Ilya Prigogine and the PostModernity

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Introduction

As a response to the initial reactions to the ecological crisis in the 1960's, the aim of many researchers is now to provide frameworks to understand it. Thermodynamics and Ecology then became reference disciplines to achieve this goal. Ilya Prigogine contribution's to non-equilibrium thermodynamics was crucial to identify the principles of ecosystem functioning and the specificities of artificial ecosystems. This approach is currently developed by the 'Département de l'environnement[2]' at the Paris 7 University. The following text of Ilya Prigogine introduced the 1976 session of the E4 School (Ecole Européenne d'Eté d'Environnement)

Text of Ilya Prigogine

« The organizers of this School have asked me to write a short introduction. This is, of course, a great pleasure as more as several of my coworkers and colleagues have actively participated in these lectures and seminars.

It may be somewhat asthonishing at first that a physical chemist is interested in ecological problems. However, this is a natural outgrowth of my longtime interest in chemical systems which present the following characteristics: they are open to exchanges of matter with the outside world, they are in far from equilibrium conditions and present non linear chemical mechanisms. All these three characteristics are obviously present in ecological systems. In fact, already many years ago, my standard example for dissipative structures has always be a town. The importance of exchange of goods in the birth and development of towns is indeed obvious and it becomes easy to contrast the functional structure of a town with the equilibrium structure as manifest, for example, in crystals.

Ecology is a field of research in which the temporal evolution through successive instabilities can so to speak be seen with the naked eye. Also biological evolution proceeds on a very slow time scale while ecological and some aspects of sociocultural evolution can be perceived on a much more rapid scale comparable to our own life-time.

[1] The autor thanks Laurent Batréau and Catherine Brousse (Tecomah-Paris Chamber of Commerce and Industry) for helping him to write this article in English.
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> The dual aspect of the role of fluctuations and deterministic response can be described at least in simple situations in a mathematical form accessible to computer simulations and even in some cases to analytical analysis. It may be hoped that we reach here a type of description that may subsequently be extended to much more complicated situations.
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> Physics and chemistry have, for long time, been dealing with highly idealized objects ("pièces de musée" as they were called some what irreventially by Michel Serres). The considerations of the problems of importance in ecology are therefore likely to produce a deep impact on the evolution of modern physics and chemistry. This is one of the reasons why I am very happy that ecological problems play allways an important role in the applications of non-equilibrium theory as developed by our school. (Ilya Prigogine)"

Paris-Brussels

In addition to that introduction, Ilya Prigogine wrote, in French, an article developing his views under the title: « Métamorphoses de la Science[3] ». His main thesis is that the consolidation of a non-thermodynamic equilibrium demands to reconsider the epistemological foundations of Modern science. Besides this, the ecological crisis was mainly associated with the crisis of Modernity.

The views of Prigogine, both scientific and philosophical, presented a high level of interest to understand the issues involved in this major ecological disaster. His introductory text shows how he supported this approach. The School E4[4] has been one of the attempts to consolidate this innovative approach. Jacques Vigneron (1936, -), founder of the 'Département de l'environnement[5]' at the Paris 7 University[6] was there one of the main protagonists. The 1976 session took place at the University of Venice under the chairmanship of Professor Angelo A. Orio.

A major contribution to the seminar was Paul Duvigneaud's one (1913 -1991). His article quoted long extracts from his major work : "La synthèse écologique[7]" first published in 1974. Paul Duvigneaud conducted his research at the 'Université libre de Bruxelles[8]', where Ilya Prigogine was working too. There was therefore in the 1970' an axis Paris-Brussels, along which a theoretical vision of the environmental crisis from the combination of Thermodynamics and Ecology was initiated, under the guidance of these two scientists as main protagonists.

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[3] Metamorphosis of Science
[4] Ecole Européenne d'Eté d'Environnement (European Summer School for Environment)
[5] Department of Environment
[6] The Paris 7 University is one of the universities established in 1970 after the breakup of the Sorbonne.
[7] The Ecological Synthesis
[8] The Free University of Brussels

Ilya Prigogine was born in 1917 in Moscow. He died in 2003 in Brussels after having spent there his whole life. He had been the disciple of Théophile de Donder (1872-1957).

He extended his work in the non-equilibrium thermodynamics. I. Prigogine and P.Duvigneaud's teams gave a class within the « Maîtrise des Sciences et Techniques 'Protection de l'environnement[9]' » at the Paris 7 University, founded by Jacques Vigneron in 1970 (cf. Thierry Lavoux).

But while the class on non-equilibrium thermodynamics was given by Jacques Chanu, Paul Duvigneaud gave its own class on ecology from 1977 to 1983. This association has led to a thermodynamic approach of ecosystems functioning and an attempt to understand the ecological crisis by that light.

Entropy and Ecosystem

The entropy is the cardinal concept. The reference frame is the ecosystem designed as a 'dissipative structure'. Ilya Prigogine invented this term to characterize any system in non-equilibrium thermodynamic.

His contribution is crucial. He takes place in a long line of philosophers who questioned the complexity of living structures while the Second law of thermodynamics condemns them to disappear. This law states that any system tends, without constraint, to a state of thermodynamic equilibrium. The entropy of the system is then at its maximum. The conclusion issued from this work is that these structures remain in thermodynamic non-equilibrium dissipating flows of energy and materials.

The information theory emerging in the 1960' completed this vision. The non-equilibrium thermodynamics may be as well seen as the result of the dissipation of information flow. Ilya Prigogine's contribution to have developed the notion of dissipative structure, the assumption of local balance and the entropy balance equation.

A dissipative structure is a system far from equilibrium conditions whose characteristics, the state variables of the system, distinguich it from its environment. So, the entropy of the system is inferior to the entropy of the milieu; its environment.

The assumption of the local balance leads to the idea that this structure dissipates flows of material, energy and information (MEI flows) and produces entropy. The increase of this entropy condemn it to disappear. The solution is to export this entropy out of the system. Just as well as the law of Universal gravitation, no one escapes the Second law of thermodynamics.

[9] Masters degree in Science & Technics dealing with 'Environment Protection'

Ludwig Boltzmann (1844-1906) has indeed created a link between entropy, imprecise concept invented by thermodynamicists, and the 'disorder' in the common sense.

Here is the heart of the ecological crisis thermodynamical approach. Entropy export is possible only under one condition: to have an area appropriated to receive it. That's necessary. But it's not sufficient.

The development of non-equilibrium thermodynamics forced to segment the concept of entropy in two: the irreversible entropy and the reversible entropy. The baseline equation that formalizes this approach is the entropic balance equation:

$$\mathbf{dS = d_iS + d_eS}$$

- $\mathbf{d_iS}$: irreversible entropy;
- $\mathbf{d_eS}$: reversible entropy. That's entropy exported by the system.

While d_eS sign is undetermined, d_iS is always greater than 0.

Then, the ecological crisis seen from the frame of non-equilibrium thermodynamics is due to the production of reversible entropy generated by the dissipation of energy, material and informations flow. The evacuation of the entropy of the system is a prerequisite for its survival as well as the MEI flows dissipation. The evolution space of a dissipative system is therefore limited by these two borders: the MEI flows dissipation and the reversible entropy export.

One of the conclusions imposed by this model is that the more a system dissipates MEI flows, the more it produces entropy. The environmental crisis is one of the consequences. This model helps also to understand that our highly complex societies are producing an amazing entropy because they can use hidden flows of energy (coal, oil, radioactivity, and so on). The evacuation of that entropy is the condition for their survival, as well as for all dissipative structures in the biosphere.

But while natural ecosystems generate moderate entropic flows, modern societies create the conditions for their destabilization. The challenge is to choose the best strategy to overcome the consequences of this paradox. From this model a recent research has been developed. The purpose is to determine Principles of ecosystem functioning wich could be valid for all types of ecosystems.

One of the first application of this theory is Economics. Indeed, the first paradox that surprises the ecologist is that the economic science was built from the epistemological assumptions of Mechanics.

However, mechanical systems are in thermodynamic equilibrium while economic phenomena are not. They are consubstantial to artificial ecosystems. They exist because they dissipate MEI flows. The oil geopolitics proves that our modern societies could not exist without this resource.

Conclusion

Whereas Mechanics has more than three centuries of anteriority - Issac Newton published " Philosophiæ Naturalis Principia Mathematic[10]" in 1687 - Thermodynamics is a recent science. We have not yet measured the reach of its contributions. One certitude might be considered as confirmed : Ilya Prigogine will be, tomorrow, one of the emblematic figures of the PostModernity as well as Isaac Newton was for Modernity.

This PostModernity will participate to the worl 'reecologization'. The 'Département de l'environnement[11]' at the Paris 7 University has been during the 1970-1980 period, with Ilya Prigogine and Paul Duvigneaud, a trait-blazer in this field.

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[10] Principles mathematics of natural philosophy
[11] Department of Environment