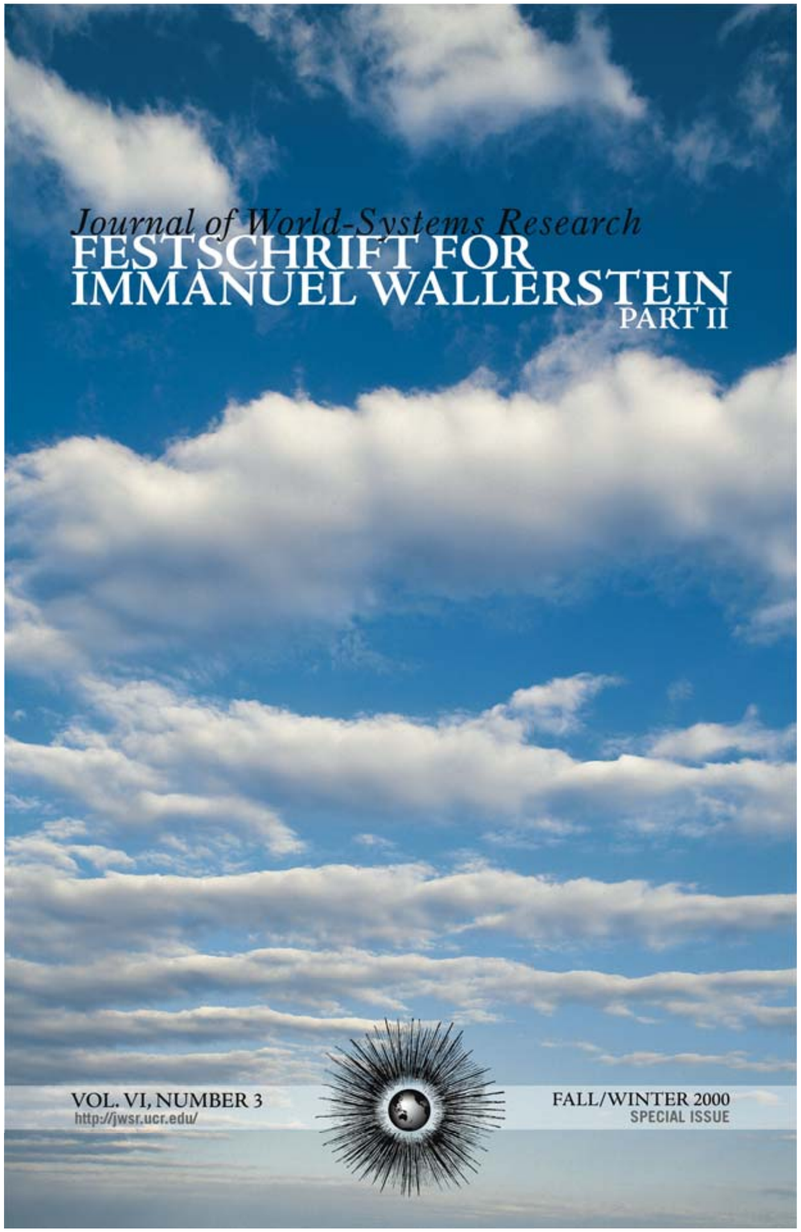

The Networked Society

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I.

It is a great privilege to participate in the Festschrift honoring Immanuel Wallerstein. I am very grateful to Professor Wallerstein for having recognized in my work in physics and chemistry aspects which may be of interest for history and sociology. (Wallerstein 1998)

Orthodox physics presented us with a view of a time-reversible, deterministic universe. This is in contrast to our observation that time-oriented processes appear at all levels of our observation. The classical answer to this contradiction is that it comes from our approximations, that we introduce the flow of time—history—by our approximations. This introduces an unacceptable dualistic view. In the past few years we have achieved a reformulation of the laws of physics which includes time-symmetry breaking. (Prigogine 1997) These are rigorous and important results that apply mainly to "large systems" as they are studied in thermodynamics or in fields theory, the main point of which has been to introduce probability as the most basic element. (Prigogine 1998a) In this new formulation, the world is a system in construction to which we bring a modest contribution. This

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change of perspective is mainly due to our progress in dynamical systems and spectral theory of operators. (Antoniou & Lumer 1999)

My scientific path began with philosophy and history. I also was interested in operational research. One of the first papers in which I applied non linear dynamics and bifurcation theory was "Kinetic theory of traffic." (Prigogine & Herman 1971) My coworkers and I were also deeply interested in the evolution of towns as a spatio-temporal problem.

It is therefore not astonishing that the scientific roads of Professor Wallerstein's and mine crossed, an encounter that has been the source of great satisfaction for me. In this volume, which I suppose will be mainly read by historians and sociologists, I thought that it would be more appropriate to center the presentation around one of the present sociological problems, a rather adventurous and risky undertaking. I attended recently a conference on the "networked society" organized by Professor G. Metakides. (Prigogine 1998b) I was impressed by the enthusiasm of the participants, leading me to formulate some ideas I now present here.

First, I feel that there is some analogy between the present evolution toward the networked society and the processes of self-organization I have studied in physics and chemistry. Indeed, nobody has planned the networked society and the information explosion. It is a remarkable example of spontaneous emergence of new forms of society. Complexity is moreover the key feature of far-from-equilibrium structures. The networked society is of course a non-equilibrium structure which emerged as a result of the recent developments in Information Technology.

The question is then "What will the future bring?" Is the networked society leading to some form of unification of humanity? This conclusion is by no means certain. My friend, Professor Jean-Louis Deneubourg, made the remark that networked societies have long existed amongst social insects. Today we know of about 12,000 different ant species, their colony sizes ranging from a few individuals to 20 million. Interestingly, the behaviors of the small colonies and the large ones are quite different. In a small colony individuals know what they must do at any moment. They forage and they come back to share their prey; they behave independently.

However, once the society becomes large, coordination becomes the major problem. There appear complex collective structures that spontaneously emerge from simple autocatalytic interactions between numerous individuals and the environment, mediated by chemical communication. In small colonies the complexity is localized at the individual, while in large ones complexity is more on the level on the interactions between the individuals. It is certainly not coincidental that in the largest and most integrated colonies—that is, in the army ants and termites—the individuals are practically blind. The networked ant societies are capable of extraordinary performances. In recent years, super colonies of ants, which contain hundreds of millions of individuals, have been discovered. These large colonies develop a network of communication between individual nests on tenths of kilometers—millions of times the size of a single ant.

The evolution from the small ant society to large ant society was the result of qualitative changes involving discontinuities. Such discontinuities appear in many fields (physics, chemistry and biology, for example) and are associated with bifurcations which play an important role in our present view of nature. These bifurcatoins lead to multiple possible outcomes associated with probabilities, destroying the classical deterministic view of nature. As such, I find it appropriate to first say a few words about bifurcations in nature before coming back to the problem of the human networked society.

II.

Results in nonequilibrium thermodynamics have shown that bifurcations require two conditions. First, systems have to be far from equilibrium. We have to deal with open systems exchanging energy, matter and information with the surrounding world. Secondly, we need non-linearity. This leads to a multiplicity of solutions. As mentioned above, the choice of the branch of the solution in the non-linear problem depends on probabilistic elements. Bifurcations provide a mechanism for the appearance of novelties in the physical world. In general, however, there are successions of bifurcations, introducing an "historical" element. It is now generally well understood that all structures around us are the specific outcomes of such historical processes. The simplest example is the behavior of chemical reactions in far-from-equilibrium systems. These conditions may lead to oscillating reactions, to so-called Turing patterns, or to chaos in which initially close trajectories deviate exponentially over time. The main point is that, for given boundary conditions (that is, for a given environment), allowing us to speak of self-organization. In this view the universe, including the human universe, is only one of the possible realizations of the laws of nature—the "possible" is richer than the actual.

Many authors have emphasized the importance of self-organization in nature. We experience this everyday in our networked society where information technologies provide the interconnections that introduce many nonlinearities and give rise to many new possibilities manifested as bifurcations. Consider for example electronic commerce, the virtual communities, the virtual enterprises and the more recent trend towards the cyber city-states like Singapore, San Diego, Krefeld and the European Project for Venice, Turin, Bologna, Florence. As Bart Steukers of IBM mentioned, the successful smart cities of the future are expected to address the multiple needs of their people. Their electronic hubs will be colorful and user friendly with convenient links to departments and services, multidimensional and interactive, not so unlike the animated piazzas of fifteenth-century Florence.

I also want to emphasize the extraordinary sensitivity of bifurcations. There are quite remarkable experiments by my former student, Professor Dilip Kondepudi, which show that small perturbations can affect the future of billions of molecules.

In order to assess the intrinsic uncertainty of nature, we have to look for statistical regularities and search for formulations of the laws of nature which are probabilistic and break the time symmetry, thus introducing an historical element. Such probabilistic formulations are indeed possible for complex systems. (Wallerstein 1998) Problems which have no solution on the deterministic level may have one on the probabilistic level. The resulting probabilistic algorithms are useful in pure science as well as in specific technological applications. My friend Professor Ioannis Antoniou mentioned to me the example of Optical Coherence Tomography where the uncertainty due to chaotic scattering of coherent light by the skin tissue is effectively assessed by a probabilistic filter resulting in tomographs very close to histological pictures. (Prigogine 1997)

In human society, the condition of non-equilibrium is obviously satisfied. Life is only possible in open systems exchanging matter, energy and information with the outside world. It is also clear that a society is a nonlinear system; what one person does influences the actions of others. This nonlinearity increases with the size of the society. Our present society is already full of possible bifurcations. Of course, bifurcation is a rather general term. If I decide to take my umbrella because of uncertain weather, or leave it at home, I may consider this already as a kind of bifurcation. Thus we must make a distinction between trivial bifurcations and bifurcations which indeed lead to new historical systems.

The great French historian Braudel has written: "Events are dust." This is only partially true. There are "well-defined events" which have shaped human history, a simple example of which is the neolithic bifurcation associated with an increased flow of energy coming from the discovery of agriculture and metallurgy and ultimately leading to a complex hierarchical society. I always found remarkable that the neolithic bifurcation emerged everywhere about the same period about ten thousand years ago, but that it emerged in different forms in the Middle East, in China or in Precolumbian America. This is similar to the branches of bifurcations which appear in chemical or physical systems.

We can of course quote other social bifurcations related to fossil energy: coal and oil which lead to the industrial society. Now we have information technology which leads to the networked society.

What will be the effect of the present bifurcation? Because of the scales involved we can expect a larger role for non-linear terms and therefore larger fluctuations and increased instability. Of course the present revolution is part of the technological bifurcation which started at the end of the 19th century and went through the whole 20th century; we therefore already have a period of about one century behind us. What effect did the technological revolution have on humanity in the past? In the 20th century there were, and still are, tragic events: wars, ethnic purification. But war and bloodshed are not something new.

We must recall the constructive, positive part of the technological revolution—the decrease of inequality. At the beginning of this century we had the gap between the "civilized" and the "uncivilized." The uncivilized were treated only slightly better than animals. Over the course of the century, the inequality between social classes has also decreased as well as the inequality within the family. However we are still far from a satisfactory situation. The gap between industrial states and developing countries is increasing. People have tried to give a quantitative formulation of this gap. According to what I read, the gap was one to five at the time of Louis XIV, one over hundred in the 1970s and would be now one over 4000. A large knowledge gap is also developing. This issue acquires a new formulation in the Networked Society. As Alvin Toffler puts it : "*The illiterate of the future will not be the person who cannot read. It will be the person who does not know how to learn*." Education objectives and priorities should change towards the ideal of continuous learning.

I believe that in the future the networked society will be judged according its impact on the inequality between the nations. Of course, there are well-known advantages to the networked society. However I think the judgment has to be based on more fundamental criteria. The American philosopher Whitehead has stated that the Greeks developed two aims for humanity: first, the intelligence of nature that is a rational formulation of the laws which rule matter or life, and, on the other hand, the establishment of a democracy based on the role of values. Will the networked society be a step in the direction of the realization of this goal? From this point of view it is interesting that each bifurcation in the past resulted in people who benefited from it and in people who became victims. The neolithic revolution led to extraordinary gains in the field of the arts. It led to the construction of pyramids for the pharaohs but also to common graves for the common people. However, slavery probably also started with the neolithic civilization and has continued up to this day. Similarly, the industrial civilization led to the development of the proletariat in addition to increased wealth.

To conclude, I would like to formulate some questions:

(1) Who will benefit from the networked society? Will it lower the wealth gap between nations?
(2) What will be the effect of the networked society on individual creativity?
(3) A recent pool has shown that, for the large majority of people, the hope of the third millenium is for greater harmony between man and nature and amongst humans. How will the networked society affect this harmony? For me, these are not only abstract questions, but also guidelines for reflection and action.

Finally I want to express my admiration for the work of Immanuel Wallerstein. We need to break with traditional wisdom. The work of Immanuel Wallerstein is full of new perspectives. I can only wish that he will be able to continue his seminal work for many years to come.

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