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LUCUBRATION

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ABSTRACT
The fascinating study of biological evolution has not yet provided answers about what separates living from inanimate matter. Although evolution is evidently part of a programme involving self-organization, it is unclear whether this programme is part of an established plan. Time plays a complex fundamental role, but no precise definition of time has yet been proposed. However, connections between modern theories, especially Prigogine's irreversibility and Tiezzi's ecodynamics, provide a macroscopic view of the world that enables comparison of the different levels that compose it.
Keywords: entropy, self-organization, time.

1 INTRODUCTION

When a sperm enters an ovum, an ordered sequence of events is triggered. The cells multiply, differentiate and form organs that begin to carry out cooperative functions. At the end of gestation a baby is born. When the umbilical cord is cut, the respiratory system comes into action, air enters the lungs and oxygen supply resumes by this new, especially predisposed route. The digestive system is also predisposed for the baby to receive nourishment in its new external environment. The baby is raised with care because of emotions, which are also predisposed for this purpose. The child becomes an adult and the cycle repeats from generation to generation.

It is impossible not to see a programme in all this; it is also evident that the programme implies self-organization: the characteristic of biological systems to acquire increasing levels of complexity, both individually and as global evolution.

Because this observation holds for the animal and plant kingdoms but not for the minerals, there is the perennial problem of understanding the diversity that separates the inanimate from the living. The elementary constituents are the same. It follows that diversity must be purely organizational, in other words it obeys some higher law that we do not yet understand. This obviously does not mean that understanding this law will give us the possibility of building life in the laboratory.

Irrespective of this basic unresolved problem, things seem to happen as if they had an aim or sprang from a starting point Alpha, fulfilling an evolutionary process to reach a destination Omega.

At all levels we observe events associated with emergence of novelty, that we can in turn associate with the creative power of Nature (Ilya Prigogine).

Prigogine's view introduces the transition from space culture to time culture, ascribing the scientific revolution at the end of the 20th century to the emerging properties, events and narrative elements of biological history. Concepts such as *dissipative structures* and *self-organization* have become quite popular.

Cycles, *arrow of time* and *events* represent a new lexicon for chemistry and physics that finally become evolutionary, taking up the challenge of complexity in an evolving biosphere. Chance plus choice (stochasticity) and the interactions between them are the basis of a new *ecodynamic science*. Quality and quantity are both necessary for the global description of Nature. *Biodiversity* is the result and the salient property of biological evolution.

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The adventure of biological evolution is marked by *chance events* and exact *choices*: it is a *stochastic adventure* in the etymological meaning of the word, from the Greek '*stokazomai*' to 'aim at the target' in archery. The arrows are distributed in an apparently random way around the bull's eye, but the hand of the archer chooses, as far as they can, the direction of the arrow: the system combines chance with selection. This combination can also be internal, when autocatalytic configurations select among their constituents.

Ecosystems arise and evolve stochastically by co-evolution and self-organization. They are complex systems, the components of which are all interconnected, and they do not obey linear deterministic laws.

As underlined by the palaeontologist Roberto Fondi: 'Cells differ from other physical systems by virtue of the increased complexity inherent in their *epigenetic development*, or in other words due to a series of geneses, each of which creates new structures and new functions. No machine or inanimate physical system can increase its complexity as can the simplest living cell'.

This means that the information necessary to assemble proteins, which DNA merely copies, can only result from the increase in complexity inherent in an *epigenetic process*.

Roberto Fondi adds that it is impossible to interpret the living world as a 'mere assemblage of objects dominated by the rigid deterministic dialectic of chance and necessity'.

Ecodynamics is a new science aiming to offer a proposal of cross-fertilization between Charles Darwin and Ilya Prigogine [1–3], but it has a flaw, because blind, mechanical, purposeless evolution happening by chance does not explain the constancy of the laws of nature that keep evolution ordered and regulate its course.

This also means that it is not possible to force nature into a cage of mechanical laws and aseptic mathematical models.

'The rules of law are accessory, those of Nature essential; those of law are agreed upon, not native, those of Nature native, not agreed upon.' (Antiphone the Sophist, 5th century BC) [1–3].

The obvious alternative view proposes considering the world as the effect of the plan of an Author whose work we are unable to understand. However, again one comes up against an almost captious difficulty. If one asks what this Author is doing and why, what he wants, who he is, where he comes from … one only shifts the problem. The statements of religious doctrines clearly cannot be mixed with the discoveries of scientific investigation, the only way to seek a rational explanation.

Comparison of the two views shows that the first implies the chance appearance of rigid but purposeless laws, like the mechanics of an avalanche, albeit so complex that they involve the unintentional development of life. The second offers the idea of a plan towards a goal (*metaphysical design*) with the consequence that inanimate matter seems to have a role purely supportive of living matter. The need to determine whether life can come only from life or whether it can also be built in the laboratory then becomes less pressing, because in either case, particularly in the second, one is faced with the operation of higher laws that drive self-organization to increasing levels of complexity, the development of intelligence and hence the advancement of knowledge, perhaps with some faculty of intervention in the general trend.

If one considers the purposive view more credible than the random one, it is necessary to critically examine the logical assumptions of the ideas to which it can give rise. If human collaboration is needed to reach Omega, the distant future cannot be determined, nor the near future, because then human actions would be just as obligatory as other events and everything would be preordained according to a rigid programme. However, it is risky to speak of future without first codifying the concept of time. When questioned on the subject, Augustine replied: 'If nobody asks me, I know, but if I have to explain, I no longer know'. We are not much further ahead today.

2 THE COMPLEXITY OF THE ROLE OF TIME

Time is commonly conceived as an axis, along which runs a point that indicates the present. The part of the axis already covered by the point represents the past, the other part the future. The past is known, univocally determined like a recording, whereas the future is unpredictable. This classical view holds for an observer united with the moving point. Like a traveller, he knows the state of his present moment and those that went before, but nothing about those to come. What would the situation looks like from a dimension outside the time axis, where time can be observed not as it flows, but as a whole, just as all the frames of a movie film can be observed simultaneously?

Various reflections are possible. If we suppose that the observer external to the time axis sees everything exactly defined as in the film, then the indeterminateness of the future is an illusion of the internal observer and not an objective property resulting from a rigid inescapable programme. One can object that this analogy is forced, because events that are now fixed on the film became definite progressively as filming proceeded, but were not determined beforehand, even if this objection offers its flank to fine criticism. However, it is difficult to image how the objective indeterminateness of internal future would appear to an external observer. An alternative is that the external observer sees the point running along the time axis and separating a well-defined past from a future that appears nebulous both to him and to the internal observer. But if this were so, the present of one would be the same as the present of the other and time would flow at the same rate for both and for any other observer, since (ignoring relativistic effects) there would be absolute universal time that would make calculations much easier, but futile.

The problem becomes even more complicated comparing irreversibility ‘in time’ with irreversibility ‘of time’ [4–7]. In the first case, as we have seen, it is impossible to invert the course of a phenomenon, reproducing the forward microstates in inverse order, but with regard to macroscopic effects, it is not impossible to open a door and then close it again without offending uncertainty and irreversibility. In the second case, it is interesting to reflect on a hypothetical universe under the same laws as the world we know except that the arrow of time is inverted, a hypothesis that can be contemplated in theory. Here some distinctions must be made. Without uncertainty [1–3], all events appear obliged as if they had already happened and had already been filmed in forward mode but were played backwards like a recording run backwards, something that is as unlikely as it is sterile. If on the other hand, we introduce uncertainty, the latter must be assumed so limited as to permit the nerve signals involved in movement of a hand to go backwards to the brain where they cause the corresponding mental operations, something that current knowledge of the physics of complex systems makes just as indigestible as the previous example.

In other words, the conceptual difficulties encountered with these problems indicate that the search for truth will require great effort. While physicists work at forcing what they are endeavouring to understand into equations, nature systematically rebels.

Inevitably, the aim of formalizing the notion of time connects with other studies, from which novelties emerge. Examples are Planck’s quantization, Einstein’s relativity, the Einstein–Podolsky–Rosen dispute on theory completeness, Heisenberg’s uncertainty, Dirac’s hidden variables, Schrödinger’s wave function, Prigogine’s irreversibility and Tiezzi’s ecodynamics [8].

According to Prigogine, entropy changes with time in according to the following equation:

$$dS/dt \geq 0 \tag{1}$$

where

$$dS = d_iS + d_eS \qquad d_iS \geq 0 \tag{2}$$

where d_eS is the transfer of entropy across the boundaries of the system and d_iS is the entropy produced within the system by irreversible processes.

In this formulation, the distinction between irreversible and reversible process is essential. Only irreversible processes produce entropy. For isolated systems $d_eS = 0$ and the previous equations becomes the classical Second Law of Thermodynamics. Open systems can conceivably evolve to steady states with:

$$d_eS = -d_iS, \quad dS = 0 \tag{3}$$

This is a non-equilibrium steady state in which order may be created from disorder.

Prigogine illustrates this entropic behaviour using the concept of entropy production (Fig. 1) [1–3].

This entropic behaviour marks the difference between living systems and inanimate things: living systems need a continuous flow of negative entropy from outside and a sink for an even greater amount of positive entropy. Indeed, the most probable state of living systems is an ordered one arising from chaos via self-organization: in this case entropy can decrease [3, 9].

The customary mental schemes are swept aside, theoretical aspects that cannot be ignored or visualized alternate or interweave and the task of finding a satisfactory univocal definition of time seems more and more difficult.

The spectator unfamiliar with such abstruse subjects, but anxious to understand and therefore unwilling to accept unproved assertions, can only try to follow and make do with the right to ascertain that elementary logical consequentiality is met. Obviously, the spectator must be able to string

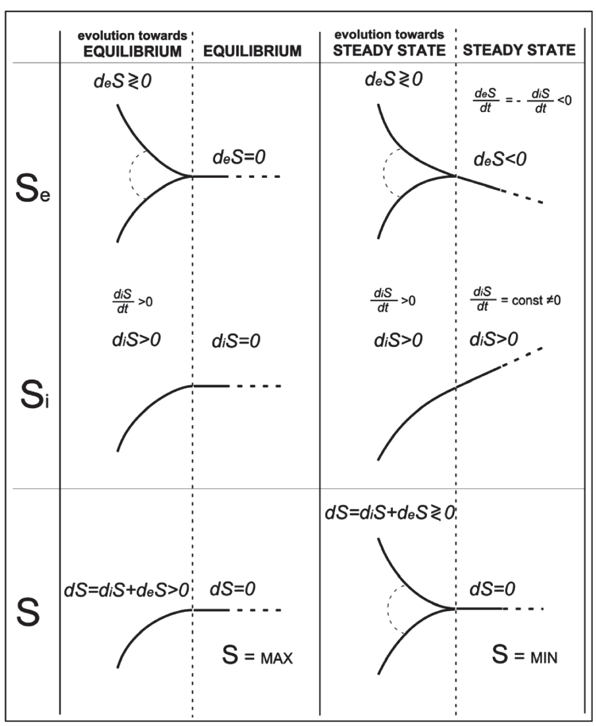

Figure 1: Variations in entropy in four different cases.

consequential propositions together in a self-compatible logical system (even if incomplete, as proven by Gödel) [10, 11], otherwise his observations have no value. If, for example, he shrugs off the mass-energy equivalence of Einstein, he only shows that he does not understand that to reject the result of a calculation, it is necessary to find an error in the process and/or choice of starting points.

Returning to the problem of time, it is clear that to speak of a future implies reference to a present that separates it from a past, in other words, reference to a stage of a process underway that cannot be distinguished from the history of a system in evolution (namely, a system far from thermodynamic equilibrium). This last condition is imposed because if the system was stationary instead of in a transient state, there would be no potential differences to drive entropic phenomena, and no evolution: the flow of time would not produce any observable effects and would therefore become a pure abstraction.

Considering a system in a transient state, the interconnections between Prigogine's irreversibility and Tiezzi's ecodynamics show that any event in nature proves non-reversible and non-reproducible. In other words, if the system has undergone a transformation from initial state A to final state B, it is impossible to bring it back to state A by running it back through all the microstates that led it to state B, and it is also impossible, assuming state B is the same as state A, repeat the cycle by the same sequence of microstates as before. All this places the unpredictability of the future on the solid pillar of objective uncertainty, which from the level of minute analytical representation – linked to the intimate structure of matter – has repercussions on the level of macroscopic observation. However, at that level, the same interconnections reveal other properties that somehow throw new light on the picture, since they show that the manners in which an event unfolds are not exactly reproducible; they also explain how the event can repeat in different but similar enough manners to be classifiable. That is, they explain how nature envisages trees, even if it never makes two the same.

Another illuminating aspect explained at macroscopic level regards mass phenomena. If, for example, one studies large quantities of water, one finds manifestations such as ice, an ocean or a snowfall, which elude the microphysicist. These are emerging phenomena, thus named because they only emerge from group behaviours and therefore present as responding to higher laws.

Taking the idea to its maximum, one may compare the different apprehensible aspects of the world at the microphysical, human and cosmic scales. In the first case, wherever it is, an electron interacts with other particles according to known mechanical and electrodynamic laws. In the second case, if situated in a living organism, the same electron behaves in the same way in its cell microenvironment, but also takes part in cooperative mechanisms that make up the overall activity of a much more complex system and are therefore ruled by higher laws. This is even more evident in the third case of cosmic level, where one may well think that supreme laws operate and generally tend to orientate evolution, not according to a fatal programme like a fall, but a targeted programme like growth.

3 CONCLUSION

To conclude, one may ask whether the world as a whole is knowable or if our position is like that of the foetus who cannot understand the external world, or like that of Saccharomycetes in an industrial process that could at most deduce that they are in the hands of the gods, who act for reasons they cannot understand. Apart from this basic doubt, which is more philosophical than scientific, the sights of research are set on smaller and larger dimensions. Taking the microscope as a symbol of the former, obviously not as an optical instrument but as a criterion of the type of study, the symbol of the latter can be termed 'macroscope'. Looking through the microscope one sees entities that cannot be translated into models seen at human scale; looking through the macroscope one can only see groups of celestial bodies. However, the hypothesis of an Intelligent Universe appears and is contemplated with attention, albeit for the moment only as something desirable.

Indeed, in that perspective, we could glimpse a possibility of liberation from our prison of matter and its inescapable natural laws. It is comforting to think of a system organized in such a way that the more complex it becomes, the more capable it is to change itself (aggradation, a trend in the opposite direction to thermodynamic equilibrium) and thus develop a directing force that enables it to intervene in the orientation of its own evolution. Neither is it unthinkable that the Universe as a whole constitutes an immense organism, nor that this organism, in the key of evolutionary physics, has the potential – inherent to intelligent life that is developing within it – to correct the flaws causing the ills. In other words, it seems legitimate to consider the hypothesis that our research drive is the effect of a design, as Paul Davies expressed it, our existence was wanted.

As St Augustine observed: 'What happens never breaks the laws of nature, but can be contrary to what we believe about those laws.' This is why research is done.

On one hand, we are prisoners because we are made of matter and cannot escape the laws of matter by changing or eluding them. On the other hand, we are operators capable of improving our state because we can investigate and discover the laws and exploit them to our advantage. Use of this faculty is always, however, subordinate to the condition of considering all observational data to be natural [12].

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