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Big Data and the Thermodynamics of Discretisation

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Technics derive from our organism's thermodynamic condition. We must think of hominisation and its technological advance as being fundamentally driven by a thermodynamic relaxation process. Observation, retention, protention, memory, expectation, and the technologies that have always mediated these activities, are ultimately inscribed in material reality's economics of hot and cold, movement and stasis, chaos and order. As living beings, we are *negentropic*, and our technologies are ultimately extensions of our biological drive to expand our phase space [1] and avoid fatal thermodynamic phase transitions. When it gets too hot, we sweat to release excess heat; when it gets too cold, we get goosebumps and our hairs stand on end, producing an insulating air-barrier. Artificial, technical modes of self-regulation expand the organism's capacity to pursue its metastable becoming. What is key here is how the organism knows if it is too hot or too cold: cognition. The organism gathers information about its environment. Indeed information derives from this process of observation; it emerges from the transductive production of the organism-environment relation, in the gap that progressively appears between the terms. Claude Shannon's original theory described information as a measure of the *improbability* of a signal: a signal contains information to the degree that it deviates from the most probable state.[2] Information is a by-product of the organism's activity of observation: an unexpected occurrence is an event, which causes an update in the organism's horizon of expectation, whereas an expected occurrence merely confirms the anticipation. Information is therefore

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[1] Giuseppe Longo and Maël Montévil, "The Inert vs. the Living State of Matter: Extended Criticality, Time Geometry, Anti-Entropy – An Overview", *Frontiers in Physiology* 3 (2012) page numbers?

[2] Claude Shannon, "A Mathematical Theory of Communication", *Bell System Technical Journal* 27, no. 3 (1948), 379–423. .

reflected in the various states that the organism adopts in reaction to incoming sensorial fluctuations. As Karl Friston's work shows, the biological system's active Bayesian inferential behaviour is intimately linked to the thermodynamic principle of free energy reduction.[3] And if our organism is geared toward avoiding thermodynamic thresholds and phase transitions, the same also goes for our technologies, our media, and communications systems, which are extensions of the immediate negentropic functions of the body.

In this light, Bernard Stiegler is right to stress that the fundamental drive behind the historical development of technics is the process of *discretisation*. Technics have in a sense always been about discerning and keeping track of the salient characteristics of the organism's environment, about putting a finger on the previously unknown microscopic events composing the macroscopic phenomena of our world, about increasing the granularity of our observations in order to make more precise predictions.

Data, Scale, Heat

Today, our technologies can peer into the smallest constituents of matter, and simulate the universe as it was moments after its spontaneous break from eternal silence. One of the most important big data endeavours is that of the Large Hadron Collider (LHC), the most complex machine ever built, whose collision detectors collect an unprecedented amount of data. The ATLAS detector captures 40 million 3D photos per second, each snapshot containing 92 million pixels. The vast datasets collected are then analysed with algorithmic tools, in order to find meaningful events, such as new particles. It uses up 1000 Gw of electricity per year.

This invocation of the LHC is meant to illustrate a certain nexus of ideas. First, it emphasises that *big* data is matter of scale. Literally, if big data is so big, it is because it results from the technical impetus to discern smaller and smaller details of the world. *Big* data should therefore be regarded as a contemporary effect of this historical

[3] Karl Friston,"The Free-Energy Principle: A Unified Brain Theory?" *Nature Reviews Neuroscience* 11, no. 2 (2010), 127–38.; Karl Friston, James Kilner, and Lee Harrison, "A Free Energy Principle for the Brain", *Journal of Physiology-Paris*100, no. 1–3 (2006), 70–87.

process of discretisation, of measuring, and of keeping track of ever more minuscule details, events, interactions, locations, positions, and correlations, in the technological pursuit of more optimal predictive inferences.

Secondly, and just as importantly, the LHC demonstrates that in a sense Marshall McLuhan was right: there are *media hot and media cold*.[4] That is to say, our technologies, our measuring devices, our media and communications systems, in sum, all of the extensions of human existence into the non-living realm, are submitted to the thermodynamic constraints of the universe. Great quantities of energy are needed to run the LHC's subatomic collision experiments. In order to discern the fundamental constituents of matter, it must recreate the extreme temperatures of the early universe. This is characteristic of all discretisation: it consumes energy to break things apart, to pulverise, to filter matter and reveal an ever finer granularity of the world. But energy is also required by discretisation's complimentary aspect: recording, storage, *memory*. If discretisation is a matter of heating, memory is a matter of cooling. All information storage is, in some sense, 'cold storage'. Memory is a keeping-cool, a slowing down of entropy's insatiable drive to chaos. And if technological progress has contributed to a 'global warming', it is because an increase in *environmental entropy* is the price we pay for *mnemonic negentropy*. Let's look at some examples. According to the influential *early anthropogenic hypothesis* put forth by climatologist William Ruddiman, the Anthropocene has deep historical roots going back thousands of years; since the neolithic transition to agriculture, humans have inevitably modified the concentrations of methane and CO_2 in the atmosphere, and perhaps even prevented the earth from sliding into the next ice age.[5] On the scale of human physiology, a similar thermal process is evident: when humans evolved larger, thermally expensive brains, they lost their body hair and developed sweat glands to help dissipate the excess heat. Similarly, to cool today's energy-hungry data centres, we increasingly build them in arctic climates. In other words, there is always a thermal trade-off for the technological taming of

[4] Marshall McLuhan, *Understanding Media: The Extensions of Man* (Cambridge, Mass: The MIT Press, 1994).
[5] William F. Ruddiman, "The Anthropogenic Greenhouse Era Began Thousands of Years Ago", *Climatic Change* 61, no. 3 (n.d.), 261–93.

unexpectedness in the environment: we heat the globe in order to keep our memories and expectations cool; we increase entropy *over there* in order to decrease it *over here*.

It is furthermore important to stress the material condition of information. As Rolf Landauer showed, *thermodynamic* irreversibility is linked to *logical* irreversibility.[6] All information has a thermodynamic signature. This is due to the fact that information is invariably expressed in physical configurations of matter, in the organisation of a given system's *degrees of freedom*. When we copy information from one context to another, we have to physically implement the information by placing the variables into some specific configuration, which expresses it. In early computers we had arrays of electromechanical relays constantly clicking away as a computation was taking place: in order for computations to happen, actual material objects need to be physically flipped into various configurations. And when they are not flipping they need to stay in place. That is why electronic components begin to malfunction when they get too hot; bits flip for no apparent reason, making computations unreliable. The physical components of a computer are not merely *representing* data, as if it were elsewhere, for example in some spooky world of immateriality. The configuration of the elements of an information processing system, be it a computer or a brain, does not represent information, but *instantiates* it. There can be no information that is not physically implemented in some material system. Even thought itself, as immaterial as it may seem to the thinker, is itself implemented by its material substrate and functional configuration.

With all this in mind, the evolution of mnemotechnics toward this horizon of big data appears to result from a material, thermodynamic process that concerns information's connection with the molar/molecular distinction, as well as with energy and its inscription into an economy of motion and rest, hot and cold. Since information emerges from the organism's discerning and tracking of differences in the world around it, it is inextricable from the living being's irreducible orientation within time, and the fact that it does not know the future. If, as Shannon observed, information is a measure of

[6] Rolf Landauer, "Irreversibility and Heat Generation in the Computing Process", *IBM J. Res. Dev.* 5, no. 3 (1961), 183–91.

the unexpectedness of an event, it is therefore inseparable from the essentially *predictive* character of life's pursuit of existence. The organism makes these predictions by repeatedly sampling, memorising, and comparing new results to past ones, updating its horizon of expectation. Discretisation refines the granularity of these samplings and comparisons and, in principle, increases the reliability of the organism's predictions, allowing it to extend its phase space.

Material Limits of Discretisation

The history of computing follows discretisation's progressive shrinking toward the nanoscale. For decades *Moore's law* has served as an index of this exponential progress. Moore's law is a measure of the rate at which civilisation miniaturises its computational technologies, the rate at which the quantity of components we can 'cram' onto integrated-circuits doubles. Long gone are the days of the relay and vacuum tube in the computer circuit. Simultaneously, it concerns the acceleration of processing speeds, as well as the rate at which energy consumption per computation decreases. But for over a decade, we have seen Moore's law slow down, and level off. The curve is flat-lining. Why is this? While there are some economic and environmental factors involved in this slow down, Moore's law has been shown to be rubbing up against physical limits.

We are now manufacturing the most advanced processors with individual components of only 16 nanometres, using lasers and optics capable of etching silicon at sub-wavelength scales. Yet at this scale, thermodynamic limits and material constraints come into play, beyond which transistors and logical components fail to be reliable. At these scales quantum tunnelling becomes a factor, and it becomes increasingly difficult to design circuits that keep the bit of information in place for the duration of the computation's time step.

So, being derivative of the more fundamental process of discretisation, if Moore's law is rubbing up against thermodynamic limits, might this mean that discretisation more generally is beginning to meet its own material limits? This would certainly resonate with the discontents of the Anthropocene. For what is the Anthropocene other than a collective realisation of the material finitude of human progress? This would stem from big data's sublime 'bigness', which implies not only a question of quantitative degree, but perhaps the transgression of a qualitative threshold: that it is *too big* for us to fathom, that there is *too much* information for us to process or track. As Leonard Susskind says: "entropy is hidden information. In most cases, the information is hidden because it concerns things that are too small to see and too numerous to keep track of."[7] It follows that, as our process of discretisation plunges into the nanoscale, our capacity to track and to produce meaningful information gives way to entropy. Actuality is traded in for superposed possibilities, and the world progressively recedes into digital obscurity. We are in effect blanketing the world in a *data cloud,* which, like the weather, is ultimately unpredictable save for short-term probabilistic forecasts. Perhaps the future promises data storms and data floods, various information disasters in parallel to climate change. For in the century of automation, not only are machines displacing the body as means of production (for example, by taking the place of the factory worker), but more importantly, now the endeavours of observation, interpretation, and discernment themselves are outsourced to machines.[8] If today the fabric of intelligibility is wearing thin, it is in part because our world is increasingly determined by vast banks of meaningless data, that is, data that is generated by, and for, 'discrete-state machines' which do not directly participate in the 'extended criticality' of biological organisms.[9] Simultaneously we are socially isolated within our individual accesses to information, increasingly living our lives in the *solitary confinement* of our 'filter bubbles',[10] and the algorithmic eyes which now do the work of recognising patterns in the petabytes of social and economic data we process, may no longer route back to any human mind. The big data horizon might thus signal an increasing cultural *myopia*, a question of *no longer seeing the forest through the trees*, where discretisation has reached a threshold beyond which it offers diminishing returns. We have perhaps always

[7] Leonard Susskind, *The Black Hole War: My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics* (New York: Back Bay Books, 2009), 133.
[8] Bernard Stiegler, *La Société automatique, I: L'Avenir du travail* (Paris: Fayard, 2015).
[9] Francis Bailly and Giuseppe Longo, *Mathematics and the Natural Sciences: The Physical Singularity of Life* (London: Imperial College Press, 2011).
[10] Eli Pariser, *The Filter Bubble: How the New Personalized Web Is Changing What We Read and How We Think* (New York: Penguin, 2012).

outsourced memory with technical aids, but now algorithmic social automation risks outsourcing the central role of cognition itself.

From a speculative thermodynamic perspective, these symptoms of discretisation in the Anthropocene evoke a system that is creeping toward a critical state, no longer capable of dissipating excess heat and entropy to ensure the pursuit of individuation. For if information is the product of our organismic process of free-energy reduction, what else could be signified by the diminishing returns of information production? The post-human horizon, the technological singularity, and other variants of this contemporary narrative of the 'boundary' reached by techno-genesis, might therefore be thought of in terms of a *phase transition*, where all trajectories become non-linear and impossible to predict. To gloss on Max Tegmark's convenient terminology: might it be getting *too hot* or *too cold* for 'perceptronium'? [11] Is our runaway process of discretisation doomed to exceed the thermal bounds of the living? Are we exhausting the material conditions for the exotic states of matter that correspond to cognition? Of course, such a threshold may still be a long way off, but it is crucial to think about this tendency now that the symptoms begin to appear.

Logical Limits of Discretisation

The narrative of human enlightenment through the application of reason, the dream of eliminating uncertainty through the rational application of algorithmic rules, ultimately evoke the prospect of omniscience. The figure of Laplace's demon, for whom the future and past are as vivid as the present moment, is the prime representative of what is projected by the narrative of transhuman progress toward total mastery of the unknown. But in addition to the thermodynamic constraints already visited, the narratives that legitimate the historical process of discretisation in this way may also encounter *logical* limits. This is due to a curious epistemological *circularity between cognition, information, and matter*.

[11] Max Tegmark, "Consciousness as a State of Matter." *arXiv:1401.1219 [cond-Mat, Physics:hep-Th, Physics:quant-Ph]*, accessed January 6, 2014, http://arxiv.org/abs/1401.1219.

Recall that, as physics now sees it, from a cosmological perspective, matter is ultimately made of information. As John Wheeler famously said, the universe is constructed "it from bit". If one zooms into any parcel of reality, eventually one reaches the Planck scale, where the reciprocal constraints between the known forces and constants of the universe impose a block on microscopy, and one can zoom in no further. At this scale, reality bubbles into a quantum foam of reciprocal relations between causally entangled cosmic degrees of freedom. In one compelling theory, the entire observable universe is thought to be completely specified by information inscribed at the Planck scale on the surface of our inflationary bubble.[12] The stuff of the world is just as immaterial as a choice between yes or no, existence or nonexistence. The recalcitrance and resilience of matter is an effect of 'spontaneous' symmetry breakings, which will have distributed matter this way and not another.

But stating that matter is ultimately made of information implies that the role of cognition in the universe is ineliminable. Wheeler notes:

> 'It from bit" symbolizes the idea that every item of the physical world has at bottom [...] an immaterial source and explanation; that which we call reality arises in the last analysis from the posing of yes–no questions and the registering of equipment-evoked responses; in short, that all things physical are information-theoretic in origin and that this is a participatory universe.[13]

This makes sense because, as we have seen, information derives from the organism's cognitive activities: information is a measure of the unexpectedness of an occurrence for the given observer. This leads to the epistemological circularity which Wheeler illustrated with his famous 'U' symbol for the participatory character of cognition and cosmos. If the observing organism is itself a material entity, then it too is ultimately reducible to information, which implies a strange

[12] Susskind, *The Black Hole War.*
[13] John Archibald Wheeler, *Information, Physics, Quantum: The Search for Links*. Physics Dept., University of Texas, 1990.

loop: not only does information *depend* on observation, it is also its *precondition*.

To put it schematically:

- Matter derives from (is made up of) information.
- Information derives from cognition (for it depends on the observer's horizon of expectation).
- Cognition derives from the toils of matter (for living matter presumably emerges from non-non-living matter)… and the cycle begins anew, with living matter observing the universe and deriving information as a measure of its predictability.

This circular explanatory chain suggests that, on its own, the unilateral discretisation of nature in the pursuit of uncertainty reduction need not be sustainable in the long run. If anything we should be less optimistic about our capacities to reduce uncertainty, for it suggests that omniscience is logically unobtainable and that more contingency always awaits us beyond each new granular scale of observation.

The prospect of omniscience rests on the ontological validity of *superveniance*: the absolute reducibility of every macroscopic event or property to the microphysical structure that composes reality. Superveniance implies that there is no novelty on any level of organisation except the most fundamental microscopic one, and that macroscopic organisation is inefficacious and not causally involved in the production of new events. Once the microphysical constituents of a phenomenon are in their places, so are its macroscopic properties, meaning that the macrophysical is absolutely specified by, or *supervenes* on, the microphysical. This view implies that, if only we could build larger and larger particle accelerators and track the microphysical constituents of reality, there would be no need for any other form of science. The chemical folds perfectly into the physical, as does the biological and even the psychological. The intricacies of mind and the complexities of social interactions are held to be perfectly stipulated by the fundamental indivisibles of reality. Thus superveniance implies that any novelty observed on the macroscopic level, or any so-called irreducible 'emergent' properties, are merely illusions resulting from observer ignorance. There is no novelty on the macro scale, there is no possibility for 'top-down' causation, and any property we may ever observe that resembles such phenomena, isultimately the effectof our ignorance of the microphysical 'particles' which underlie them. As in the influential arguments of Jaegwon Kim, this means that there is no way for anything like human 'normativity' to emerge, no possibility for 'mental causation', no way for an emergent network of reciprocal determinations to boot-strap themselves, as it were, to 'lift off' from their substrate and become autonomously self-sustaining and regulating, selecting and organising their milieu, like the mechanisms of life and cognition.[14]

But the matter-information-cognition loop challenges this picture. First of all, by 'explaining away' agency and cognition, superveniance abandons its ontological status. For, as Johanna Seibt argues, "just like theoretical concepts in science need a *model* or canonical illustration to serve their explanatory function[,] [a]n ontological model must be […] 'founded' in […] agentive experience".[15] But furthermore, in its evacuation of agential cognition, the theory of superveniance also undercuts science's best understanding of matter: it from bit. The information matter must derive from makes no sense in the absence of cognition. Superveniance therefore fails to account for matter in the scientific sense because it stubbornly rejects the logical circularity of cognition and world.

If we take the matter-information-cognition loop seriously, however, we are left with a world that resembles that explored in Eugene Wigner's famous little paper, *The Unreasonable Effectiveness of Mathematics in the Natural Sciences* (1960). "[I]t is possible that the theories, which we consider to be "proved" by a number of numerical agreements which appear to be large enough for us, are [nevertheless] false because they are in conflict with a possible more encompassing theory which is beyond our [current] means to discover." "[Our] level of ingenuity is a continuous variable and it is unlikely that a relatively small variation of this continuous variable [will change] the attainable

[14] Jaegwon Kim, *Supervenience and Mind: Selected Philosophical Essays* (Cambridge: Cambridge University Press, 1993). Page number?

[15] Johanna Seibt, "Free Process Theory: Towards a Typology of Occurrings", *Process Theories: Crossdisciplinary Studies in Dynamic Categories*, ed. Johanna Seibt (Dordrecht: Springer, 2003), 25.

picture of the world from inconsistent to consistent."[16] In other words, our science will always be left facing a boundary of pure chaotic unpredictability. For cognition is and always will be bounded and situated within a path-dependent, contingent process that may lead toward relatively higher degrees of granularity, or lower levels of symmetry, but there is no reason to believe that this process is anything but *asymptotic*. Organisms and their cognitive relationship to the world are path-dependent. All the symmetries and invariances that we observe in nature, and which come to be the basis of scientific knowledge, are functions of the paths (of least resistance) that our organisms and their ancestors have adopted to interact with objects in the world, and vice versa. We would not know what we know if we had had a different, contingent history, both on the social-historical scale and on the scale of the deep time of evolution. The fact that we gain knowledge from such path-dependent, contingent processes as observers means that we are necessarily imperfect knowers.Even though there are ways of reducing the negative effects of our bounded rationality, all of these amount to nothing more than provisional strategies of risk management, for there is no objective measure for the optimisation of our inferences about the world. There seems to be an irreducible gap between cognition and world, which implies the impossibility of a total knowledge of the universe, of total predictability. The Laplacian world, like the pseudo-ontology of superveniance, is not only practically unfeasible, but also logically untenable.

Conclusion

In my view, we are urged by these realisations to seek ways out of the monadic relation which characterises discretisation's unidirectional decoding of nature and which leads ostensibly to the horizon of big data. Is there not a different class of relations that characterise the organism? Bailly and Longo[17] aptly describe the "singularity of the

[16] Eugene P. Wigner, "The Unreasonable Effectiveness of Mathematics in the Natural Sciences. Richard Courant Lecture in Mathematical Sciences Delivered at New York University, May 11, 1959", *Communications on Pure and Applied Mathematics*, Vol. 13, No. 1 (February 1960), 1–14..

[17] Bailly and Longo, *Mathematics and the Natural Sciences*.

living" as an organismic mastery of the perpetual phase transition, corresponding in many ways to the integrative process of what Whitehead called 'concrescence', or what Deleuze called 'synthesis'. The organism's mereological resonance does not follow from the process of discretisation; it is a different class or category of activity, one of integration, of renormalisation, of 'passing to the limit'. Today, while in its unilateral application of the rule the algorithm is intrinsically eliminative and selective, *aesthesis* remains essentially integrative[18] and specifically concerns an inclusive concrescence of differences. Cognition not only requires discernment, but also concerns the inclusive *all-at-onceness* of an experience, which corresponds to a *multilateral* relationality, a transduction of many perspectives, many points of view on the world, many *monads*. And it is this capacity for integration that the algorithmic machines, to which we have outsourced cognition, fail to realise. Our runaway process of discretisation evacuates the synthetic condition of sensation, on which the participatory universe, and all intelligibility, depends. Rather than a unilateral monadic relation between subject and object (or predicate), *aesthesia* concerns the co-conditioning of multiple expressions of the world, a world which, as in Leibniz, is nowhere but in its diffractive perspectives upon it, mutually constrained by their *com-possibility*, their reciprocal inclusion. We can thus conclude with the speculative suggestion that the automated society of unilateral control, which Deleuze influentially described in his *Post-script*,[19] will best be fought with a privileging of aesthetic integration and reticulation, as a necessary compliment to the process of discretisation which now runs amok.

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[18] Giulio Tononi, "Consciousness as Integrated Information: A Provisional Manifesto", *The Biological Bulletin* 215, no. 3 (2008), 216–42.
[19] Gilles Deleuze, "Postscript on the Societies of Control", *October* 59 (1992): 3–7.