Opinion

Life’s arrow: the Epistemic Singularity

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For centuries people have been asking, “Why is there something rather than nothing?” Science has not been able to give us an answer so far. We still have to live with the basic statement that “Everything that is, and it is as long as it keeps its identity, that is, its onticity”, which we may call the “Strong Ontic Principle”. Nonetheless, science can answer another ontological question, namely “Why does something happen; why there are events in the universe?” The answer is the second law of thermodynamics, which we may call the “Weak Ontic Principle”. It was discovered by Rudolf Clausius in 1865, and it has been applied successfully in technological practice. However, at the conceptual level, the law has been subject to an amazing misinterpretation for almost a century. Its recent reformulation may become one of the most remarkable chapters in the history of science.

Energy is distributed unevenly in the universe, and it is those differences in energy densities—energy gradients—that drive all events. The universe has a “time arrow”: it is moving in one direction while a quantity called entropy always increases. Entropy has been interpreted incorrectly as being equal to disorder. However, the increase of entropy is in fact a measure of diminishing energy gradients, of energy dissipation and “homogenization”. Without energy gradients, the universe would be in thermodynamic equilibrium, and events would no longer be possible.

The original version of the second law by Clausius—that entropy always increases—therefore defines the direction of the movement of the universe. During the second half of the 20th century, several scientists pondered over the rate of the movement and their reasoning culminated in a principle now called the “Maximum Entropy Production Principle” (MEPP): entropy not only tends to increase, but it tends to increase at the fastest rate given the constraints. Martyushov and Selezniev argue that the MEPP may be viewed as the natural generalization of the second law [1]. Arto Annila and his collaborators state, “The second law of thermodynamics simply says that differences in energy densities will level off in least time” [2]. Annila further argues that the imperative of maximizing the rate of entropy increase has its equivalent in the principle of least action (PLA), which stipulates that a quantity called ‘action’ is minimized. Incidentally, Max Planck characterized the PLA as the most general principle of physics in 1958. Ever since, many physicists have proven that PLA is a simple but powerful framework for unifying Newtonian mechanics, relativity and quantum mechanics.

Another breakthrough has been the discovery that, in a universe that abounds with steep energy gradients and aims at equalizing them as fast as possible, the most efficient way to dissipate energy is by “structuring work”. Bénard convection cells, tornados, hurricanes and chemical autocatalytic systems are examples of such “dissipative structures”, as Ilya Prigogine named them. Life itself may be interpreted as a very efficient mode of abolishing energy gradients. It emerged to speed up the rate of dissipation by continually removing constraints, generating diverse dissipators and successively replacing these with novel dissipators that are ever more effective in energy dissipation. We may assume that the evolution of the universe is a continuous acceleration of energy dissipation and, correspondingly, increase of structural complexity and that life is a specific step in this continuous process.

With the single exception of life, no structure uses energy purposely to serve their self-preservation, to ensure their onticity. Once the energy gradient sinks below a critical point, an inanimate dissipative structure disintegrates and ceases to exist. Living structures are not only able to maintain their onticity, but also to grow, break up to give rise to self-similar structures—which, eventually, became the source of reproduction in living systems—to survive if the energy gradient becomes weaker and even, transiently nil, and to spread to new localities to find new gradients of energy. The work used for maintaining permanence of such a system, its onticity, corresponds to the “ontic work”. In fact, living systems can be named ontotelic systems, as maintaining their onticity seems to be their ultimate purpose and utility.

Furthermore, ontotelic systems consist of aggregations of dissipative and non-dissipative structures; the latter represent constructions. Constructions do not continuously dissipate energy, but transiently maintain their stability and a distance from thermodynamic equilibrium, because high kinetic barriers prevent their falling apart. So far, we have no thermodynamic theory of constructions. In biological evolution, constructions came into existence by chance, and the memory of this particular chance has been retained and repeated. In extant living systems, this memory has been deposited in genomes, in specific connections of brain neurons and, in the case of the human species, in the artefacts of cultural evolution.

The driving force behind this permanent acceleration of evolution is epistemogenesis: the acquisition and steady accumulation of knowledge. The view that life is cognition, and that the evolution of life is the evolution of knowledge, has gained further support by the recent reformulation of the second law of thermodynamics. To ensure the persistence of mutually competing dissipators in an ever more complex world, life performs increasingly efficient epistemic work. This acquisition of new knowledge is not deterministic. It can eventually be reached only by blindly fumbling in all directions. In the course of evolution, living species move forward in an epistemic maze with countless
blind alleys and possibly only a single way out. Cognition enables species to compete for effective dissipation of energy gradients and to search for new ones; the individual members of a species function as “fumbling fingers”. The losers end up in a deadlock, and new and more complex living forms move ahead. On Earth, humans are the species that has advanced most in the epistemetic maze.

Humans are now living at a time when a single generation can witness the quick rise of energy dissipation and the parallel growth of knowledge. From our vantage point, we can oversee the full panorama of the evolution of the universe. “In the beginning”, to borrow from the Book of Genesis, there was no life and no structures—just unhomogenously distributed energy patches and matter. No superior intelligence to create life. No Aristotle’s Unmoved Mover, no Georg Friedrich Hegel’s Absolute Spirit, no Pierre Theilard de Chardin’s God Creator, who moulded humans to his image and made them his co-creators [3]. No knowledge at the start. Life arose out of nothing as a slow, continuous growth of knowledge, and matter was moving ever farther away from equilibrium through sheer trial and error. A random walk that zigzagged through trajectories, using the accumulated knowledge; a model of the world, which was becoming ever less simple, ever more comprehensive, until a twisting curve became a straight line—a paragon of reason and rationality.

The reason why cognition has become the most important factor for accelerating evolution is straightforward: the kinetics of epistemogenesis is exponential or even hyperbolic. In the simplest case, an increase of knowledge $\frac{dK}{dt} = cK$ with $K = e^t$. However, existing pieces of knowledge can interact in synergy; in such a case, the increase of knowledge $\frac{dK}{dt} = ck^2$ and the growth become hyperbolic: $K = \frac{1}{c} (t_m - t)$. While the doubling time during exponential growth is constant, hyperbolic growth is characterized by the fact that the doubling time halves at every doubling of a variable. Hyperbolic growth is linked to the notion of a mathematical singularity: a point at which the rate of change and the quantity of a variable become infinite at a finite time $t_m$.

The human species may now be close to a particular kind of singularity commonly called the Technological Singularity: a point, at which knowledge and artificial intelligence would surpass understanding and control by humans. Ray Kurzweil and many other singularitarians have dated the Technological Singularity to the middle of the 21st century [4]. But life as a whole is apparently directed towards a distinct singularity, the Epistemic Singularity. The Technological Singularity specifically concerns the human species on Earth, while the Epistemic Singularity applies to life in the entire universe. Two variables should converge to infinity at the Epistemic Singularity: knowledge, and the distance between the objective world and its mirror image in a cognizant subject—the one that will have traversed the entire maze of epistemogenesis.

Maximum knowledge would equal omniscience. Recalling that “knowledge is power”, one could argue that maximum knowledge may also equal almightiness. It would be creation as described by traditional religion, but in reverse, or Theilhard de Chardin’s cosmogenesis naturalized: from zero knowledge to omniscience and almightiness. The distance between Object and Subject increases hyperbolically to become eventually infinite. At the apex—the Epistemic Singularity—the world is equal to its model; Cosmos, facing complete knowledge faithfully mirrored by the Subject, will recognize itself. What a spectacle!

And yet, at the point of maximum knowledge and maximum distance from equilibrium, all energy gradients will be exhausted and the universal thermodynamic equilibrium, the state of indifference, will set in. Life will cease to exist. Cosmic evolution and time itself will stop. At the Epistemic Singularity, the self-recognition of the Cosmos will occur for an infinitesimally short instant and then vanish.

We do not know what the meaning of this is, because we are just actors in the middle the drama. We should accept with serenity and wisdom the prospect that the human species, once it will have reached the Technological Singularity, might end in deadlock and face extinction as many other species before. But in the meantime, we should enjoy the singular trait of our species, which enables us to delve deep into the structure of the universe. In 1927, Arthur Eddington wrote that the second law of thermodynamics holds “the supreme position among the laws of Nature”. As argued here, the second law can be derived from the principle of least action, which, in turn, can be derived from a description of the universe through general relativity and quantum mechanics. It seems likely that if we delved still deeper, the “final theory”, which we have not yet invented would be a theory of mind and its relation to the universe.

References