, they are biologists, pharmacologists, or medical doctors. Today, if you submit the A380 for worldwide certification, it is certified. It has the right to fly. Because you take Newton's physics. But if you take thermodynamics, it shouldn't fly. Because it destroys its conditions of possibility. Why, you ask? Because it consumes so much fuel and causes so much pollution that it will exhaust all the conditions under which it can fly in the very short term. You could say that it's no big deal, that it will pay for itself in 30 years anyway, except that means that there are no more planes that can fly after that. So it's the death of aeronautics.

What I mean by this is that, of course, Newton is not dead. We are not at all saying that Newton is dead. Newton was a great scientist. Nobody has ever said that Newton was wrong. We're saying that he's no longer good enough. In other words, the principle of inertia and gravitation are two principles that are still used in aircraft certification, of course. They are Newtonian. Newton came up with them. After that, Newton didn't foresee the questions of thermodynamics, which he didn't ask himself. Now, what an aeroplane does is to articulate the laws of Newtonian physics with the laws of thermodynamics, except that it articulates them negatively with the laws of thermodynamics. And since we don't certify them, we can't see it.

What I mean by saying this is that we are not at all opposed to calculation. At all, at all. You have to calculate. Nothing can be done without calculation. Even playing football. Even a guy who plays football doesn't make rules of three, he doesn't do calculations, he doesn't have rules to calculate: by simply playing, his body calculates. In other words, his eye, with his muscle, his foot, etc. are making calculations that are encoded in his body, that are embodied. It calculates, it's always calculating. It's just that living beings cannot be reduced to calculations. Living things calculate all the time, and natural selection is a form of calculation. It is stochastic, and the neo-Darwinians are right on this point. But that's not enough to say what living things are.

So, if you want to fly an aeroplane, which is an exosomatic organ, you have to integrate calculation, Newtonian calculation, but also thermodynamic calculation, but also biological calculation. I say thermodynamic + biological + critical information theory.

And these are all theories of calculability, so we're not at all saying that we should reject calculability or efficiency, quite the contrary. But efficiency must be subject to purpose. That's the big question. What are the libertarians in Silicon Valley saying today: we're much more efficient than Washington, so let's do away with the state. In fact, they are carrying out the neoconservatives' programme with extreme violence. And they are effectively ridiculing public power. But why is that? It's because public power hasn't got to grips with the issue itself.

Mr. Macron thinks we need to create a start-up nation. It's not certain that this will work very well. We don't believe that. We need what I call a new critique of political economy, which means building a new epistemology of industrial society, which for us is not post-industrial. It will remain industrial precisely because ... and what does industrial mean?

It's what formally inscribes the calculation. In other words, the person who transforms everything into an equation and so on. Before industry there were craftsmen, who did absolutely incredible things, often of a much higher quality than industry. They do things intuitively, empirically, not by calculation. There are exceptions, like Leonardo da Vinci or people like that ... But these people prefigured what would later become exosomatic production based on calculations. Which allows for economies of scale. Economies of scale are very, very important.

What do they achieve? Sometimes they enable us to optimise the food supply for human beings, thus combating hunger and so on. Not everything in this model should be condemned. I think that today it is condemned—it condemns itself. But it's a fact that rationalisations have been made. Even if I'm not necessarily a fan of pasteurisation. Pasteur made some very important contributions. All that was based on calculations, formalisations... we're not rejecting science at all, on the contrary, we're saying: we need to redo science. Because today, on the other hand, industry is no longer doing science. It uses scientific models to transform them into tools, without taking into account what every scientist does, which is theory: the theory of its own limits, otherwise it's not science. Today we practise pseudoscience, but it is not science, it is the use of scientific models.

M.M.: In fact, the limits of predictability and therefore of calculability were discussed and introduced by physicists and mathematicians quite early on. For example, at the end of the 19th century, Poincaré showed that we could not predict the stability of the solar system, because it is a chaotic dynamic. This is the butterfly effect before its time. A small disturbance can have huge effects.

And that's in a deterministic framework. We can't predict. In the same way, part of the birth of computing is Gödel's theorem, with a similar version by Turing, which shows that there are propositions that can be written but that cannot be demonstrated, in the sense of being demonstrated by a computer (which didn't exist at the time). In other words, the computer makes it possible to calculate the fact that there are things that it cannot calculate. And yet they are well formed. I don't know if that's very clear ... ?

M.C-N.: It's simply a question of uncertainty.

M.M.: It's the undecidability.

B.S.: It's not exactly uncertainty in the sense that Prigogine, in any case, talked about it.

M.M.: In fact, the computer is largely the result of questions that arose in mathematics. These questions arose because there were contradictions. In other words, people who thought they'd proved theorems, then went on to find counter-examples. All mathematics collapse if you find counter-examples. So, they tried to find new foundations for mathematical practice. And the foundation that was explored was potentially mechanisable logical reasoning. So mathematical proofs would have to be a logical sequence, that a machine could reproduce. This gave rise to Hilbert's programme, which aimed to transform geometry by reducing it to logic (Boolean logic, i.e., with zeros and ones).

What Gödel showed was that, in fact, when we do this, we can state propositions that are neither demonstrable, nor the opposite of which is demonstrable. You can't decide them. Nor can we demonstrate that there is no contradiction. In doing so, he invented coding, the idea of coding theorems with zeros and ones. That's how he proved it. Then we coded all sorts of things, we coded texts, we coded videos, we coded images, sounds and so on. It's all based on a negative result. And the current tendency is to forget that, including in the training of people who do theoretical computing and the idea that you can do anything by calculation. Without any limits.

B.S.: These are questions we'll be coming back to in Arles. In the seminar on theoretical computer science.

V.C.: With regard to your question, Marie, about efficiency, and to come back a little to what Bernard was saying about the question of purposes ... in fact, it seems to me that the question is: How can we divert efficiency, which is indeed very efficient and works well, so that it serves interests greater than just efficiency. So that it has some purpose other than itself. When Bernard said that the original purposes were mainly theological, that the purpose was once God, it seems to me that today, in the context of the Anthropocene, the primary purpose is to maintain life. Both human and non-human life. So, at this point, diverting efficiency so that it serves life...

B.S: I'd say adopt efficiency. Diverting it, yes, in other words, diverting the research that Amazon, or I don't know who, is doing—all these people are efficient for a reason, because they know how to manage their programmes in a pretty impressive way. Of course, you have to divert, but above all you have to adopt. In other words, you have to integrate.

V.C.: Practice?

B.S.: Not just practice ... theorise. They don't theorise. They don't bother with theories, which is why Anderson says [that we've reached] the end of theory, that we don't need theory anymore—he doesn't bother with theory any more. He thinks it's a waste of time. And they're absolutely wrong. Because to stop theorising is to make a mockery of sustainability. It means what it means in concrete terms. But we need to go back to the adoption of efficiency. The current efficiency of what we call information technology, and digital technology in general, which is ultra-efficient, and which is in fact computing everywhere.

It's the programme of mathematical physics generalised to absolutely everything, and it dates back to the seventeenth century. So, it's not a new thing at all, but they've managed to do it. By throwing [religion] out the window, on the pretext that we need to get rid of God, and I think they're right. The greatest scientists of the 20th century were often believers, and they said the same thing: in science you don't need God, you do without. In church, yes, but not in science. But this efficiency is the efficiency of an exosomatic extension of understanding, in the sense of Immanuel Kant. In other words, the analytical faculty. In fact, calculation is analysis, it's a way of analysing. And in analysis, well, there are formal analyses, i.e. I'm going to put all this into an equation, or I'm going to make calculations, measurements ... and then there are totally empirical analyses: a bricklayer, for example, he also calculates a bit, he has a square, and that is all he has...

M.M.: The Pythagorean theorem.

B.S.: He uses the Pythagorean theorem a lot. He doesn't know how to demonstrate it, but he uses it a lot. But then he's very fickle about a lot of things, you see. Nowadays, they calculate for a certain number of resistance problems and all that, because there are insurance obligations, ten-year guarantees ... well they've learnt to integrate a certain number of things, they have software for that, too. But they don't calculate, they don't really analyse at a given moment, they decide on a whim. And that's what we'll call the art of the bricklayer, in other words his craft.

In industrial construction, we're working on it right now in Seine-Saint-Denis—it's completely different, everything is calculated in BIM [Building Information Modelling]—

and this calculability today tends to replace any decision. So, what I believe is that we need to adopt efficiency, and that means re-politicising the economy, and saying that the economy cannot erase politics, and that politics is not Donald Trump, it is not Emmanuel Macron, it is not Putin. It has to be reinvented. In fact, it's the art of deciding collectively, by developing knowledge and integrating people who don't necessarily have mathematical knowledge, but who aren't idiots for all that.

V.C: So ... in order to re-politicise the economy and in a sense also save entropy, in relation to the aircraft you mentioned and the certifications, the legislation that governs aircraft today, which means that at least in the short term of an air journey, we are significantly protected from accidents and death ... I was wondering whether, in this desire to legislate on efficiency, to save entropy ... there should also be some legislation and criticism of air travel, for example in relation to domestic flights. For example, concerning the Extinction Rebellion movement (in which Marie and I are involved): last Thursday they blocked Orly airport with regard to domestic flights. Which doesn't mean banning planes, but criticising the absurdity [of domestic flights], in the sense that it increases entropy, or at least paraffin, when you could just as easily take the train for almost the same amount of time.

B.S: Of course. And you see, I totally agree with that, absolutely agree. What's really important now is that it's the local people who take the decisions. That's why I say repoliticise. And we say, we need a political economy based on contributory accounting. If, at some point, the people of Nantes, for example, had been led to adopt a contributory economy, Nantes airport would never have been built. So I'm not at all against the idea of limiting speed on the motorway to 110 kph. Not at all, not at all.

So, in any case, what's very important is that it's the residents who take these decisions and who take them consciously, as we say. In other words, with instruments that enable them to make decisions by really weighing up the consequences and making choices. Bear in mind that Maël said earlier that there is indecidability in mathematics, and every time we have to make a decision, it's because there is indecidability. In other words, at some point you have to make a decision. And we're not going to decide with maths. You have to decide, you have to make a decision. And so, I say this because political economy is what returns the question of decision-making to human beings, and not to calculus.

Who decides today? It's the financial markets, the stock exchange, and so on. And that's a disaster: they make all the decisions. So we think we're making decisions, but we're not making them anymore. Of course we do, in a certain sense, but the decisions taken in these contexts are infinitely more effective. So what we're trying to do—along with you, incidentally (we're in complete agreement on these things, for example stopping planes when they're not essential)—is to say: above all, we need to create the economic models that will enable people to decide. Including small businessmen, who say to themselves "oh, if there's an airport, I could do it," and these same people then realise, when they do their calculations properly—but taking entropy into account! [laughs]—that in the end it may not be as obvious as all that. In the end, he is much closer to the Gilets Jaunes than imagined. And the Gilets Jaunes themselves realised that they are closer to the ecologists than they first imagined. By discussing, deliberating … it's the deliberation that does it.

M.M.: Perhaps one way of moving in that direction is that in physics, among the sciences of nature, I mean, the question is first and foremost always: what calculation should we make? What is the right calculation to understand a situation, to predict if we can. What can we predict? And so there are conceptual changes when we can't predict: for example, chaotic dynamics - we move from predicting the trajectory to predicting the attractor, in other words, what happens when we look at the trajectory over a very long time. What is the domain covered, etc. So the question of what calculation to make is not one that cannot be resolved by calculation.

B.S.: Of course, this decision cannot be calculated.

M.M.: And to come back to what is being done, for example, in the use of Big Data and what Chris Anderson is proposing. There is some bad theorising going on. But there is still this kind of work being done, bad theorising, in the sense that there are mathematicians, for example, or physicists doing statistical physics. But these scientists carry out their analyses within a very reductionist framework, i.e., one that posits hypotheses that are not criticised by them. And they don't engage in dialogue or deliberation around these hypotheses. This is reductionist in the sense that they just look at how to get things out of the data, and they don't look at all at the consequences this has for society. So they have a very partial vision, which is also political: in other words, they choose to make this calculation rather than another.

M.C-N.: And since you explained that entropy cannot be calculated, cannot in fact be measured, how can it be taken into account in calculation models?

M.M.: Well, entropy in the physical sense is not measurable in the sense that you can't use something like a thermometer to measure it. But it can be calculated. On the basis of other variables.

B.S.: Measurement and calculation are not quite the same thing.

M.M.: Measuring means putting in an instrument and getting a number. In fact, it involves commensurability between two objects. Calculating, on the other hand, means looking at several things and having to make a calculation too say: there's been this change in entropy. But for entropy, in physics for example, you need to know how much heat has passed from one object to another, and at what temperature. That's the basic trick in physics. Now, thanks to computers, there are other methods of calculation and another link with measurement. When I talk about temperature and heat, for example, from a distance it's very macroscopic. From a microscopic point of view, there are things moving all over the place, particles ... whereas in physics, if there are too many of them, it's not possible to measure. There's a thought experiment with ping-pong balls in space, for example. There, we can follow each particle, and so we can make a calculation about what these particles are doing, based on the observation of their individual trajectories.

B.S: There are many, many misunderstandings about these questions of entropy. There are also disciplinary presumptions of the word. For example, there are physicists who say, entropy is a physics problem, full stop. Leave us alone. Mind your own business. We don't think that's true. After that, we also think that the translation of Boltzmann's probabilistic models into other fields, such as biology and information, for example, is very problematic.

In other words, it's an open project. If I were in charge of, I don't know what, if I had the means, I'd say: I'll put a billion into this. That's the challenge of the century. Of the 21st century. And there are plenty of people who don't agree with each other at all. Physicists, biologists, mathematicians, computer scientists, economists, everyone is getting involved. But there's a reason for that. It's because some people are talking nonsense. One minute they were talking about order, the next about chaos, the next about organisation. I think that Edgar Morin has played a very, very harmful role in this area. He turned scientific questions into sometimes almost poetic essays and that was that. I say Morin because he's the best known, but there are many others. And that's very important to bear in mind.

What we are talking about is not a constituted field of knowledge. It's a field in the making. We're not saying: "We're going to explain..."—we don't know. There are lots of things we don't know. Or we don't even agree on: there are disagreements, and these are disagreements between very good people, very serious people, very rational people—these are legitimate disagreements. It's not like the Lancet and I don't know what. These are not polemics, they are controversies. But here, the question of vocabulary is extremely important. So we don't use the word chaos to describe this kind of thing. There are chaos theories, which we need, but that's not what we're talking about. That's why I say that.

And the word order, well, just to clarify, because Ilya Prigogine played a very important role, he's a great scientist Ilya Prigogine. He worked with a philosopher called Isabelle

Stengers. They wrote a book which, at the time, was one of the books of the year. It was called *La Nouvelle Alliance* [*Order out of Chaos*]. The idea was that we were going to reunite knowledge from mathematical physics to philosophy, biology and all that, we were going to reunite everything through the concept of dissipative structure. And that was completely problematic. For the reasons Maël mentioned earlier.

M.M.: Just to emphasise a little because I haven't really described physical entropy itself, which is a starting point, but it's important to describe it well. The idea is that you have a system that is separated from its exterior, not necessarily physically separated but virtually, say, for example, this box here. This system is coupled to its exterior, macroscopically, on a large scale. And the idea is that for a given macro description, there are lots of microscopic possibilities that correspond to this macro description, and this is Boltzmann's entropy that I'm describing.

The idea is that a system will spontaneously move towards a situation that is compatible with its constraints and corresponds to as many possibilities as possible. Why is that? Because it's just a probability, in fact. That's all it is. So, for example, if you toss a coin lots of times, the most probable situation is the one that corresponds to the higher number of possible outcomes of the coin toss, and it's the one where, on average, you get about 50% heads. And the idea is that when there are lots of quantities like that, there's a really big difference in frequency between the most likely situation and the others. So, what the system will do spontaneously is move towards this state and then it will stay there because the probability of it getting out is less than 1 in the lifetime of the universe, for example. That's just it, the increase in entropy means moving towards the most probable.

M.C-N.: So, regarding the idea of a negentropic industrial revolution, how would it be sufficient to meet all the challenges of the Anthropocene, and, in particular, how could taking entropy and negentropy into account protect biodiversity?

B.S.: That's obviously a very good question, and it's at the heart of the problem of moving from a relatively small locality to a relatively large locality, i.e. one that is less local. This is what we call the "new industrial revolution," so that we understand each other. For us, industrial doesn't mean smoky, coal-fired or whatever, like the industrial society of the 19th century. Nor does it just mean the platforms that exploit the labour of Uber drivers. For us, industrial means knowing how to scale up, to change the scale from nano to micro, from micro to meso, and from meso to macro. I also say meta-economic, but that's for myself [laughs].

What do I mean by that? It's a very important political issue. I'm going to say again something that we haven't really talked about, but which is a subject that was discussed at length in the working groups that prepared it. At the time we started talking about these issues, the Front National was launching its localist programme. It was in 2019, on the first of May 2019 in Metz, Marine Le Pen was launching, based on an economist who was an adviser to Raymond Barre by the way, I can no longer find his name ...

V.C.: Hervé Juvin?

B.S.: Juvin, that's right. By relying on Juvin, who is an economist, published by Gallimard and all that—he's not just anyone. For a long time he was considered an authority. Since then, he's been a representative of the Rassemblement National, but he's not a member of the Rassemblement National, which is a strange position to be in, well ... he's a Member of the European Parliament. They have launched their localist programme. And we say, if you want to fight Lepenist localism, you have to go back to science. Because they never talk about it—I've read Juvin's books, he never talks about entropy, he never talks about the subjects we talk about. He never talks about questioning the accounting models of capitalism. As you well know, moreover, in general fascists, Nazis, and the far right are in fact people who are there to help capitalism maintain itself—a certain type of capitalism. Take Heinrich Böll, for example: you need to read some of the novels he wrote about the links between German capitalism and the Nazis. I'll stop there. They were novels.

What we are saying is that a new industrial revolution is first and foremost one that will exploit very high-speed networks. It's what's going to exploit all these new dimensions without necessarily completely abandoning transport and all that, because there's a need for transport and it's going to rethink exchanges. Today's scandal is green beans from Kenya, for example. If we counted the price of the green beans in question in CARE's accounts and using our accounting models, they would be €70 a kilo. Because it's the cargo planes that make the most money from this, and the supermarkets. Kenyan farmers are getting their backsides kicked, and French consumers could eat frozen French green beans, which would be a lot less catastrophic—it's not great, but it's still a lot. Because frozen green beans from Brittany are very good ...

The big question today, when we have 8 billion inhabitants (not quite), 4 billion of whom are connected, is: How do we ensure that this state of affairs, a connection of 4 billion inhabitants, becomes a producer of negentropy and not entropy. When I say neguentropy producer and not entropy producer, I'm lying, because as we said earlier, we only produce neguentropy when we produce entropy. Whether the balance sheet is better, that's the question. We need to improve the balance. If we want to produce biodiversity. Biodiversity doesn't just have to be protected; it has to be reactivated. We need to repollinate.

If we want to develop this, we need to reintroduce what we call noodiversity, i.e. highly differentiated knowledge. This knowledge needs to be combined with the means to achieve economies of scale, which are powerful tools. For example, a very high-speed line that uses fibre optics and is capable of transmitting information to 200,000,000 km/s. A third of the speed of light. These are industrial resources, and we need them, just as we need all kinds of things. But the problem is that today, the needs we used to have, which were really vital needs, have been transformed into needs for speculators ... mass tourism, for example.

So the question is to make a new industrial revolution (I come back to what I said earlier about rethinking theoretical computing) by integrating everything we've just said. We're saying that Europe needs to launch a new industrial revolution, starting again with mathematics, the limitation of decidability and taking these things on board. What for? To work. At the moment, as you know because we talked about it last week, we're in the process of setting up a project with livestock farmers and fishermen—it hasn't even started yet, it's in limbo, but we're in the process of setting up the system. We intend to use the platforms and all those things, so it's hyper-industrial technology. But it's a technology that is being used to achieve a positive negative environmental balance.

So that means completely rethinking the platforms. At IRI [Institut de Recherche et d'Innovation] in particular, we've been saying this for a long time: we say that there must be incalculable fields of information. So it's no longer information, it's knowledge, and it mustn't be transformed into information. There are things that can be transformed into information, because sometimes there are fields where it's interesting to use algorithms to optimise statistics and so on. This is very, very important. There's no question of abandoning statistics, on the contrary. It's a question of criticising them and making them deliberative. So that's what we call contributory platforms. And it's linked to contributory accounting and so on.

Then, and I'll stop there, there are some changes of scale. In the next 10 years—the next 7 or 8 years, if we believe the G.I.E.C (if we follow what the G.I.E.C said in 2014, we have about 8 years still), to really make a change, these will be years of negotiating compromises. Because you can't do something like that if you can't mobilise forces, including people and capital, who have technologies. So we're going to have to negotiate compromises. First you have to convince the higher macroeconomic levels, which are collapsing. If the economic level collapses, it collapses. It's also a pyramid. And it's like biodiversity.

We're saying that it's not just a pyramid of biodiversity: it's a pyramid of noodiversity. We need to organise it, and we need to use the industrial resources available today to put them back at the service of that, and here I'm saying the same thing as Socrates said about writing. Socrates was a great critic of writing, but he never said you shouldn't write.

He said that writing should be subjected to a real model, not that of the sophists. It's not about making money; the aim of writing is to produce knowledge. So, we're saying the same thing, in fact, but not just with writing but with all technologies.

V.C.: It also seems to me that in its statistical interpretation, entropy raises the question of homogenisation, so in relation to biodiversity, [anti-entropy] is what also fights against what is homogenous and unique, by diversifying. And so, it applies just as much to noodiversity, i.e., the diversity of knowledge and cultures, as it does to biodiversity. Both of which, it seems to me, can be seen in parallel in the question of resilience. In the sense that the resilience of ecosystems, as a result of biodiversity, is more or less equivalent to the resilience of societies and cultures, as a result of the diversity of knowledge?

B.S.: So on the subject of resilience ... but I think Maël will say something about that. It's one of the interesting aspects of what we want to launch with dairy farmers, milk and cheese producers. Here we can see how biodiversity and noodiversity are linked. Because—to pick up on what you've just said about resilience—there's a homogenisation today of digestive systems, for example, linked to diet. This leads to a loss of diversity (we all have internal biodiversity). And if we standardise it, well, we undermine the human species. So all these issues are very much integrated, in fact.

Then there's the fact that scientific specialisation has led to a disintegration, with people working on [isolated] things and never working together. What we're trying to do, with what we call laboratory territories, is to get biologists, mathematicians, and computer scientists to work together, alongside farmers, consumers, lovers of cheese, milk and whatever else. So that we can begin to reconstitute a biodiversity brought about by noodiversity—which is also the diversity of cultures.

M.M.: To go along the same lines, the current development model, whether in the agri-food or digital sectors, for example, is very much based on what physicists would call extensible variables, i.e. the more you sell, the better. The aim of development is to sell more, to have a bigger place in the market. And that, by its very nature, is extremely resource-intensive, whatever the resources. And it's also standardising because we're selling relatively standardised things, even if there is a little customisation through personalisation algorithms. It's standardised customisation.

Here, the opposite, anti-anthropy, consists of focusing on the production of novelties, but not novelties of any kind, not novelties for novelty's sake: the novelty that allows a locality to last. The locality that lasts can be a city, a field, or a fishing ground with its ecosystems. So by thinking in terms of locality of entropy and anti-entropy, we are focusing development on making the ecosystem last, from which we also draw resources.

And then from a more theoretical biology point of view, so just anti-entropy and its relationship to entropy, in fact there's a lot of work to be done to which I'm contributing on how to theorise what's happening at the level of living organisms. In other words, there's a loss of diversity, that's one thing, but it's not necessarily as easy as that to define precisely because we count species, but that's a crude way of getting an idea. But in fact, some of what happens is extensive, meaning that habitats are lost, for example, and so the living things that live there disappear, but some of it corresponds to disorganisation, which we can't really grasp in purely quantitative terms.

So, for example, global warming is disrupting the relationships between plants and pollinators. It's not that there's no more room for them. It's just that there's also this problem, and the two add up. And so, this is analysed in terms of anti-entropy, the fact of being organised, the fact of being able to reorganise as well, and in terms of entropy, i.e., the fact that we push living things towards something random, we simply disorganise them. And it's the same thing, for example, with endocrine disruptors, to take two very different examples. So the analysis we're developing of what's happening with living things needs to introduce these concepts, in my opinion.

B.S.: What we're saying is that we need to create local economies that are open and not at all closed. It's absolutely not a question of closing the local economy in on itself. It's about opening it up, deliberately opening it up, and ensuring that there are exchanges between localities. Then there are the possible scales of exchange. How far ore can be transported, I don't know, 20,000 km. These are very big questions, and there are trade-offs to be made. A carrier will always say that it's perfectly possible to transport ore 20,000 kilometres. So it's in his interest. But it's not at all clear that this is sustainable in terms of the biosphere. So what I'm trying to say is that the idea of creating a new industrial revolution is not about inventing new industrial technologies and so on. It's about producing a new industrial economy. One that takes advantage of existing technologies and creates strong relationships of exchange between localities. Because exchanges are extremely important.

For example, I don't agree at all, and I think it's extremely dangerous to say that the biosphere is Gaia, an entity—it's not true at all. But on the other hand, and this is why I say you have to read Vernadsky: [the biosphere] forms a whole. And that's extremely important to introduce today, as one of the dimensions. That's what I call meta-economics. It's a dimension: it's not just macroeconomics, how I consolidate exchanges with international or national chains. I call it meta-economics, because it's about the trade-offs involved in maintaining the biosphere as a whole. This is a question that has never been asked. The West has never asked itself how I can also look after Africa and the Middle East, and that's why we're facing a catastrophe in those countries today. Because it exploited all that. And in a totally irresponsible way. And we can't do that anymore.

Because now, all these countries have equipment, etc., and we absolutely have to maintain a dynamic with them. But what I wanted to say is that the industrial revolution here is not about geo-engineering or whatever. Of course, it can also involve research and technological development programmes. But it's a new industrial economy. It's a new way of counting in economics. And it means that localities should be recognised as producers of value as localities. But they have to be open. That's the only way they can produce value. If they are closed, they die.

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Contributions to Neganthropology: Agroforestry and Syntropic Agriculture

Felipe Alves Leão

Abstract

The present text aims to discuss the proximity between two central concepts in the works of two authors: "syntropic agriculture" and the "Neganthropocene," respectively in the works of Ernst Götsch and Bernard Stiegler. First, a review of the terminology of the terms "syntropy" and "negentropy" is carried out, establishing that the terms are quasi-synonymous. Secondly, a succinct explanation of syntropic agriculture as an "epistemological key" is offered, one very similar to that of Isabelle Stengers and Ilya Prigogine from *Order out of Chaos.* Second, an explanation of its origin in indigenous cosmology, as expressed by Viveiros de Castro in *Cannibal Metaphysics*, is outlined. Syntropic agriculture is one of the ramifications of techniques carried out in agroforestry systems and, therefore, is also called "successional agroforestry systems" (SAFs). It has been used not only for reforestation, but also for small and large-scale agricultural production. The big differences between syntropic agriculture and other agroforestry systems are how the biodiversity of cultivated species is emphasized and how ecological succession is used as a guide to cultivation. That is, syntropic agriculture mimics the processes carried out by ecological succession. The role of human beings is also great, given that the farmer needs to act constantly, intervening in cultivation, sowing, and pruning. Thus, syntropic agriculture establishes the height of syntropy when there is an organization similar to that of a forest, but above all similar to a forest in which man is properly equated. At this point, a parallel is drawn between this model of agriculture and that carried out by Amazonian indigenous peoples, which most likely gave rise to the Amazon Forest.

Keywords: Neganthropocene; anthropocene; cosmotechnics; syntropic agriculture; successional agroforestry; negentropy.

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Introduction: Stiegler and Götcsh

This text aims to discuss the proximity between two central concepts—"syntropy" and the "Neganthropocene"—present, respectively, in the works of Ernst Götcsh and Bernard Stiegler. It seeks to demonstrate how "Syntropic Agriculture" can contribute to the study of "Neganthropology" as encouraged by Stiegler in his last writings. Through the shared study of such approaches, the article also intends, inversely, to contribute to the expansion of the theoretical basis in the study of syntropic agriculture, bringing up a potentially relevant perspective. Since this form of agriculture, practiced mainly in Brazil, is very similar to that practiced by indigenous communities in the Amazon, so-called "agroforestry," the article will, through the use of concepts present in the works of Eduardo Viveiros de Castro, Donna Haraway, and Isabelle Stengers and Ilya Prigogine, draw a coherent parallel between such agriculture, its indigenous heritage, and ways of bifurcating away from,[1] as Stiegler demands, the Anthropocene, (A)entropocene, and, most specifically, the Plantationocene.[2] Before starting these comparisons, a summary of the authors' work and the use of the referred to concepts is necessary both to theoretically contextualize the article and to better understand the theme at stake.

Syntropic Agriculture and the Plantationocene

Ernst Götsch, a Swiss farmer, researcher, and theoretical agriculturist working mostly in Brazil, is the inventor of "syntropic agriculture." Its main concepts, theory, and techniques are outlined in his pioneering articles "O Renascer na Agricultura,"[3] from 1996, "Homem e Natureza,"[4] from 1995, and in the book "Agricultura Sintrópica Segundo Ernst Götsch"[5] from 2021.

The fundamental concepts of syntropic agriculture are developments of the ancestral technique of agroforestry, which aim to emulate a forest system in anthropic crops, that is, in agriculture. These systems are called SAFs (Successional Agroforestry Systems). Agroforestry systems are modes of agriculture that value the existence or preservation

1 Bernard Stiegler, *Bifurcate: There is No Alternative* (London: Open Humanities Press, 2021), 270.

2 Donna J. Haraway, *Staying with the trouble: Making Kin in the Chthulucene* (Durham: Duke University Press, 2016), 99.

3 Ernst Götsch, *O renascer da agricultura* (AS-PTA-Assessoria e Serviços a Projetos em Agricultura Alternativa, 1996).

4 Ernst Götsch, *Homem e natureza: cultura na agricultura* (Centro de Desenvolvimento Agroecológico, 1995).

5 José F. Dos Santos Rebello and Daniela Ghiringhello Sakamoto, *Agricultura Sintrópica Segundo Ernst Götsch* (Editora Reviver, 2021), 85.

of trees amid cultivated crops, or simply an integration between native and foreign forest species, planted with the sole purpose of human consumption. Generally, its main objective is to maintain the sustainability of the cultivated soil.[6] Many other examples demonstrating the applicability of agroforestry in different parts of the world have been shown in studies in the Americas, as well as in Asia and Africa.

In addition, agroforestry has been used as a technique for regenerating cultivated areas.[7] This is because, when the process of deforestation for the installation of plantations begins (the agricultural system that is more common in those countries on the periphery of capitalism), a cycle of desertification also begins. Such desertification occurs gradually, and mainly in countries with an agricultural economy, given the need for the hyper-production of commodities.

The process of installing plantations begins when an area of forest is cleared, the land is ploughed, and a single species is planted in the deforested area. As a result of this process, all biodiversity is eliminated and, in addition, some very specific nutrients are introduced into the area in large quantities. A soil that used to feed a forest that was highly integrated in terms of its exchange of nutrients, now finds only one species, which demands only one type of nutrient. This process will now demand inputs (fertilizers) external to the original soil; or, it will become unproductive since all the nutrients that were present in the forest soil initially derived from the decomposition of those species present in that forest (species now removed through deforestation).

A recent example of how monoculture agriculture depends on extremely specific inputs external to the planting environment is the "fertilizer crisis" that occurred as a result of the war in Ukraine. Brazil, the country with the largest tropical forest in the world, became so dependent on Russian agricultural inputs that its agricultural production was seriously hampered by the unavailability of Russian fertilizers (especially the most basic ones, such as Potassium, Phosphorus, and Nitrogen).[8]

This same process goes through other phases after the inputs are exhausted: first, the species used in that monoculture is replaced by another species, which better supports the absence of nutrients; then, with the total depletion of nutrients, the monoculture is

6 Maria Teresa Vilela Nogueira Abdo, Sérgio Valiengo Valeri, Antônio Lúcio Mello Martins, *Sistemas agroflorestais e agricultura familiar: uma parceria interessante*. *Revista Tecnologia & Inovação Agropecuária* 1, no. 2 (2008).

7 Nair Ramachandran, *An Introduction to Agroforestry* (Springer Science & Business Media, 1993), 55.

8 Fabrício Gomes de Melo, "Efeitos Sobre o Agronegócio: uma análise da comercialização de fertilizantes a partir das relações bilaterais entre Brasil e Rússia," *EmpíricaBR-Revista Brasileira de Gestão Negócio e Tecnologia da Informação* 4 (2024), 10.

transformed into pasture, for raising cattle; and finally, when such cattle have already made the soil unusable even for the growth of grasses, desertification will be complete. This process may seem incoherent (which it is), but even so, it is the main method of carrying out agriculture, mainly in underdeveloped countries in Africa and Latin America.

The consequences of the use of plantation techniques as the main mode of Western agriculture in the colonized world, and that these techniques are so dominant, leads Donna Haraway in *Staying with the Trouble*, to employ the term the "Plantationocene" as an approximation for the overlapping nature of the Anthropocene and the Capitalocene. Drawing on discussions[9] carried out primarily by Anna Tsing and Scott Gilbert, Haraway produces a leading diagnosis that "the world is collapsing" as a result of the ubiquity of this technique:

> In a recorded conversation for Ethnos at the University of Aarhus in October 2014, the participants collectively generated the name Plantationocene for the devastating transformation of diverse kinds of human-tended farms, pastures, and forests into extractive and enclosed plantations, relying on slave labor and other forms of exploited, alienated, and usually spatially transported labor.[10]

Wolford confirms the social, political and economic motivations behind maintaining plantations as the main mode of agricultural production. Using the example of countries colonized by Portugal, such as Angola and Mozambique, the author demonstrates that plantations generate a configuration of permanent land ownership (few landowners own most of the land, with their production mostly destined for export).[11] That is, even after the decolonization or relative independence of colonized countries, the plantation system remains and, with it, this configuration of land ownership that maintains social and economic inequalities. However, in Brazil, where this method seems to have intensified even more with the use of new technologies (something which has allowed for the "plantationification" of the Midwest of Brazil), alternatives to the agricultural *status quo* have also been proposed. These alternatives seek ecological solutions in indigenous techniques from the riverside and *quilombola* communities, techniques which have resulted in subsistence agriculture for centuries and centuries.

Knowing that monoculture (which can be translated, then, as the dominant mode of

9 Donna Haraway et al., *Anthropologists are Talking–About the Anthropocene*, *Ethnos* 81, no. 3 (2016), 537.

10 Haraway, *Staying with the Trouble*, 206.

11 Wendy Wolford, *The Plantationocene: A Lusotropical Contribution to the Theory*, *Annals of the American Association of Geographers* 111, no. 6 (2021), 1627.

industrial agriculture, that is, as the plantation model) tends to deplete the nutrients present in a soil very quickly, agroecology gave rise to SAFs as a way of systematizing a coherent alternative to the monoculture model. Its strengths are greater water retention in cultivated soils, disease prevention, product diversity, and a reduction in the need to use chemical products such as chemical fertilizers, pesticides, and herbicides. Around the world many different agroforestry systems have been developed, with adaptations according to the environment and the techniques of native populations. Results have been found in all the populated continents: in Malawi, India, Germany, Kiribati, and even near to Antarctica (in Southern Patagonia).[12] One of these types of agroforestry is the one elaborated by Götsch, biodiverse successional agroforestry, also called "syntropic agriculture."

The big difference between conventional agroforestry systems and syntropic agriculture is the emphasis on the practice of techniques that reproduce natural succession and biodiversity: frequent pruning, diversity of species in cultivation, stratification, planting of grass and the different systems, namely colonization, accumulation, and abundance. In addition, syntropic agriculture exclusively uses fertilizer from biogeochemical processes (i.e., fertilizers and micronutrients produced by the local environment), instead of external inputs, as, for example, in conventional organic agriculture.

Syntropy in Thermodynamic Terms

According to Götsch,[13] after many years of research and through the development of specific techniques (such as periodic pruning, stratification according to each plant's need for sunlight, and understanding how the rhizospheres of planted crops affect each other if planted together), his model of agriculture could no longer be included into the term "agroforest," preferring the use of "syntropic agriculture." "Syntropy," and what is meant by syntropy, thus becomes the operative concept that distinguishes Götsch's techniques from other forms of agroforestry. However, to facilitate understanding, in academic works that address the techniques used by Götsch, the use of "Sucessional

12 See Jeanne Y. Coulibaly et al., "Adoption of Agroforestry and the Impact on Household Food Security among Farmers in Malawi," *Agricultural Systems* 155 (2017); Jyotish Prakash Basu, "Agroforestry, Climate Change Mitigation and Livelihood Security in India," *New Zealand Journal of Forestry Science* 44 (2014); Nerlich, K., Simone Graeff-Hönninger, and W. Claupein, "Agroforestry in Europe: a review of the disappearance of traditional systems and development of modern agroforestry practices, with emphasis on experiences in Germany" *Agroforestry Systems* 87 (2013); R.R. Thaman, "Kiribati Agroforestry: Trees, People and the Atoll Environment," *Atoll Research Bulletin* 333 (1990); and N. Oro Castro et al., "Effects of Alternative Silvicultural Systems on Litter Decomposition and Nutrients Dynamics in Sub-Antarctic Forests," *Agroforestry Systems* 93 (2019).

13 Rebello and Sakamoto, *Agricultura Sintrópica Segundo Ernst Götsch,* 51.

Biodiverse Agroforestry" is also used instead of "syntropy." To understand what is at stake in Götsch's mode of agriculture, it is necessary to grasp what is meant specifically by "syntropy," especially its relation to thermodynamic notions such as "entropy" and "negentropy."

According to Andrade et al., the first author to use the concept of "syntropy" was Luigi Fantappiè in 1942, in the publication "The Unitary Theory of the Physical and Biological World."[14] Its etymology conveys its meaning, as being the inverse of entropy. The concept of "entropy" is directly related to the second law of thermodynamics and was adopted by Ludwig Boltzmann from classical thermodynamics (originally being coined by Rudolf Clausius) to define the degree of energetic disorder in a system. The more the entropy of a system increases, the closer that system will be to thermodynamic equilibrium; that is, the more the system has moved from an ordered particle distribution (say hot on one side of the system and cold on the other) to a disordered particle distribution at a microscopic level, the more the system is at thermal equilibrium with itself (the more homogenous the distribution of particle energy is). Fantappiè thus used the term "syntropy" to describe certain biological events that seemed to go the opposite way to entropy, producing diversity and complexity, instead of dissipation and simplification.

Beyond the use of "syntropy" by Fantappiè, other comparable terms and theorizations of the *inverse of entropy* occurred around the same time, being used concomitantly by other authors from other fields; for example, in his 1944 theoretical work on life, *What is Life?*,[15] Schrödinger coined the term "negentropy" to mean something similar to the inverse of entropy, and in biochemistry, in 1974, Albert Szent-Györgyi suggested that "syntropy," in fact, replaces "negentropy." The reason for the terminological variation by Schrodinger will be seen later. One might want to also note the use of the term "negentropy" as theorized and used by Norbert Weiner and Léon Brillouin to account for the relation that entropy has to information and signal noise. Crucially, both negentropy and syntropy denote an elementary character in their meaning: a merit of perspective, that is, both concepts are only perceptible, considerable, or applicable to an integrated system, a "whole," more than to particular or specific phenomena. The next section will discuss how such a notion of "perspectivism" is important for syntropic agriculture. Before that, an overview of what Götsch means by "syntropy" is needed.

Ernst Götsch chose the term "syntropy" because it has the same Greek etymology as the word "entropy," making clear, from the beginning, its dialectical relationship. Most people

14 Dayana Andrade, Felipe Pasini, and Fabio Rubio Scarano, "Syntropy and Innovation in Agriculture," *Current Opinion in Environmental Sustainability* 45 (2020), 22.

15 Erwin Schrödinger, *What is Life?: With Mind and Matter and Autobiographical Sketches* (Cambridge University Press, 1992), 70.

are more familiar with the concept of entropy, which, within thermodynamics, refers to the function related to the disorder of a given system, associated with energy degradation. Everything that refers to the consumption and degradation of energy is, therefore, explained by the Law of Entropy. On the other hand, living systems have the ability to overcome the tendency to entropy through, for example, growth and reproduction. Even more evident is the tendency of natural systems to evolve towards increasingly complex organizational structures. In a macroorganism, the participants act synergistically and, through their metabolism, carry out the task of optimizing life processes, increasing the organization and complexity of the system as a whole. The translation of this logic into productive agricultural systems is what makes agriculture syntropic being an information agriculture and processes, not inputs.

In a simplified way, for Götsch, syntropy refers to the organization of particles in a given system. While entropy is the measure of disorder and unpredictability, syntropy is the function that represents the degree of order and predictability that exists in that system (in this case, the system of a forest). Throughout Götsch's work, syntropy is seen as the function that represents the degree of order and predictability existing in that system. When the system goes from simple to complex, verging and concentrating energy, it is a syntropic system.

It is important to state, therefore, that, while syntropy is understood as the inverse of entropy, given that the second law of thermodynamics is an end in itself, there could be no such thing as syntropy qua a realizable general reversal of entropy, as entropy is a universally encompassing concept. But as an epistemological resource or as a usable method to acquire a new perspective on the use of energy, syntropy is certainly fruitful. Bernard Stiegler, in his book *The Neganthropocene*, refers to the same idea that the difference between entropy and negentropy is always one of perspective:

> Referred to as negative entropy by Erwin Schrödinger and as anti-entropy by Francis Bailly and Giuseppe Longo, negentropy is always defined in relation to an observer (see the work of Henri Atlan and of Edgar Morin) – that is, it is always described in relation to a locality that it, as such, produces, and that it differentiates within a more or less homogeneous space (and this is why a neganthropology is always also a geography). What appears entropic from one angle is negentropic from another angle.[16]

Götsch, like Stiegler, when he talks about making the availability of energy more complex,

16 Bernard Stiegler, *The Neganthropocene* (London: Open Humanities Press, 2018), 54.

maximizing the functioning of the agroforestry system, and using the minimum possible for the maximum results, is treating the term "energy" in the *stricto sensu,* that is, considering all the energy spent in the whole cycle of production, i.e., not just locally but also broadly. Not only the water and sunlight used as nutrients are accounted for, but also the energy that is spent in the production of insecticides, chemical fertilizers, and herbicides. An example can help illustrate: every crop needs some basic nutrients to produce. Suppose that a crop uses a certain amount of chemical fertilizers to supply these nutrients. These fertilizers were probably taken from some phosphate or potash mine in a remote location and used in this crop. Therefore, to carry out the general calculation of the energy used to produce this crop, it would be necessary to include the energy expenditure spent on the extraction and commercialization of these fertilizers.

Syntropic Agriculture as a Perspectivism

Götsch, in his experiences in Brazil, "syncretized" his technique in conventional agronomy with indigenous knowledge, or rather, with the closest thing to what can be considered an indigenous epistemology.[17] The difference between Götsch's method and, for example, the Fukuoka method, is the active role of the farmer in generating feedback through pruning. If in Fukuoka, nature does the work alone, in Götsch's method the farmer is not the one who plows the soil, sows, and waits, but an agent who is always pruning, because he himself also makes up nature; pruning is within the "natural" equation. The biomass pruned by the farmer is left in the soil and ends up decomposing. Consequently, it fertilizes and regulates soil temperature. Fabiana Mongeli Peneireiro[18] has already stated how such an exchange of knowledge (of the relation between pruning, decomposing, and fertilizing) was already in practice, and, for this very reason, Götsch never applied for patents on his technique. This is because the "epistemology" with which Götsch allied himself is nothing more than the "perspectivism" demonstrated by Viveiros de Castro in his work,[19] applied to agriculture. Indeed, such an epistemological perspectivism is also an "ontological multinaturalism" since no "transcendental" differentiation is made between man and nature, man and animal, man and forest. The indigenous (those studied

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17 Research indicates that agroforestry (and its disambiguation, syntropic agriculture) as a technique was formed in a very "syncretic" historical process, with a huge contribution from indigenous peoples. See Walker, D. H., F. L. Sinclair, and B. Thapa, "Incorporation of Indigenous Knowledge and Perspectives in Agroforestry Development," in *Agroforestry: Science, Policy and Practice*, ed. F.L. Sinclair (Dodrecht: Springer, 1995) https://link.springer.com/chapter/10.1007/978-94-017-0681-0_12.

18 Fabiana Mongeli Peneireiro, *Fundamentos da agrofloresta sucessional,* Artigo apresentado no II Simpósio sobre Agrofloresta Sucessionais em Sergipe (2003), 203.

19 Eduardo Viveiros De Castro, "Cosmological Deixis and Amerindian Perspectivism," Journal of the Royal Anthropological Institute (1998), 471.

by Viveiros de Castro include the Yanomamis, the Tukanos, the Arawetes, and the Sateré-Mawé) see no ontological difference between a jaguar and a man, they share the same spiritual category, the same type of "soul." The only difference between the two is the body they inhabit, the corporeal nature in which they come into existence. According to Viveiros de Castro, in these Amerindian cosmologies, all beings—humans, animals, and even supernatural entities—are essentially endowed with the same subjectivity. Everyone shares a common "inside," which can be understood as a soul or spirit. However, although they share this subjectivity, each being sees the world differently, depending on their specific body.

Things could not be otherwise, since nonhumans, being humans in their own domain, see things as humans do, but differently. What humans take for blood, jaguars see as beer; the souls of the dead find a rotten cadaver, when humans see fermenting manioc; what humans perceive as a mud puddle becomes a grand ceremonial house when viewed by tapirs.[20]

In Amerindian perspectivism, culture is something that all beings possess from their own perspectives. To humans, other species are seen as part of "nature," while from the jaguar's point of view, jaguars are the "cultural" beings and humans can be seen as "animals." Such Amerindian cosmologies also emphasize transformation between beings. The idea that, under certain ritual or shamanic circumstances, humans can become jaguars or other beings, and vice versa, reinforces the notion that identity is fluid and defined by the bodily perspective one temporarily adopts.

Amerindian perspectivism produces, therefore, a truly interspecific (among different species) relationship between the inhabitants of the world. There is a kind of "respect" for nature, precisely because one does not see a difference between culture and this "other thing" that is nature. All the relationships that develop depend on the perspective, all the activities that the beings of the forest carry out are done in such a way exclusively because of the perspective of that being. When a person catches a fish, this person is no different from a jaguar hunting another animal (or even a man). When the earth (with the worms) feeds on a corpse, it is no different from a man harvesting *cassava*.[21]

Here, *technique* acquires a totally different meaning from the Western one, because the very concept of nature changes. "Western modernity" views animals, plants, and men as components of the same nature, where the difference between them is only in the category of their spirits. The bodies that exist in nature are formed exclusively by the elements

20 Eduardo Viveiros De Castro, *Cannibal Metaphysics* (University of Minnesota Press 2015), 71.

21 De Castro, *Cannibal Metaphysics*, 58.

of the periodic table in different rearrangements, but they still share the same nature. Therefore, the only possible differentiation would be transcendent to matter.[22]

In certain respects, perspectivism is diametrically opposed to the objectivist epistemology encouraged by Western modernity. The latter's *telos* is provided by the category of the object: to know is to objectify by distinguishing between what is intrinsic to the object and what instead belongs to the knowing subject, which has been inevitably and illegitimately projected onto the object. To know is thus to desubjectify, to render explicit the part of the subject present in the object to reduce it to an ideal minimum (and/or to amplify it with a view to obtaining spectacular critical effects). Subjects, just like objects, are regarded as the results of a process of objectification: the subject constitutes or recognizes itself in the object it produces and knows itself objectively when it succeeds in seeing itself "from the outside" as a thing. Our epistemological game, then, is objectification; what has not been objectified simply remains abstract or unreal.[23]

The epistemological key to understanding the complexity in using the concepts of syntropy and synergy is right on the border of the concept of nature. Indigenous Amazon peoples (those mentioned above) are in a symbiosis (or a non-separation, a non-othering) with respect to the forest, and as such, are able to produce an agriculture that is integrated with that same forest. At this point, even the concept of agriculture begins to dissolve, since the symbiotic "agriculture" produced by the indigenous people is nothing more than the forest itself, intact, since they are not "something else;" being part of the forest, they can only produce more forest.

That is, this indigenous epistemology of perspectivism comes from an ontology in which there is no metaphysical difference between man and the rest of life in the forest. In this logic, man is part of the forest, he is an organ of Gaia that acts in favor of its existence. The issue here is that we were never a body. We have always been organs of Gaia. Our yearning for becoming a Body-Without-Organs, as demonstrated by Deleuze and Guattari,[24] is a desire to become only and just an organ.

Because of this completely different attribution in the sense of the society-nature relationship, the indigenous peoples of the Amazon knew how to deal with the forest, knowing that ontologically they "were it." Cultivating it is also cultivating yourself. This is how these peoples "cultivated" what can be called the largest edible forest in the world. This species of "forest-orchard" was evidenced after conclusive studies in the Amazon.

22 De Castro, *Cannibal Metaphysics*, 59.

23 De Castro, *Cannibal Metaphysics*, 60.

24 See Gilles Deleuze and Felix Guattari, *Anti-Oedipus: Capitalism and Schizophrenia Volume 1* (New York City: Viking Press, 1977).

Patrick Pardini demonstrated that the Amazon, the largest forest in the world, is anthropic in part, meaning that it has been caused by the action of human beings.[25] It has, therefore, a significantly greater number of "usable" species than the average for the world's biomes. A large part of the plants that seem to grow "naturally" (this term, again, not coherent to describe the process) and according to "natural" ecological succession, have, in fact, been selected for centuries by the inhabitants of the forest. The Amazonian indigenous people did (and still do) expand the forest's biodiversity, contrary to monoculture, which privileges very few species.

Essential for understanding the logic behind indigenous agroforestry, Davi Kopenawa and Bruce Albert in *A Queda do Céu* [*The Falling Sky*] demonstrate how the Yanomami, for example, were collectors (in the sense of being anthropologically designated as hunter-gatherer) by an imperative of their own. The collection of fruits, nuts, and whatever else was necessary for their subsistence was "planned," infiltrating useful species into the middle of the forest, which adapted to the ecosystem, generating even more biodiversity. As Kopenawa and Albert write:

> What white people call nature, in our language, *urihi-a*, the forest-land […] The forest is alive, that's where its beauty comes from. It is she who animates us. It's very much alive. White people may not hear her cries, but she feels pain, like humans do. Its big trees groan when they fall and it cries in pain when it is burned […] The forest has a very long breath of life. It's your breath.[26]

It is not a question, then, of another thing, but of the same thing. The forest is being directed, solving the problem that Stiegler formulates as follows:

> [...] the question is to know if we can predict and, if possible, orient the evolution of technics, that is, of power [*puissance*]. What power [*pouvoir*] do we have over power [*puissance*]?[27]

An example may clarify the logic: syntropic agriculture has a very interesting nomenclature[28] for dealing with "pests," such as ants and grasshoppers; they are called

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25 Patrick Pardini, "Amazônia indígena: a floresta como sujeito," *Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas* 15, no. 1 (2020).

26 Davi Kopenawa and Bruce Albert, *The Falling Sky* (Cambridge: Harvard University Press, 2013), 382-389

27 Bernard Stiegler, *Technics and Time, 1: The Fault of Epimetheus* (Stanford: Stanford University Press, 1998), 21.

28 Rebello and Sakamoto, *Agricultura Sintrópica Segundo Ernst Götsch,* 98.

"optimizing agents." After all, what does the ant do when it destroys an agricultural crop cultivated by man? Instead of the ant "destroying my farm," "destroying my money, my bread, and my house," and above all "costing me time," we could affirm that there is a natural reason for this to happen. Biologically, the ant is just "pruning" the crop. For some reason that the farmer was unable to understand, that particular plant/culture is not optimized to the place where it is located (either due to the incidence of sunlight or too much shade), so the ants "appear" and optimize the environment, pruning and decomposing the leaves, taking them piece by piece to the anthill, where they are digested and decomposed by fungi, accelerating the total decomposition process of the plant. If ants consume a crop, it is because they understand that matter is not well invested within its cycle, and not just to generate food for itself. According to Ernst Götsch, the ants are actually pruning the excess, and taking this excess underground, where it will decompose in the best way possible. By "pruning," the ants are actually demonstrating that the tree they are cutting should not be there, either because it is not fully healthy or because it is in excess:

> [...] someone who receives leaf-cutting ants as messengers of nature and understands them as part of the immune system of the Earth macroorganism will take other measures: he will plant in high density in the areas close to the lookouts, he will cover the soil with a lot of organic matter, helping the ants in their work to bring more life to that agroecosystem, after all, ants do not cut plants indistinctly. What makes an anthill close to dozens of eucalyptus trees (a plant commonly cut by them) travel more than 50 meters to cut a neem tree or a jabuticaba tree? By the logic of western capitalist rationalism, it would be much easier and cheaper to cut down nearby trees. But nature does not work following capitalist logic, nature works all the time to optimize the system, to create systems of abundance.[29]

And that is why pruning is such a fundamental element in the elaboration of Syntropic Agriculture. According to Gotsch, men are professional pruners produced by nature, but at some point (by becoming just a Body and no longer an Organ) we prefer to favor entropy over syntropy. We are, or should be, giant ants that periodically destabilize the system to boost its stabilization. By pruning, we speed up the process and "play the game" of the forest.

This method, in addition to, as already demonstrated, expressing the cosmology of non-objectification shamanism, also expresses what Stengers and Prigogine, based on

29 Rebello and Sakamoto, *Agricultura Sintrópica Segundo Ernst Götsch*, 98.

Boltzmann's work, called "active matter":

> The units we use to describe thermodynamic evolution will therefore behave in a chaotic way at equilibrium. In contrast, in near-equilibrium conditions correlations and coherence will appear. We come to one of our main conclusions; At all levels, be it the level of macroscopic physics, the level of fluctuations, or the microscopic level, nonequilibrium is the source of order. Nonequilibrium brings 'order out of chaos'.[30]

A momentary and microscopic break in the equilibrium seems to be the key to perpetuating or expanding the general and macroscopic equilibrium. In an entropy paradox, overall entropy depends on certain disruptions to keep itself in order and stay current. Life seems to be the agent that promotes small disorders in the general system, generating even more life.

Perhaps one of the first entropizations accelerated by humanity, monoculture is a highly efficient vector in the consolidation of the Entropocene demonstrated by Stiegler. Not only in the reduction of biodiversity, which is its first preponderant factor, but in all the expenses that its permanence and survival demand. Inputs external to the agricultural system are extremely necessary to maintain production in monoculture. From fertilizers to herbicides, practically nothing that is used as inputs in monoculture is generated by the system itself, everything comes from outside, that is, it causes entropy in external places.

Syntropic Neganthropology

At a grand scale the ecological problem at hand is that man is transforming highly intertwined life that rapidly recycles itself in its cycles, into "dead" matter. This activity is entropization. In the Amazon, for example, forests are burned to raise cattle or to set up plantations. Where did the forest go? It is in the air, in the form of carbon. In a mine, mineral fertilizers are extracted from rock or soil. Where did those minerals go? They are dispersed in soil. Carnot's heat engine, as Joel White argues, demonstrates how such a process occurs in thermodynamic terms, how entropization is a process of dissipation:

> The engine's endurance is conditioned by the maintenance of the energy difference between a hot body and a cold reservoir. To maintain this energy difference, one is required to 'feed' the engine from the global

30 Isabelle Stengers and Ilya Prigogine, *Order out of Chaos: Man's New Dialogue with Nature* (New York: Bantam Books, 1984), 286–287.

> store house of not-yet-dissipated energy—often in the form of chemical energy—to maintain the temperature of the hot body. The entropy of the local system is, therefore, kept from increasing by displacing it to its surroundings. Because the process of 'feeding' the engine irreversibly transforms not-yet-dissipated energy into already-dissipated energy, the global store house of not-yet-dissipated energy is depleted or exhausted through the very same process of maintenance. This renders the process finite and explains why all energetic systems, if they are to endure, exhaust their own conditions of possibility.[31]

In an ideal scenario, natural succession proposes the return of the forest, sending "pioneer" species such as grass, which would feed on part of the carbon released into the air. Afterwards, bushes and medium-sized trees begin to integrate such a "colonization" by these pioneer species. Finally, trees cover the ground, and the forest returns in force. But man refuses to play by these terms; shortly after the fire, he sends his cattle to feed on the "pioneer" species. It thus causes a perennial entropy.

But then, how is it possible to play "on the team" of Gaia, and get sustenance from a syntropic relationship? How can we not depend on this "not-yet-dissipated energy" to make our food engine work? That is the question Götsch seeks to answer. His specialty is recreating forests in lands devastated by monoculture and cattle raising. For this, he uses the same techniques as used by the natural forest. He starts his agroforestry by first using the pioneer species, plants often considered "weeds" and only later, with time and ecological succession, does he start reforesting the area. This reforestation, of course, is also efficient for man. The cultivation of food species does not exclude the existence of a forest. It is entirely possible to produce edible forests. According to him, we must syntropize, transform entropy into negentropy, as recommended by Stiegler:

> [...] if being-there exists only as being-put-in-question, then it is always organological becoming that puts it into question in the process of a doubly epochal redoubling within which the therapeutic care required by the new organological situation transforms this becoming into a future, that is, transforms this entropy into negentropy.[32]

It would be worth quoting Stiegler again now under the understanding of Amerindian perspectivism: "What appears entropic from one angle is negentropic from another

31 Joel White, "Outline to an Architectonics of Thermodynamics" in *Contingency and Plasticity in Everyday Technologies*, ed. Natasha Lushetich, Iain Campbell, and Dominic Smith (London: Rowman & Littlefield, 2022), 189–190

32 Bernard Stiegler, *The Neganthropocene*, 36.

angle."[33] Indigenous peoples understood this logic very well, and even combined it with their cosmology. As already mentioned, many indigenous peoples seem to have boosted the Amazon rainforest. Pardini[34] makes it clear that the studies are conclusive in finding a landscape and biological configuration highly anthropized for thousands of years. Managed and mainly cultivated, the Amazon was shaped to be an orchard-forest, which gave the indigenous people what they needed. These knew how to "infiltrate" their agriculture in the middle of the forest, without having to deforest it.

The "original affluent society" that Marshall Sahlins[35] proposed to explain hunter-gatherer societies was extensively "planned" by Amazonian societies. The collection was the result of an agriculture cultivated for millennia and that was reflected in abundance in the present time. However, as above, even the term "agriculture" should be questioned, because such an accomplishment is far from what the West conceives as "agriculture." An "agri-nature" is formed on the cosmotechnical horizon. Similar to the butcher Pao Ding, addressed by Yuk Hui in his book *The Question concerning technology in China*,[36] who follows the Dao of meat in order not to waste his knife, we must seek the path of an agriculture that boosts the forest, which uses its movement to exist. In fact, we need an agroforestry.

Conclusion

With terms used by Stiegler, we conclude using a "cosmopolitical medicine": geophysiology is the general practitioner, which diagnoses the disease of Gaia: the Entropocene; and the negantropologist is the scientist who seeks alternatives for its cure. These healing alternatives permeate cosmotechnics other than European ones. Among them would be syntropic agriculture, an example of the "translation" of indigenous cosmology as an agroecological technique, systematized in more conceivable terms for conventional agriculture, making its application possible.

33 Bernard Stiegler, *The Neganthropocene*, 54.

34 Patrick Pardini, "Amazônia indígena: a floresta como sujeito," *Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas* 15, no. 1 (2020).

35 Marshall Sahlins, "The Original Affluent Society," in *Limited Wants, Unlimited Means: A Reader on Hunter-Gatherer Economics and the Environment*, ed. John Gowdy (Washington D.C.: Island Press, 1998), 5.

36 Yuk Hui, *The Question Concerning Technology in China: An Essay in Cosmotechnics* (Fallmouth: Urbanomic, 2016): 101–108.

The concept of pharmakon, rescued by Derrida in "Plato's Pharmacy," and used by Stiegler,[37] is very similar to the agency that man exercises in syntropic agriculture. The pharmakon is at once what enables care to be taken and that of which care must be taken—in the sense that it is necessary to pay attention: its power is curative to the immeasurable extent that it is also destructive.

Man, *Homo sapiens*, this machine (because he often behaves as such) that we are used to seeing destroying, razing landscapes, can indeed be a nutrient, a coherent agent within the ecosystem. Not only can this human species choose to change its trajectory, but it has also become an imperative. Stopping much of the ecological harm would be a start, of course, but it is also important to note that humans have an active role to play, that they make up part of the ecosystem. Syntropic agriculture reveals one of those roles in which man can be active, in which he can be coherently "in order" by generating "chaos," as Prigogine and Stengers suggest.

Acting in the right amount and in a way that boosts agroforestry systems, man can "destroy" the forest: pruning, bringing organic matter to the soil, increasing the vegetation cover of the soil, which fertilizes the flora. Leaves and branches, when covering the soil, protect the microbiota residing in its subsurface, regulate temperature, and conserve moisture. "Hurting" trees in specific amounts and points, man acts like substances that, also in specific amounts and points, act on the human body. The way, intensity, and level of sophistication with which we deal with the forest influences the results, generating impacts that return and return. The pruning carried out is a bifurcation in the system.

Neganthropology can be constituted only within a speculative cosmology, that is, only by conceiving the cosmos as a process within which localities are produced that give rise to various feedback loops.[38] That is why, in conclusion, syntropic agriculture can contribute to neganthropology. It is a cosmological (and speculative) perspective that not only opposes monoculture and plantation, but also takes into account general thermodynamics, generating those feedback loops.

37 Bernard Stiegler, *What Makes Life Worth Living: On Pharmacology* (Cambridge: John Wiley & Sons, 2013), 4.

38 Bernard Stiegler, *The Neganthropocene*, 239.

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TECHNOPHANY
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A Moving and Exhausting Cosmos: A Discussion on Entropy

Thomas Nail and Joel White

Thomas Nail (**TN**): *How do you define entropy?*

Joel White (**JW**): Firstly, I would like to thank you for agreeing to this discussion on the topic of entropy for *Technophany*'s special issue "Entropies," edited by myself and Gerald Moore. I would also like to take this moment to say that I very much enjoyed our conversation on the phone the other day/night, it was very inspiring for me to talk with someone that shares the same passion for questions regarding energy, entropy, process, flow, metastability, chaos, and everything in between the big bang and heat death (*Nepantla*—inbetweeness—as one might call it in Nahuatl).

Your first question, "how do you define entropy?" has remained with me since I received your email. It is comic or perhaps tragic to start our discussion with what seems like a simple question. As Dorion Sagan writes, ventriloquizing the Devil in "Entropy, Said the Devil," his article for our special issue: "I'm afraid most of you are quite lost. Entropy is both simpler and more complex than commonly thought." Entropy is a tragicomedy not just because its definition is so infamously obscure (thinking here about von Neumann recommending Claude Shannon the use of "entropy" in information theory precisely because it was so obscure) but also because, from a classical thermodynamic point of view, its mathematical definition (a condition which unambiguously qualifies what a mathematical term is and is not), as first formulated by Rudolf Clausius in 1865, is rather simple—outstandingly simple: the unit of entropy (S) is energy (J) over temperature (K), or S = J/K. *How* we define entropy, the method of definition, in classical thermodynamics is through calculus: we determine the change (Δ) of entropy ΔS by integrating the change in the difference between the internal energies (Q) and temperature of two systems: $\Delta S = \Delta Q / T$ (the incremental irreversible transfer of heat energy from the hotter system to the cooler system). Quantitatively, then, entropy can be defined as this change or transformation of energy content between systems (*Verwandlungsinhalt*), a transformation that renders the internal energy of the hotter system no longer capable of increasing its entropy, or in other words no longer capable of work. This is why in textbooks entropy is a "measure of a system's thermal energy per unit temperature that is unavailable for doing useful work." Indeed, when entropy (*Entropie*) was coined by Clausius this is precisely why the Greek *entropia* was chosen; it defined the quantity of energetic (*ergon*) transformation (*trope*) that occurs between systems (Shannon Mussett's book *Entropic Philosophy* is a brilliant

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resource for the Greek uses of *entropia* as a "turning towards.")

But entropy is not just the *quantity* of transformation. It describes a particular *type* of transformation, one that pertains to the configuration of energetic systems and their tendency (their turning towards, their movement, perhaps, between) one state rather than another. The question then of *how to define* this quantity opens the question of the qualitative nature of this quantitative unit of irreversible energetic transformation. Here, I, like many others including Sagan, believe it is best to avoid notions of order and disorder (*Unordnung*). While disorder makes the most sense in statistical mechanics, due to Boltzmann's terminology, it makes less sense if what we want to qualitatively define entropy as is the quantity of irreversibly transferred energy from a hotter to a colder system. Particles are always "disordered"—just look at Brownian motion. This has led physicists such as Frank L. Lambert to readopt Kelvin's terminology of energy dissipation, or dispersal. This is the best way of defining thermodynamic entropy—as energy dissipation—since dissipation means both that energy *tends* to become "spread" or "scattered" over time (and this holds down to the quantum level as energy excitations decay down to lower excitations) and that this spreading out equates to a type of "expenditure" of a system's capacity to perform work.

This brings me to how I define entropy. Amusingly, I actually have a specific "working definition" both of *entropy* and of that which is *entropic* ("working" since it has changed and will likely change):

> 1. Entropy is the *dissipative condition of possibility and impossibility* of any metastable energetic system.
> 2. A phenomenon or an energetic system can be predicated entropic insofar as it *exhausts its own dissipative condition of possibility*.

Both of these definitions were the result of a method, that I term, after Gilbert Simondon, "transduction," which itself can be defined as Cécile Malaspina defines it in *Epistemology of Noise* as how "one field of knowledge [...] transduces its guiding principles, concepts or problems, across academic divisions and institutional boundaries, into other fields of knowledge." In the same way that Kant, for example, *deduces* the categories of the understanding, which is to say, justifies them *as categories*, the trans-duction of concepts such as entropy could be seen as the operation through which a definition that is deduced in one domain (mathematically, say, for entropy) may guide the deduction of the definition of that concept in another domain, say philosophy. Philosophy, just like science, has lots of guiding principles, concepts, and problems as well as organizing structures and systems. For me, I believe that the Kantian transcendental architectonic system is the most useful, or perhaps that which is most apt to being restructured (like a crystal from a saturated solution) by thermodynamics, and by entropy in particularly. I believe this to be so because the Kantian system seeks to locally determine what the conceptual conditions of the (objects) of experience are, as well as retaining general regulative unifying Ideas that guide notions of unity. For example, I see something like Heat Death and the Conservation of Energy as unifying Ideas; Ideas that cannot be experienced but, nonetheless, regulate the concepts of experience, concepts such as entropy.

JW: *The question I have for you is, how might entropic movement, this "tending toward dissipation," or this continual exhaustion of the dissipative conditions of possibility of metastable systems compliment or complicate kinetic materialism?*

TN: Thanks for these great reflections! I love how much you have really dug into the history of how people have defined entropy. It's not something that I have found many people doing outside of Sagan and Mussett. But it's so crucial. I fully agree with definition 1.

> "1. Entropy is the dissipative condition of possibility and impossibility of any metastable energetic system."

It's a great way to reframe the idea and avoid the unhelpful and metaphysically laden notions of entropy as "increasing disorder." Once we dig into the equations of entropy, we can see that everything hinges on the ontological status of Δ. J/K is just a description of the fact that energy spreads out proportionally as the temperature of something decreases. But this is hardly an explanation of why the cosmos would work this way and what the nature of Δ is such that it creates this ongoing effect. In other words, without Δ, S= J/K is just a statement of a static situation. All the magic happens with Δ, because Δ is the way or agent, if you will that produces the spreading effect with declining energy. And since all energy has momentum, and all momentum generates heat, Δ insures that this process does not stop and applies to all energy we know of so far. Δ is not just abstract "change" in general. Mathematically, you can reverse equations, no problem. But entropy is not reversible! The Belgian chemist Ilya Prigogine's book *Order out of Chaos* is unrelenting on this point against physical and quantum formalisms that suspend the irreversibility of Δ. Many quantum equations do not take seriously this irreversibility, so Prigogine creates his own!

Anyway, what is so cool about $\Delta S = \Delta Q / T$ is that it actually reveals something very specific and singular about the nature of change and motion in our cosmos that the mathematical formalism could never arrive at strictly formally. There is no mathematical or ontological "reason" why Δ must be necessarily irreversible. Let's be honest. No one knows *why* this cosmos is *entropic*. No one knows why there is *turbulence* or can predict it with complete accuracy. No one knows why *fractal* patterns are so widely distributed across so many scales of nature or how to predict deterministically. And yet, we can easily observe, measure, and record them everywhere. It's fantastic and fundamental.

Before I answer your related question about "kinetic materialism," which is being answered mostly along the way in all this, I have a question about your second definition.

> 2. A phenomenon or an energetic system can be predicated entropic insofar as it *exhausts its own dissipative condition of possibility.*

What do you mean by "exhaust" here? Do you mean "heat death" as it has been classically understood, i.e. this universe will eventually be "fully" dissipated to "equilibrium"? Because, if so, I am not sure I am convinced on this point. And here is why. The idea of equilibrium in thermodynamics comes from the idea that there are "open" systems defined by energy coming into "a system" and "closed" systems where energy is "neither coming in nor going" out of a system. If the universe is a closed system, and entropy is universal, then equilibrium i.e. heat death follows. But I am not so sure I am willing to commit to two big metaphysical points here a) that the universe is a closed system and b) that entropy is universal.

It seems to me that the universe is not a closed system because it is rapidly and unevenly expanding. It is simply not a "system" or "substance" but a process whose changing or Δ is itself also changing. There is not just one Δ, but a Δ of Δ of Δ, and so on. In other vocabulary this is also a problem in the mathematical logic of category theory because one can never totalize all the potential features of a single "arrow" in category theory.

In other words, I am not prepared to lock Δ into one kind of process or change, even if this is all we have seen so far in scientific observations. If the universe, i.e. energy/space/time continues to expand unevenly, it's not clear to me that it will ever reach equilibrium, because it will not stop, ever. Δ may not exhaust Δ because there is no totality of energy in the universe. Yes, energy is not created or destroyed, but in quantum physics there is no such hard zero energy state. So-called "vacuum energy" does not have a determinate value. It is an indeterminate process. Thus, classical notions of thermodynamics begin to fall apart at the quantum level as the vacuum increases and decreases indeterminately. So, in this very technical quantum sense the world is not a system which is either open or closed by a classical definition.

As such, it seems to me that it must remain possible that energy, at least at quantum scales, could change its Δ to not be entropic if even for just a moment. But a moment might be all that is needed in a very dissipated universe to generate enough gravity to bring things back together. It's speculative, I know. But the idea of a cosmic "big bounce," is based on known features of energy and argued for by physicists including Carlo Rovelli.

All this, I think, roughly answers your question about kinetic materialism. Your first definition complements KM, but the second one *may* conflict with it insofar as I have tried to keep KM consistent with the key experiments in quantum physics, which pose a challenge to nearly all the classical terms of thermodynamics including the nature of Δ, the nature of J (energy), and the belief in "closed" or "open" systems. But that is my question back to you. Does Δ S really exhaust itself and do you think closed and open systems exist ontologically, such that heat death is an inevitable consequence of entropy?

(**JW**): There are two overlapping questions here; the first is regarding what I mean by "exhaust" and the second is whether the phenomenon of "exhaustion" is related in some way to the notion of heat death. I shall begin with heat death: whether "heat death is an inevitable consequence of entropy?"

It is worth saying that the two definitions of entropy outlined above partake of what I call the "transductive analytic of thermodynamics," they are, therefore, concerned with what is experienceable not what is speculatively possible for experience (or, perhaps, we should say speculatively *probable*); much like Kant's *Critique of Pure Reason*, the analytic follows what I call the "transductive aesthetic of thermodynamics", which is concerned with the relation that energy, entropy, and information have to space and time (the thermodynamic direction or order of time and space) and precedes the second to last "book" (to use Kant's term from the *Critique*), the "transductive dialectic of thermodynamics." This last section is concerned with transductive illusions, concepts without objects in experience but that are taken as objects of experience, *ens rationis*. These three "books" are a part of an overall critique of what I call *pure plasticity*, with *pure plasticity* analogically signifying something like Kant's notion of pure reason—*A Critique of Pure Plasticity*.

As you can see this division is architectonic in structure and highly influenced by Kant's first *Critique* as well as Helmholtz's claim from his 1854 "On the Interaction of the Forces" that: "everything was gained" (that it put science on a new advantageous footing) when Carnot inverted the dogmatic question "how can we use the known and unknown forces of the universal to create a perpetual motion machine" to the critical question "If a perpetual motion be impossible, what are the relations which must subsist between natural forces?" It is a critical question because it places a negative judgment concerning totality as its leading hypothesis. Pure plasticity for me, similar to pure reason, is related to paralogistic (false inferences based on substance) or subreptive propositions (fallacious judgment, where either concepts are taken for ideas or ideas for concepts) of infinite transformation: perpetual motion machines of any kind and of any order. Digital immortality as proposed by transhumanists, affirmations of eternally cyclical negentropic universes, and perfect information engines capable of transforming information about a system into an infinite amount of work, perfect efficiency: these are all examples of transductive illusions that illegitimately presuppose the possibility of pure plasticity *in concreto*.

To say that "heat death is an inevitable consequence of entropy?" would be subreption (heat death qua Idea is introduced into the judgment concerning the understanding); pure entropy would be as dogmatic as pure plasticity. By its very nature, heat death would block any possibility of it ever being an object of experience. At heat death, because the conditions of possibility of experience cease to exist so too does the capacity to make a judgment about experience. Quite simply, at heat death, one cannot say, "this is heat death." This is not to say that it does not have a role to play in the architectonics of thermodynamics as an Idea in the Kantian sense of the term. To be clear, I am also not proposing a pure empiricism or a positivism, things can be real and affirmed as such without being experienced by each singular unity of apperception, and as you, I am not prepared to "lock" the universe into being just a simple analogy of a closed system nor am I prepared to abandon a more sceptical approach to science, there are just too many inconsistencies. Though perhaps different to you, or maybe I misunderstood what you meant by "There is not just one Δ, but a Δ of Δ of Δ, and so on" I do place a weak cosmological principle as a rather useful guiding regulative principle for philosophy and science; which is to say, working "as if" the universe is homogenous and isotropic is pretty useful if you want theory and experiment (not to mention what's already been observed) to mean anything at all.

Before I get to the Idea of heat death, how it functions as a regulative Idea in its own right and its relation to "exhaustion," it is probably worth saying that according to the current cosmology (see for example Katie Mack's *The End of Everything*), most of the other speculative Ideas regarding the "end" of the universe, which is not really an end, are looking *less likely* (and likelihood is the operative word!). Until recently, something like a Big Crunch (see "Bouncing cosmology from nonlinear dark energy with two cosmological constants" by Molly Burkmar, Marco Bruni on the slowing and expanding of dark energy) was pretty much ruled out, since the universe is observably expanding too fast (for whatever reason due to "dark energy"), Perlmutter, Reiss and Schmitt demonstrated this through the redshift in supernova light and won a Nobel prize for it in 2011; the problem with the "big bounce" you mention is that it too, like the Crunch, would have to produce a gravitational difference that might overcome this observable accelerated expansion; but like heat death itself, all of these fall prey to the very method they use: speculative probability. This recourse to probability has haunted science since Boltzmann. Lawrence Sklar, in his amazing book *Physics and Chance,* argues that the problem with speculations that deal with small probabilities is that if a fluctuation did occur—which is, of course, always probable because that's what it means to be probable (our very universe could be proof of it!)—it is also *more probable* that it doesn't. Furthermore, given the very precise configuration needed for a bounce to happen (the models that Burkmar and Bruni are working on), it is also unclear whether our universe would get another chance at another bounce, so to speak.

Regardless of what might occur towards this so-called end of the universe, whether it is a big crunch, a bounce, a big chill or a rip, almost all physicists, Rovelli very much included, especially in his more recent work on entropy, memory, and time, do not deny that the *movement of energy*, its *tendency, direction* or *order* is towards maximum entropy. As he writes in *The Order of Time* "it is entropy that drives the world, not energy." It is true that if quantum vacuum fluctuations were experimentally proven, then the law of the conservation of energy could be violated. But given the amount of observable evidence for conservation, perhaps the first law of thermodynamics would succumb to the same fate as entropy did at the end of the 19th century, that is to say, it would become highly probable instead of *necessary*. Where I am going with this is that that all experimentation and almost all theory thus far has not violated the second law whether probabilistic or not. There is nothing we can point to and say that is not subject to entropy. And while entropy is probabilistic from a statistical mechanical point of view (counterfactual theory proposed by Chiara Marletto is trying to turn this into the question of *what is* and *what is not* possible, which I think is a bit fraught with epistemic problems), to say that nothing has violated the second laws also means that we cannot get back to a low entropy state, the state that drives the world, without increasing more entropy! Again, as Rovelli writes (despite the recourse to the order/disorder paradigm), "The entire coming into being of the cosmos is a gradual process of disordering." That entropy envelops *all* changes and processes means that the concept of entropy (that which allows us to make the judgment: "that is entropic") connects, immanently, to an unconditioned Idea, which is the Idea of heat death. For me then, it is not a matter of affirming what will or will not happen "at the end," (how could we do this without slipping into metaphysics), but it is a matter of connecting experienceable entropic phenomena to an Idea that hypothetically unifies these phenomena as a guiding principle. Heat death is the *focus imaginarius* of thermodynamic architectonics.

Why then do I use the verb "exhaust" in English? Exhaust is a good equivalent, albeit using a different Latin root, of the French verb *épuiser* and the German verb, *erschöpfen*. These verbs (exhaust, *épsuier*, and *erschöpfen*) describe a form of de-construction, destructive creativity or negative sublation. Something is drawn out of something (*puiser*), created or invented (*schöpfen*), through the negation of its own continued possibility to be drawn out or created again. If all phenomena, fleeting or sustained, have their cause in the dissipative transformation of low entropy into higher entropy, then that very tendency, as per the first definition I gave, is the condition of possibility *and* impossibility of it. As you say, "entropy is not reversible!" We can't get that causal situation back again! (unless of course we wait for a bounce to happen). This then seems to demand the statement that something is entropic when exhaustion happens, exhaustion being understood not as destruction but as an irreversible unidirectional causation. As Rovelli writes "Causation is therefore a macroscopic thermodynamic phenomenon where the total entropy is raised by an intervention, and the effect is the trace left on the system by the intervention." This trace is not reversible. Indeed, this is precisely how Marletto turns the second law into a counterfactual, but unlike Marletto, perhaps, I do not therefore want to "lock Δ into one kind of process or change," and consistent with KM there is nothing we can point to and say, "that's not moving," but likewise I don't think there is anything that we can say, "that's not entropic," "that's not exhausting low entropy."

JW: *To change tack a bit, I know you have been doing work on non-Western conceptions of chaos, if I remember correctly? I know that in many Aztec cosmologies (which differ from other Mesoamerican cultures, for example, the Mayan) we are still in the period of the fifth sun, after which there are no more suns—they have a type of entropic logic where the sun is sustained by sacrifice. I think part of my interest in entropy is that it's a fairly novel idea in Western thought. We discuss some of the political and ethical notions related to entropy when we spoke especially in relation to how it might be possible to overcome the "negative" or "reactionary" accounts of entropy. Why do you think people have historically and still think of entropy as such a "negative" concept?*

(**TN**)**:** Thanks, Joel. That was great and provoked so many thoughts for me and questions. It is now clear to me that we both reject the *metaphysical* idea of heat death which says, "the cosmos will necessarily eventually stop and achieve perfect equilibrium," which is how that word is most often used in the history of thermodynamics. I am going to have to think more about the use of the regulative idea of isotropy because I think there may be a third option between acting as if everything is changing and everything is not stable. Do you think it's possible to act as if everything were metastable? For example, and to answer your question a bit, this is something like what we find in animistic traditions in ancient Sumer and Shinto Japan. In the most ancient texts in these traditions, a particular tree would not be treated as isotropic or pure flux but as a person-spirit with stability, like us, but also with its own unique agency that may also surprise us. I suppose I worry that a regulative idea of isotropism and its "practical" utility and instrumentality may blind us to the deep indeterminacy of the world and its capacity for novel agency. But maybe you are not thinking of this regulative idea as strictly as I am. I just worry that it comes with a deep danger with a long history and Western-centric bias that has caused a lot of harm. Again, not saying you are fully endorsing the version I worry about.

But quickly, I wanted to add that quantum fluctuations have been experimentally proven many times since the 1950s. But their *interpretation* typically falls into the same camps as the *interpretations* of QM, which I will not re-hash here and are heavily burdened by unprovable metaphysical speculations about randomness and determinism. Rovelli does a great job of debunking them in his book *Helgoland: Making Sense of the Quantum Revolution.* Thus, most physicists think quantum fluctuations do not violate the law of conservation only because they believe that Schrödinger's wave equation is a *real* description of a deterministic universe containing superpositions that balance out any *apparent* non-conservation. But Karen Barad and Rovelli both do well to show that the experiments to not have to assume this particular interpretation. Thus, not everyone agrees about the violation of conservation. But we can save debates about the first law for another time! Let's get back to the second law.

I think we are in agreement on this one and I love the way you put it: that if entropy is ever violated it will happen *through* entropy. Thus, one effect of entropy might be to produce non-entropy. And the converse is true, if our current universe was the result of a previous Big Crunch, then entropy would have been the result of non-entropy. And then we have what Empedocles imagined as the cosmological dialectic of Love and Strife.

In any case, I now understand what you mean by "exhaustion," and I agree with your definition as "the fact that we cannot point to anything in the cosmos so far that it is static or is not proceeding from low to higher entropy." It helps me to think of this word more of a gerund than a past participle. The cosmos is not exhausted but *exhausting*. And here is where the philosophy of movement connects up well to this idea of exhaustion. That said, I can't bring myself to use the word "heat death," though, although I understand your definition well, it just has such historical and metaphysical baggage I can't shake and don't want to confuse people with. But "exhausting" or perhaps "exhaustion," I am ok with.

I think one difference between us on this is that it sounds like you are taking a more post-Kantian approach thinking of entropy as a new transcendental. It's a cool idea and I like it a lot more than the typical metaphysical scientific approach or the typical phenomenological approach. Indeed, the line between it and the ontology of movement is pretty fine, I think. I think we both have a pretty *historical ontology* such that we accept that the cosmos may become different than it is and that we may learn something that changes what we knew. If we find something that violates entropy, it seems like your transcendental thermodynamics becomes weaker, but maybe you would still want to use it because most things still follow entropy. So it's just practical even though it's not ontologically true. I think for me, much more would be on the line if we found something that didn't move. Perhaps the difference between us is that I have a performative historical ontology and you have a more historical transcendental? Or my historical transcendental is slightly larger and has a performative dimension? If you think that is a fair characterization? The ontology of motion can handle entropy and non-entropy just fine as long as it's all happening *through movement*.

However, if we found something static or some region of the cosmos became static, then everything falls apart for my view because it would mean that our performance here on earth would no longer be an iterative performance of the cosmic drama itself, as Bataille says. Some part of the cosmos would be ontologically different than the rest and we would get a dualism. It would be almost theological. Indeterminacy would be the cause of emergent stasis, but in stasis, kinetic indeterminacy would be abolished as would any ontology committed to it. I wonder what you think of the strengths and limits of our positions if you agree with my characterization.

But to your question, which I would in turn pose to you, why has Western metaphysics understood entropy as "negative" and even "bad?" In my most recent work on ancient cosmogonic texts, I think a big part of the historical antipathy toward entropy has to do with a single cosmogonic difference. The conclusion of my book *The Birth of Chaos* is that all twelve of the oldest surviving native-language cosmogonic texts in the world began with a primordial condition of formless, flowing, indeterminate, moving, creative darkness or "chaos." In the book, I show that in these texts, primordial chaos had nothing to do with disorder at all. Order always emerged from chaos and returned to it. I can't go into all the textual evidence supporting these conclusions, but they mean that these cosmogonies are consistent with the cosmic entropy you and I are describing.

However, I also tracked the precise times and places where all these chaosmogonic texts were transformed by later largely conquering peoples who removed primordial chaos from the narrative. This happened around 1500 BCE in Egypt and Sumer and then around the 6th century BCE in Greece, India, and China. After this the history of Eurasian civilizations was exclusively dominated by cosmogonies where a principle of order came first, and chaos increasingly was redefined as the "lack of order." All Eastern and Western philosophies, religions, and sciences have followed this turn away from chaos and eventually fuelled colonial powers who travelled around the world murdering and burning nearly every trace left of indigenous world chaosmogonies. Again, big claim, but I think I have good textual evidence for it.

The bigger point here is the following hypothesis: to the degree the story I am telling above is accurate we should expect to find an antipathy to entropy in every culture whose cosmogony begins with a principle of order and not in cultures whose cosmogony begins with chaos. In chaosmogonies, entropy (they do not use this word of course) is the creative expression of a beautiful cosmos of which we are fully performative and iterative aspects of. Everything is born and thus everything dies. To die is to do what the cosmos is doing and thus be iteratively united with it. There is no god, principle, or law which was not born by something else. On the contrary, cosmogonies that place any kind of order first are fundamentally at odds with the process of exhaustion because it threatens to exhaust them and destroy their orders. It may also contribute to certain culturally specific fears of death. And so, I would hypothesize that nearly every religion, science, and philosophy which does not begin with chaos would necessarily be threatened by cosmic entropy. It would also explain why worldviews that begin with order also call entropy "disorder," just as they have been calling chaos "disorder" for the last 2,500 years. This is an important connection between our respective research programs. I know you have spent a lot more time looking at entropy in the modern European context, but our stories are in some way tell a continuous story. Movement and entropy are strongly related (although not strictly identical) and are major world historical conceptual lynchpins or pivots that distinguish many ancient and indigenous worldviews from modern ones. Their explanatory power runs deep.

JW: Thank you for this Thomas; correct, we are not here to debate quantum fluctuations or the first principle but the second! Though in a way the second is contingent on the first in so far as if energy could be created from nothing then the effects of entropy would be less weighty, there might be something like actually existing negentropy; but that is for another day. And as you also rightly say, there *is* experimental evidence for fluctuation or at least there is experimental evidence for the effects of fluctuation (electrons popping up in different orbitals) when and where they shouldn't and there are different interpretations of this; whether physics, especially of a quantum variety, should bother with "should" is a different story, though this story is perhaps one connected to our shared historical approach to philosophy and science.

Other than strictly neo-Kantian (though Helmholtz, Lange, and Vaihinger are a great influence on me) I would say that my "method" is something I call *critical epistemology*, or perhaps this is the "domain" of philosophy that I see myself developing. It is epistemological since it is it concerned with the historical development of certain *epistemes* (the conditions of knowledge and the formation of ontologies and discourses that arise from out of these systems—I concentrate on classical mechanics, thermodynamics, and information theory). It is critical, in the Kantian or neo-Kantian sense of the term, in so far as it seeks to do two things: 1) determine the conditions of possibility of these *epistemes* (both materially and theoretically) and 2) to construct, through transduction (as I defined it above), an architectonic system that enables us to see with some more clarity the very *episteme* in which we think and act. This architectonic system is one that places a strong emphasis on the *"as if,"* as influenced by Vaihinger's *The Philosophy of the "As if."* Moreover, it is with good reason that Yuk Hui argues that we are still in a "thermodynamic ideology." I believe thermodynamic architectonics will serve to understand what a thermodynamic ideology is and why entropy has not been properly integrated into it. A thermodynamic ideology is an ideology of energy not entropy, or at least is views entropy as dangerous to its own basic premise: energy extraction, accelerative production, and perpetual growth. To the question: "why has Western metaphysics understood entropy as 'negative' and even 'bad?'" I might answer quite simply that it undermines the metaphysics and any accompanying political economy based on infinite growth.

Thermodynamic architectonics is, then, practical insofar as it seeks to better survey this ideology, but it is not a closed system. One must be open to the inevitable re-structuring of the scientific structure and its models (as Serres might put it). The construction of my thermodynamic architectonics is thus practical but results from an experimental spirit, it asks the question: "What might a transcendental philosophy look like, if, instead of Newtonian mechanics, which inspired Hume, Kant, and Hegel, it took thermodynamics and/or information theory as its point of departure." (This is not a discussion about information, but I believe that the information paradigm is but a further reduction of the same basic thermodynamic ideology, information is viewed as that which can ultimately increase production via an increase in the capacity for energy to produce work [the more I know of a system, the more I can extract from it]—our thermodynamic ideology is at once a thermoinformatic one).

I am currently finishing a book called *On Logomachy* that might also help to link our positions and will give further clarity to your question about my approach to science and philosophy. I believe strongly that we should not have to choose between either absolute stability on one side and absolute instability on the other—metaphysical claims *par excellence*. We have the third option you mentioned: metastability. The book is called *On Logomachy* because this term—*logomachia*—is used by Socrates in the *Cratylus* to shut down the debate that Cratylus and he are having about the meaning of *episteme* (the dialogue is about the correctness of names): one where either the *movement* or the *stasis* of things in their relation to the soul etymologically defines *episteme*. In this dialogue, knowledge must be either only moving or only stable; to reopen the debate would consist of a conflict (*machia*) in and of the logos, a *logomachia*, something that Socrates argues must be avoided since Cratylus and he are supposed to be friends, and no one wants a civil war between friends! As Simondon writes, the Ancients (perhaps Heraclitus aside, whose *logos* qua fire is metastable and middle voiced) didn't really have a notion of metastability. What would happen to our notion of *episteme*, indeed to knowledge itself, if its definition was instead: "the metastable relation of the soul (itself being metastable) to metastable things in a metastable world"? *Of Logomachy*, seeks to answer this question.

Beyond the regulative nature of metastability—meaning that the "as if" is metastable—I have been experimenting with a fourth notion recently to replace what I was calling meta-metastability (which is clunky): patastability. One can hear in this notion resonances of Alfred Jarry's "pataphsyics," which is often defined as being "the science of imaginary solutions," or "the science that is beyond metaphysics." In *On Logomachy*, I argue for a conception of knowledge that is meta-metastable, that is, knowledge is a metastable relation between metastable systems, systems that include conceptual networks relating through *différance* (I think Derrida was spot on here), objects that are in different stages of metastability and instability and so on (I include the metastability of perception and the perceiver, emotional states or internal working memory models etc). Logomachy is perhaps my thermodynamic transcendental logic, to talk in Kantian terms.

Regulative ideas, then, to answer your question, are ideas that immanently unify knowledge and function at a patastable level: the regulative use of isotropy would be patastable, it would be that type of metastability that holds together the metastable relations of other metastable systems. Just as in Simondon's theory of individuation, such a patastable system, or *episteme*, would necessarily have to re-structure its relations if and when new evidence arises.

Concerning your suggestion of using the gerund "exhausting," I couldn't agree more. This is much better than the past participle or even just the noun "exhaustion." Though taking this a step further, one might want to think of this not as being in the gerund but as being in the old middle-voice tense called the passival. The cosmos is exhausting. Where the subject and the object of the verb are mediopassive: "that a person or thing both performs and is affected by the action represented." It is the cosmos that exhausts *itself through itself as both object and subject.*

This also brings me to your statement about cultures that are antipathic to entropy, how their cosmogonies begin with a principle of order and not chaos. Here one might want to think of that philosophical principle *par excellence*, the sun. If the sun is placed as the ultimate principle, that metaphysical being beyond being, as it is for Plato, which is to say Formness as such, then anything that does not participate of that perfect life-giving sphere is damned. As you write, to die is to do what the cosmos is doing, dying is returning to the universe. Here Artaud, more than Bataille, is the great Nietzschean philosopher-poet I turn to. We are not just of the sun, but we are the dying sun, we are its shit. As Artaud writes in his first ever poem: "*Le soleil se meurt*" (the sun is dying). Here the sun is dying in the passival, it dies *through itself as both object and subject*, and it is through its dying (here in the gerund) that life is at all possible. This is why I write that any metaphysics and any political economy that grounds itself on such a metaphysics of the sun qua absolute life-giving order cannot think life itself. Life exhausts (destroys and creates) itself through itself, the *élan vital* is always once at the same time an *élan mortal*. We need a politics that actually takes into account not only the moving but also the exhausting cosmos.