About the Relationship between Science, Technology and Society[+]

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1. Arts and Sciences. Existential Questions

Presenting the subject about the relationship between science and technology and society at this symposium in the famous Guggenheim Museum of Bilbao, there could not be a better way for situating the subject of this contribution in referring to a marvelous painting of Paul Gauguin. On the painting (1897, Museum of Fine Arts, Boston) are painted the following three questions:

D'où Venons Nous (where are we coming from?)
Que Sommes Nous (who are we?)
Où Allons Nous (where are we going to?)

The artist may have thought that the answer of these questions should be given by philosophers. In this presentation, the contribution of sciences in the search for answers on these questions will be attempted. The impact of technology on society of will also be discussed.

From an historical point of view science and technology, but in the first place science, have largely contributed to the vision of man about himself. Science has largely contributed to a profound modification of the perception of man about the universe and the place of our planet within this universe. Also science has modified the opinion about the place and origin of man on earth. Through the results of scientific discoveries the perception of man on its environment has been modified profoundly, at the same time his own perception about himself changed in the same degree. The scientific methodology is based on observation, experimental verification and the use of mathematical equations and laws, allowing a quantitative evaluation of the relations between phenomena. The construction of the scientific argumentation is the result of a rational analysis.

Along with scientific activity, technology has emerged and its impact on society has become overwheming. In all fields of society, in all fields of human activity technology is present. The pace of technological progress and

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innovation has reached tremendous heights, at a degree one may wonder to what extent society will be able to follow that continuous change.

In the conclusion of this presentation some perspectives for the future of science and technology related to the described fundamental questions, are drawn.

Finally, having made reference to the painting of Paul Gauguin and the fundamental questions painted on it and the answers brought by sciences and technology, it has hopefully allowed us to narrow the gap between sciences and arts and between sciences and philosophy. It can also be regarded as an homage to the mission of our European Academy of Sciences and Arts.

2. Sciences and Knowledge

2.1 On the Study of the Laws of Motion. The Universe

The thinking and the status of Western society is largely the result of the activities of scientists and technologists throughout several centuries. The starting point of these endeavors goes back to the period of the Renaissance. Indeed, it is in the sixteenth and seventeenth century that fundamental questions and new insights have brought a considerable change in the way man thinks about himself, how man sees himself in the world in which he is living.

It is through the study of astronomy that the understanding of the structure of the universe and the forces at work to held it together, that a profound change in the vision about the place of mankind in it took place. It is now generally regarded as a shift from a geocentric to a heliocentric universe in which the earth is a little object among many others instead of being its center. This change has led to fanatic discussions and disputes between the theocratic autorities and the scientific community of that time. The names of these scientists are all very well known to us. To name a few of them: Nicolaus Copernicus, Johann Kepler, Galileo Galilei, Isaac Newton and many others. Their fundamental questioning about the movement of stars and about the position of the earth, on which mankind is living, has led them to review the opinion of more than two thousand years. The observations made by many astromers and scientists used in geometrical and mathematical equations has led to a radical change of the world vision. The application of a scientific methodology consisting of careful observation, the search of relationships among the observations expressed in mathematical formalism, leads to irrefutable conclusions about the reality. Up to then, the world view of European culture and society, considered as absolute truth, was deduced from

the Scriptures and appeared to be consistent with the way creation had occured. A divine creator was considered to be at the origin of the universe, of man and of the earth on which mankind is living. The center of the universe is the earth. It sounded a consistent world view in which all elements received their right and just place, the geocentric world view represented a perfect representation of reality as it was propagated by the religious autorities. The theocratic world order had dominated the societal order. Any other proposition that could be put forward, was regarded very disturbing, had to be declared as a totally unacceptable and as an erroneous vision of universe and its creation.
The modification of this geocentric vision into a heliocentric one is therefore one of the most important evolutions in thinking in the Western world. Generally speaking the Western society today is not sufficiently aware of its tremendous change brought forth by the rational methodology of natural sciences. It will further be shown that analogous shifts are taken place in other domains of science today which are of the dimension of the move to a heliocentric vision of the universe and above all of the perception of mankind about himself. Indeed, it is a shift in the perception about the origin of the universe and of life in it. The perception and understanding of how creation could have taken place and of the requirement for a divine order to be involved in it, are essential questions which man has tried to understand from the early beginning.
Scientific methodology, based on observations and supported by rational and logical reasoning about these facts led to other findings, which were in opposition with earlier generally accepted interpretations. It were Copernicus and Kepler who indicated that the earth was no longer, and had never been, in the center of the universe, but that the sun is the middle of it, or at least in the center of our galaxy as we know today. The real impact of this new vision was that mankind was no longer the center of a world vision, which was propagated by religious conviction. In fact according to the Scriptures, in which the creation of the universe was described, the vision could not be subject to whatever modification.
However the against the power of scientific methodology, based on observation and experimentation, it appeared impossible to resists. Newton is in this respect referred to as one of the most important thinkers and scientists, for the reason that he was the first to develop a representation of observations in terms of mathematical equations and was able to describe them in a quantitative way. The discovery of the relativity theory and of quantum physics has created a new momentum in the understanding of the composition matter and the structure of the universe. Since the first publication by Albert Einstein, the progress made in astrophysics has been considerable. The understanding of the universe has been increased. A work hypothesis about the origin, the evolution and even the end of the universe have been put forward. The age of the

universe has been calculated, evoking a starting and an ending point. The picture of the origin of the universe, the place of our planet in it, are the result of scientific discovery and the received a rational foundation. Quantum physics has contributed to understanding of matter in its microscopic dimensions. The contribution of quantum mechanics to the philosophy of sciences has been very important. The question about space and time and the uncertainty related to it, is a still ongoing debate.

In conclusion, physical science has brought forth a major shift about the universe and, above all, about the perception of man on himself. The first discovery deals with a shift from a geocentric to a heliocentric view of the world. Consequently man living on this planet appears not to be anymore in the center of the universe. This has raised some fundamental questions about the notion of the creation in which man and earth were in the center of the universe. The second discovery resulted from the theory of relativity and from the progress made in astrophysics have led to a vision that our universe has had a physical beginning point and also will have an end. It means that physics has contributed to the understanding of the situation of mankind on this planet and in this universe. It is of a tremendous importance to realize in which degree science has a major impact and contribution in the understanding of almost, one could say, metaphysical questions and problems. In case of a major scientific discoveries the perception of man is modified through the discoveries. This is quite an important conclusion, one can speak of an interactive relationship between science and society, and between science and mankind.

2.2 The Theory of Evolution *

2.2.1 The Origin of Species. Darwinism

A major scientific innovation came in the beginning of the nineteenth century and deals with the theory of evolution. It was in the first place Jean-Baptiste Lamarque who introduced for the first time the notion of evolution. Although his interpretation of the phenomenon evolution appeared not to be fully correct and proven by observation. It has been Charles Darwin, who in 1859 wrote his monumental work *The origin of species* and completed it a few years later with *The descent of man*. The concept of evolutionary transformation of one species into another is extended to include human beings. Darwin based his theory on two fundamental ideas: chance variation, later to be called random mutation,

* The publications of F. Capra (3), M. Eigen (6) and J. Rifkin (16) mentionned in the bibliography, have been extensively used in the redaction of the following two paragraphes.

and natural selection. In the center of Darwinian thought stands that all living organisms are related by common history. All forms of life have emerged from that ancestry by a continuous process of variations through billions of years of geological history. In this evolutionary process many more variations are produced than can possibly survive, and thus, many individuals are weeded out by natural selection as some variants outgrow and outreproduce others. These basic ideas are well documented today, supported by vast amounts of evidence from biology, chemistry and the fossil records and all serious scientists are in complete agreement with them. The difference between the classical theory of evolution and the emerging new theory centers around the question of the dynamics of evolution, the mechanism through which evolutionary changes take place. This recognition, described by Darwin, has been of the greatest importance as to the vision of man on itself. Namely that it questions the opinion from usual thinking that some type of creation, and specific the creation of man, had taken place and that creation occurs through steps which in the end enables a hierarchical description and concept of nature in which man and its creator have their place. The evolutionary theory steps down from this system and the consequence of it, in regard with creation, is that it no more requires a discontinuity or specific intervention from a creator to explain the existence of living species. Neither does it need the explanation of an a priori defined hierarchical structure. With the emergence of the evolution theory, a second shift occured in the perception and representation of the world inherited from the tradition and Middle Ages. In the meantime, the Darwinian concept about the principle of evolution has been widely accepted by scientists. However, there have been some critics expressed about the fundaments of the theory and about the way evolution is occurring. Darwin's concept of change variation was based on the assumption that was common to the nineteenth century view of heredity. It was assumed that the biological characteristics of an individual represented a mixture of those of his parents, and if both parents have been contributing more or less equal parts to that mixture. Thus it is assumed that an offspring of a parent with his usual chance variation will inherit only 50 % of the new characteristic and would be able to pass only 25 % of it to the next generation. Thus, the new characteristic would be diluted rapidly, with very little chance of establishing itself through natural selection. Darwin himself recognized that this was a serious flaw in his theory for which he had no remedy. It is ironic that the solution of Darwin's flaw was discovered by Gregor Mendel, who finished his work only a few years after the publication of the Darwin's theory, but was ignored during Mendel's lifetime and was brought to light again only at the turn of the twentieth century, many years after his death (1884).

From his careful experiment with garden peas, Mendel deduced that they were *units of heredity* -later to be called *genes*- that did not mixture in the process of reproduction, but are transmitted from generation to generation without changing their identity. With this discovery, it could be assumed that random mutations of genes would not disappear within a few generations, but would be preserved to be either reinforced or eliminated by natural selection. Mendel's discovery not only played a decisive role in establishing the Darwinian theory of evolution, but also opened up a new field of research, the study of heredity through the investigation of chemical and physical nature of genes. It was William Bateson, a fervent advocate of Mendel's work, who called this new field *genetics* at the beginning of the century. The combination of Darwin's idea of gradual evolutionary changes with Mendel's discovery and genetic stability resulted in the synthesis, known as neo-Darwinism, which is taught today as 'established theory of evolution in biology departments around the world'. According to the neo-Darwinist theory, all evolutionary variation comes from random mutation, that is, from random genetic changes and followed by natural selection. For example, if an animal species needs thick fur to survive in a cold climate, it will not respond to this need by growing fur, but will instead develop all sorts of genetic changes. Those animals, whose changes happen to result in a thick fur, will survive to produce more offspring. Thus, in the words of geneticist Jacques Monod, 'Chance alone is at the source of every innovation, of all creation in the biosphere'.

In view of another scientist, Lynn Margulis, neo-Darwinism is fundamentally flawed, not only because it is based on reductionist concepts, that are now outdated, but also because it was formulated in an inappropriate scientific language. Current research on microbiology indicates that the major avenues for evolution's creativity were developed long before animals appeared on the scene. The conceptual problem of neo-Darwinism seems to be its reductionist conception of the genome, the collection of an organism's genes. The great achievements of molecular biology, often described as 'the cracking of the genetic code', have resulted in the tendency to picture the genome as a linear array of independent genes, each corresponding to a biological trait. Research has shown, however, that single gene may affect a wide range of traits and that conversely many separate genes often combine to produce a single trait. It is thus quite mysterious how complex structures, like an eye or a flower, could have evolved through successive mutations of individual genes. Evidently, the study of the coordinating and integrating activities of the whole genome is of paramount importance. This has been hampered severely by the mechanistic outlook of conventional biology. Only very recently, the biologists began to understand the genome of an organism as a highly interwoven network and to study its activity from a systemic perspective. A striking manifestation of genetic wholeness is the now well documented fact that evolution did not proceed through continuous gradual changes over time, caused by long sequence of successive mutations. The fossil record shows clearly that throughout evolutionary history there have been long periods of stability or 'stasis' without any genetic variation punctuated by sudden and dramatic changes. Stable periods of hundreds of thousands of years are quite the norm. Indeed the human evolutionary adventure began with a million years of stability of the first hominid species: *Australopithecus afarensis*. This new picture, known as 'punctuated equilibria' indicated that the sudden transition were caused by mechanisms quite different from the random mutations of the neo-Darwinist theory. An important aspect of the classical theory of evolution is the idea that in the course of evolutionary change and under the pressure of natural selection, organisms will gradually adapt to their environment until they reach a fit that is good enough for survival and reproduction. In the new system's view, by contrast, evolutionary change is seen as the result of life's inherent tendency to create novelty, which may or may not be accompanied by adap-tation to changing environmental conditions. System biologist have begun to portray the genome as a self organizing network capable of spontaneously producing new forms of order.

2.2.2 Social Darwinism

Another aspect of the consequences of Darwin's theory have been described by philosophers and is known under the name of *Social Darwinism*. It appears, according to these analyses, the theory of Darwin is quite compatible with the mentality and the spirit of the industrial era. We know that this theory has been frequently exploited for justifying a large diversity of interests of political and economical ideologies. It is more than one century that the social Darwinism has been studied and analyzed. All the discussions start from the same basic hypothesis, namely that the theory of evolution is in itself a desinterested discourse, objective and impartial, which registers the functioning of nature without undergoing the influence of the social context or of cultural prejudices. In fact this criticism states that the underlying idea that Darwin has discovered a law of nature and it was only in a second phase that society has used this discovery for its own purposes. But a new generation of researchers starts to question the theory and Darwinism in itself and suggest that the theory has been affected at its conception in the same way by social prejudices as it has been exploited afterwards. It has to be stressed that the scientific and social critics of the theory of Darwin are not critics of evolution in itself, given the fact that life on earth has been subject to evolution and this idea is based on a large consensus by researchers and scientists. However an increasing number of researchers are putting to question the theory itself and suggest that its original conception contains the elements of the dominant ideology of his time.

For Otto Rank, the theory of Darwin is nothing else for the English society as a mirror in which is perceived the reflection of its own behavior. Even if this version would have been difficult to be accepted in the introduction of manuals of biology, it remains true that Darwin is a product of his time and was also dependent of the imagination of the Victorian society and its contemporary scientists. For example, the historian Oswald Spengler situates the theory of evolution in a very schematic context by observing that the thesis of Darwin was no more than the 'application of economy to biology'. The ideas of Darwin exercised a strong influence for the reason that they were able to explain the way of things occur in terms easily understandable. For the changes people undergo they want to have a global explication which gives them a perspective for the whole world of their time. The theory of Darwin gives an answer to this expectation precisely for the reason that it is able to discover in nature the same forces which are at work in cities and in the factories of daily life. But if this analogy was motivated by the economy, its effect on society was motivated by politics. After the publication of the O*rigin of the species*, the British society could justify its economic behavior by appealing on the supreme authority of the universal laws of nature. It was possible, and even acceptable to justify the brutal exploitation of misery of workers and the adventures of imperialists and colonialist in territories far away in the name of the fidelity of 'the laws of nature'. Looking to the political repercussions of social Darwinism, another historian concluded that one can without any discussion see in this theory the key for the industrial area. As a political instrument Darwinism praised competition, power and violence instead of norms, morality and religion. It became by this way the support for nationalism, imperialism, militarism and dictatorship, the cultus of heroism of the superman and of the superior race. This interpretation of the scientific theory may go much too far, too extreme for the evident reason that the approach is based on analyses of two different observations -the one is a scientific one, the other a social one- both dealing with totally different objects and situations. Nevertheless, it remains true that the elaboration of scientific hypothesis is bound and related to the society and the period of history from which it has emerged.

In conclusion to the concept and theory of evolution, as it has been described in the previous analysis, the underlying analysis of the phenomenon of evolution is no more subject to discussion today. The discovery of a continuous evolution of species put a new light on the concept and perception of creation. The origin of humans, its relation and descendance with other species represents a new vision of man on himself. Once again science has illustrated what its contribution is in regard with the understanding fundamental problems of life and of mankind. The theory of Darwinism has certainly largely contributed to modify and to elaborate a new vision about the dynamics of life and its evolution in time.

2.3 The Theories of the Origin of Life

2.3.1 What is life?

Manfred Eigen published, in a remarkable article, some thoughts about the question of the origin of life in the book *What is Life? The next Fifty Years*. This publication has appeared at the occasion of the fiftieth anniversary of another publication of Erwin Schrödinger, with the same title *What is Life?*, which appeared in 1944 during the war and which, according to biologists and other researchers, has been one of the most stimulating publications on this matter. Eigen writes in his publication the following words: 'not only is this a difficult question; perhaps it is not even the right question'. Things we denote as living have to heterogeneous characteristics and capabilities for a common definition to give even an inkling of the variety contained within this term. It is precisely this full variety and complexity that is one of the essential characteristics of life. Possibly it will not take very much longer until we know 'everything' about *Escherichia coli* bacterium, perhaps even about the fruitfly *Drosophila*. What will we then know about humans? It is certainly more sensible to ask: how does a living system differ from one that is not alive? When and how did this transition take place during the history of our planet or of the universe as a whole? As a chemist I am often asked: what is the difference between a coupled chemical system albeit arbitrarily complex, and a living system in which we find nothing other than an abundance of chemical reactions. The answer is that all reactions in a living system follow a controlled program operated from an information center. The aim of this reaction program is the self-reproduction of all components of the system, including the duplication of the program itself, or more precisely, of its material carrier. Each reproduction may be coupled with a minor modification of the program. Competitive growth of all modified systems enables a selective evaluation of their efficiency: 'to be or not to be, that is the question'. There are three essential characteristics in this behavior which are found in all living systems yet known:

1. Self-reproduction without which the information would be lost after each generation;
2. Mutation without which the information is 'unchangeable' and hence cannot even arise;

3. Metabolism without which the system would regress to equilibrium, from which no further change is possible (as E. Schrödinger already wrote in 1944).

In this statement one can distinguish two major approaches. The first one represents a fundamental question: is there a discontinuity between the non-living and the living world? This a revolutionary question in the sense that it puts forward a totally different view on the nature of life and on creation. The second one is related to the first and consists in the understanding of the phenomenon of life, the underlying mechanisms and thermodynamics.

2.3.2 Self-organization: dissipative structures

'We must rethink evolutionary biology', writes Stuart Kauffman. 'Much of the order we see in organisms, may be the direct result not of natural selection, but of the natural order selection was privileged to act on. Evolution is not just a tinkering. It is an emergent order honored and honed by selection'. A comprehensive new theory of evolution, based on these recent insights, has not been formulated yet. But the models and theories of self-organizing, provide the elements for formulating such a theory. Ilya Prigogine's theory of dissipative structures, shows all complex biological systems, operating far from equilibrium, generate catalytic loops that lead to instabilities and can produce new structures of higher order. Eigen has suggested that similar catalytic cycles had been formed before the emergence of life on earth, thus initiating a prebiological phase of evolution. Kauffman has used binary networks as mathematical models of the genetic networks of living organism and was able to derive several known features of cell differentiation and evolution from this models. Humberto Maturana and Francisco Varela have described the process of evolution in terms of their theory of self-making or autopoiesis, seeing the evolutionary history of a species as the history of its structural coupling.
A system that shows these properties is predestinated to selection. It means that selection is not an additional component to be activated from outside. It would be meaningless to ask who does the selecting. Selection is an inherent form of self-organization as such, as we do know today, a direct, physical consequence of error-prone self-reproduction far from equilibrium. Equilibrium would only select the most stable structure. Selection choses instead a sufficiently stable structure which is optimally adapted for certain functions which ensure the preservation and growth of the organism. Evolution on the basis of natural selection leads to the generation of information.
The basis of molecular information processing is base pairing, as discovered by James Watson and Francis Crick. This at first purely chemical interaction enables the transcending of chemistry, for the chemical building blocks act

primarily as information symbols. Evolution, first molecular, then cellular and finally organismic, was only possible through reproduction and selection. It occurs no longer according to pure chemical criteria, but according to the functional encoding of information. Man differs from *Escherichia coli* bacterium not in a more efficient chemistry, but in a greater information content, this means, in fact a thousand times more than the bacterium. This information codes for sophisticated function makes complex behavior possible. The formation of a sub-cellular information processing system occurred about four billion years ago, as we can reconstruct today from comparative studies on the adapters of the genetic code. Accordingly, life probably began on earth, and not just somewhere in the universe. It is not older, but also not much younger than our planet. This means that life arose as soon as the conditions were suitable. There were already single celled organisms at least 3,5 billion years ago. Admittedly, the part to the true masterpieces of the evolution, to the multi-cellular plants, insects, fish, birds and mamals was a long and difficult one. It took all of three billion years. Mankind entered the stage of this magnificent drama only one million years ago. Molecular biology has confirmed Darwin's fundamental idea through its ability to disclose what the genomes of living organisms have in common. Information, in this case genetic information, is formed by way of successive selection. Darwin proposes his principle about the evolution of autonomous living objects. An extrapolation to pre-cellular systems, to answer the questions: 'How did the first life forms arise? From where did the first autonomous cell come?' This seems to him to be too daring a step. Once he did express a speculative 'if' and qualified it immediately with 'oh, what a big if'. The exciting realization today is that the selection is already active at the molecular level with replicable molecules like RNA and DNA and so is amenable to a derivation on the basis of the physico-chemical properties of molecules. This closes the gap which yawned between biology on the one side, and physics and chemistry on the other. This does not imply that biology may be reduced to physics and chemistry in the conventional sense. It simply confirms that there is a continuity between physics, chemistry and biology. The physics of a living system has its own characteristic regularities. It is a physics of information production.

The new theory of self-organization goes far beyond Darwin in detail and answers questions that had to remain open or were even paradoxical in his time. Darwin's legacy is a testimony of the nineteenth century.

Characteristics

The concept of self-organization is very important in the search for the interpretation of the origin of life. The concept, as gone to an evolution since it was first described in the framework of cybernetics, became and has been completed since with the following topics.

Namely the first one is that self-organization includes the *creation of new structures* and new modes of behavior in the self-organizing process. This includes creation of novel structures and modes of behavior in the process of development, learning and evolution.

The second characteristic of these models of self-organization is that they all deal with *open systems operating far from equilibrium*. A constant flow of energy and matter through the system is necessary for self-organization to take place. The striking emergence of new structures and new forms of behavior, which is the hallmark of self-organization, occurs only when the system is far from equilibrium.

The third characteristic of self-organization, common to all models, is *the non-linear* interconnectedness of the system's components. Physically this non-linear pattern results in feedback loops. Mathematically it is described in terms of non-linear equations.

Summarizing those three characteristics of self-organizing systems, one can say that self-organization is the spontaneous emergence of new structures and new forms of behavior in open systems far from equilibrium, characterized by internal feedback loops and described mathematically by non-linear equations.

The first, and perhaps most influential, detailed description of self-organizing systems was the theory of 'dissipative structures' by the physical-chemist Ilya Prigogine, Nobel price winner, professor at the Free University of Brussels and distinguished member of our Academy. Prigogine developed his theory from studies of physical and chemical systems that, according to his own recollection, he was led to do so after pondering the nature of life:

> 'I was very much interested in the problem of life. I thought always that the existence of life is telling us something very important of nature.'

Examples

In order to solve the problem of stability far from equilibrium, Prigogine did not study living systems, but turned to the much simpler phenomenon of heat convection, known as the *Bénard instability*, which is now regarded as a classical case of self-organization. When a liquid is uniformly heated from below, a constant flux heat is established, moving from the bottom to the top. The liquid itself remains at rest and the heat is transported by conduction alone. However, when the temperature difference between top and bottom surfaces reaches a certain critical value, the heat flux is replaced by heat convection, in which the heat is transferred by coherent motion of large numbers of molecules. At this point, a very striking ordered pattern of hexagonal cells appears, in which hot liquid rises through the center of the cell, while the cooler liquid descends to the bottom along the cell walls. Prigogine's detailed analysis of these *Bénard cells* showed that as the system moves farther away from equilibrium (that is, from a state with uniform temperature throughout the liquid), it reaches a critical point of instability at which the ordered hexagonal pattern emerges.

The *Bénard instability* is a spectacular example of spontaneous self-organization. The non-equilibrium that is maintained by the continual flow of heat through the system generates a complex pattern in which millions of molecules move coherently to form the hexagonal convection cells. Similar systems have been observed in nature in a very wide variety of circumstances, for example the flow of warm air from the surface of the earth toward outer space may generate hexagonal circulation vortices that leave their imprints on sand dunes in the deserts or on artic snow fields.

Another amazing self-organizing organization phenomenon, studied extensively by Prigogine and his colleagues in Brussels, are the so called *chemical clocks*. These are reactions far from chemical equilibrium, which produce very striking periodic oscillations. For example, if there are two kinds of molecules in the reaction, one 'red' and one 'blue', the system will be all blue at a certain point, then change in color abruptly to red, then again to blue, and so on, at regular intervals. Different experimental conditions may also produce waves of chemical activity. To change color all at once, the chemical system has to act as a whole, producing a high degree of order through the coherent activity of a large number of molecules. Prigogine and his colleagues discovered that, as in the Bénard convection, this coherent behavior emerges spontaneously at critical points of instability far from equilibrium.

Dissipative structures

During the nineteen sixties Prigogine developed a new non-linear thermodynamics to describe the self-organization phenomenon in open systems far from equilibrium. 'Classical thermodynamics', he explains, 'lead to the concept of 'equilibrium structure' such as crystals. Bénards cells are structures too, but of a quite different nature. That is why we have introduced the notion of 'dissipative structure', to emphasize the close association, at first paradoxical, in such situation between structure and order on the one side, and dissipation on the other. In classical thermodynamics the dissipation of energy in heat transfer, friction, and the like was always associated with waste. Prigogine's concept of dissipative structure introduced a radical change in this view by showing that in open systems dissipation becomes a source of power. According to this theory, dissipative structures not only maintain themselves in a stable state far from equilibrium, but may even evolve. When the flow of energy and matter increases, they may go through new instabilities and transform themselves into new structure of increased complexity.

Hypercycles

Another complementary approach came from Manfred Eigen in his research for the interpretation of the origin of life. He proposed in the early seventies that the origin of life on earth may have been the result of a process of progressive organization in chemical systems far from equilibrium, involving *hypercycles* of multiple feedback loops. Eigen, in effect, postulated a pre-biological phase of evolution, in which selection processes occur in the molecular realm 'as a material property inherent in special reaction systems' and he choosed the term 'molecular self-organization' to describe these pre-biological evolution processes. The special reaction systems, studied by Eigen, are known as *catalytic cycles*. A catalyst is a substance that increases the rate of a chemical reaction without itself being changed in the process. Catalytic reactions are crucial processes in the chemistry of life. The most common and most efficient catalysts are the enzymes, which are essential components of cells promoting metabolic processes.
When Eigen and his colleagues studied catalytic reactions involving enzymes in the sixties, they observed that in biochemical systems far from equilibrium, e.g. systems exposed to energy flows, different catalytic reactions combine to form complex networks that may contain closed loops. They showed in an example of such a catalytic network, in which fifteen enzymes catalyze each other's formations in such a way that a close loop or catalytic cycle is formed. These catalytic cycles are the core of self-organizing chemical systems, such as the chemical clock, studied by Prigogine. They also play an essential role in the metabolic functions of living organisms. They are remarkably stable and can persist under wide range of conditions. Eigen discovered that with sufficient time and a continuous flow of energy, catalytic cycles tend to interlock to form close loops in which the enzymes produced in one cycle, act as catalysts in the subsequent cycle. He choosed the term *hypercycles* for those loops in which each link is a catalytic cycle.
Hypercycles turn out to be not only remarkable stable, but also capable of self-replication and of correcting replication errors, which means that they can conserve and transmit complex information. Eigen's theory shows that such self-replication, which is of course well known for a living organism, may have occurred in chemical systems before the emergence of life, before the formation of a genetic structure. These chemical hypercycles are self-organizing systems that cannot properly be called 'living', because they lack some key characteristics of life. However, they must be seen as precursors of

living systems. The lesson to be learned here seems to be that the roots of life reach down into the realm of non-living matter.

One of the most striking lifelike properties of hypercycles is that they can evolve passing through instabilities and creating successively higher levels of organizations that are characterized by increasing diversity and richness of components and structure. Eigen points out that the new hypercycles created in this way may be in competition for natural selection. He refers explicitly to Prigogine's theory to describe the whole process: 'the occurrence of the mutation with selective advantage corresponds to an instability, which can be explained with the help of the theory of Prigogine et al'.
Eigen's theory of hypercycles shares the key concept of self-organization with Prigogine's theory of dissipative structure, the state of the system far from equilibrium. The development of amplification processes to positive feedback loops and the appearance of instabilities, leading to the creations of new forms of organization. In addition, Eigen made the revolutionary step of using a Darwinian approach to describe evolutionary phenomena at the pre-biological molecular level.

2.3.3 Self-making or Autopoiesis: Pattern

Due to the work of Humberto Maturana and Francisco Varela, the concept of *self-making* or *autopoiesis* has been described by these two scientists. In an essay on self-making they characterized their approach as being 'mechanistic', to distinguish it from a vitalist approach to the nature of life:

> 'our approach will be mechanistic: no forces or principles will be adduced, which are not found in the physical universe'.

However, the next sentence makes it immediately clear that the authors are not Cartesian mechanists, but system thinkers:

> 'Yet, our problem is the living organization and, therefore, our interest will not be in properties of components, but in processes and relations between processes realize to components.'

They go on to refine their position with the important distinction between *organization* and *structure*, which had been an implicit theme during the entire history of systems thinking. They make the distinction very clear. The organization of a living system is the set of relations among its components that characterize the system as belonging to a particular class (such as a bacterium, a flower, an animal, or a human brain). The description of that organization is an abstract description of relationships and does not identify the components. The authors assume that self-making is a general pattern of organization, common to all living systems, whichever the nature of their components.

On the other side, the structure of a living system is constituted by the actual relationship among the physical components. In other words, the system's structure is the physical embodiment of its organization. Maturana and Varela emphasize that the system's organization is independent of the properties of its components, so that the given organization can be embodied in many different manners by many different kinds of components.
Having clarified that their concern is with organization, not with structure, the authors then proceed to define self-making, the organization common to all living systems. It is a network of production processes, in which the function of each component is to participate in the production or transformation of other components in the network. In this way, the entire network continually 'makes itself'. It is produced by the components and in turn produces those components. 'In a living system, the product of its operation is its own organization.' An important characteristic of living systems is that their self-making organization includes the creation of a boundary that specifies the domain of the network's operations and defines the system as a unit. The authors point out that catalytic cycles, in particular, do not constitute living systems, because their boundary is determined by factors (such as a physical container) that are independent of the catalytic process.
According to Maturana and Varela, the concept of self-making is necessary and sufficient to characterize the organization of living systems. However, this characterization does not include any information about the physical constitution of the system's components. To understand the properties of the component and their physical interaction, a description of the system's structure in the language of physics and chemistry must be added to the abstract description of its organization. The clear distinction between these two descriptions, one in terms of structure and the other in terms of organization, makes it possible to integrate structure-oriented models of self-organization (such as those of Prigogine) and organization-oriented models (as those by Eigen, Maturana and Varella) into a coherent theory of living systems.
One can envisage that a comprehensive theory of living systems lies in the synthesis of two approaches, namely the study of pattern - form, order and quality- and the study of structure - substance, matter and quantity. The *pattern of organization* of any system, living or non-living, is the configuration of relationships among the system's components that determines the system's essential characteristics. That means that certain relationships must be present for something to be recognized, e.g. a bicycle or something else. That configuration of relationships, that gives a system its essential characteristics, is what is designated by pattern of organization. The *structure* of a system is the physical embodiment of its pattern of organization. Whereas the description of the *pattern* of organization involves an abstract mapping of relationships,

the description of the structure involves describing the system's actual physical components, their shapes, chemical composition, etc.

In a living system the components change continually. First, there is a ceaseless flux of matter through a living organism. Each cell continually synthesizes and dissolves structures and eliminates waste products. Tissues and organs replace themselves in continual cycles. Second, there is growth, development and evolution. From the very beginning of biology, the understanding of living structures has been inseparable from the understanding of metabolic and developmental processes. Third, the striking property of living system suggests process as a criterion for a comprehensive description of the nature of life. The process of life is the activity involved in the continual embodiment of system's pattern of organization. Thus, the process criterion is the link between pattern and structure. In the case of a bicycle, the pattern of organization is represented by the design drawings that are used to build the bicycle. The structure is the specific physical bicycle. The link between the pattern and the structure is in the mind of the designer. In the case of a living organism, however, the pattern of organization is always embodied in the organism's structure. The link between pattern and structure lies in the process of continual embodiment.

The process criteria completes the conceptual framework of the synthesis of the emerging theory of living systems. All criteria are totally interdependent. The pattern of organization can be recognized only if it is embodied in a physical structure. In a living system the embodiment is an ongoing process. Thus, structure and process are inextricably linked. One could say that the three criteria, pattern, structure and process, are three different, but inseparable perspectives on the phenomenon of life. They form the three conceptual dimensions of this approach.

To understand the nature of life from a systemic point of view means to identify a set of general criteria, by which one can make a clear distinction between living and non-living systems. Throughout the history of biology, many criteria have been suggested, but all of them turned out to be flawed in one way or another. However, the recent formulations of models of self-organization and the mathematics of complexity indicate that it is now possible to identify such criteria. The key idea is to express those criteria in terms of three conceptual dimensions: pattern, structure and process.

To understand self-making, as it is defined by Maturana and Varela, it is the pattern of life: that is the pattern of organization of living systems; dissipative structure, as defined by Prigogine, as the structure of the living systems; and cognition as the process of life.

The pattern of organization determines a system's essential characteristics. In particular it determines whether the system is living or non-living. Self-making -autopoiesis- the pattern of organization of living systems is thus the defining characteristic of life in this approach. To find out whether a particular system, a crystal, a virus, a cell or the planet Earth, is alive, all we need to do is find out whether its pattern of organization is that of a self-making network. If it is, we are dealing with a living system; if it is not, the system is non-living.

2.3.4 Cognition: Processes

Cognition, the process of life, is inextricably linked to self-making. Self-making and cognition are two different aspects of the same phenomenon of life. In the new theory, all living systems are cognitive systems and cognition always implies the existence of an autopoietic network. With the third criterium of life, the structure of living systems, the situation is slightly different. Although the structure of a living system is always a dissipative structure, not all dissipative structures are self-making networks. Thus, a dissipative structure may be a living or a non-living system, for example the Bénard cells and chemical clocks studied extensively by Prigogine, are dissipative structured but not living systems.

The three key criteria of life, meaning *pattern*, *structure* and *process*, are so closely intertwined that it is difficult to discuss them separately, although it is important to distinguish among them. Autopoiesis is the pattern of life, is a set of relationships among processes of production. The dissipative structure can be understood in terms of metabolic and developmental processes. The process dimension is thus implicit both in the pattern and in the structure criterion.
In the emerging theory of living systems, the process of life, the continual embodiment of a self-making pattern of organization in a dissipative structure, is identified with cognition: *the process of knowing*. This implies a radically new concept of mind, which is perhaps the most revolutionary and most exciting aspect of this theory, as it promises finally to overcome the Cartesian division between mind and matter.

According to the theory of living systems, mind is not a thing, but a process, the very process of life. In other words, the organizing activity of living systems, at all levels of life, is mental activity. The interactions of a living organism - a plant, an animal or a human - with its environment are cognitive or mental interactions. Thus, life and cognition become inseparably connected. Mind, or more accurately, mental process, is immanent in matter at all levels of life. Maturana asks two questions. The first one, *what is the nature of life?* and the second *what is cognition?* Eventually he discovered that the answer to the first question -autopoiesis- provided him with the theoretical framework for answering the second. The result is a system theory of cognition, developed by Maturana and Varela, which is sometimes called *the Santiago theory*.

The *Santiago theory* provides us the first coherent scientific framework that really overcomes the Cartesian split. Mind and matter no longer appeared to belong to two separate categories, but are seen as representing merely different aspects or dimensions of the same phenomenon of life. In the Santiago theory, the relationship between mind and brain is simple and clear. Descartes' characterization of mind as 'the thinking thing' (*res cogitans*) is finally abandoned. Mind is not a thing but is a process, the process of cognition, which is identified with the process of life. The brain is a specific structure through which this process operates. The relationship between mind and brain, therefore, is one between process and structure.
The brain is, of course, not the only structure through which the process of cognition operates. The entire dissipative structure of the organism participates in the process of cognition, whether or not the organism has a brain and a higher nervous system. Moreover, recent research indicates strongly that in the human organism, the nervous system, the immune system and the endocrine system, which traditionally have been viewed as three separate systems, in fact form a single cognitive network.

2.4 The Convergence of Scientific Answers. A Summary

Did the metaphysical questions painted by Paul Gauguin: *d'où venons-nous?* and *que sommes-nous?* become some answers by scientific knowledge? Indeed, the line of this presentation shows that science has considerably contributed to the clarification of these questions by giving, in some cases indiscutable answers. Moreover, the evolution of scientific thinking over more than four centuries has modified the perception of man on himself. Science, with its specific methodology and rationalism has shown to be able to change dramatically the thinking of man on the most essential aspects of the human condition. There is a quite marvelous convergence in the answers in regard with the existential questions about the planet he is living on, the origin of the species and finally about the origin of life itself. All of them have to do with questions about the concept creation: creation of the universe, of mankind and of life. The philosphical and theological dimensions of the analysis have not been considered. Science, in the sense used here, cannot answer these problems. However, what science has proven to be able to clarify are the premises from which religions started to construct their world views. Physics, chemistry, biology, paleontology and all others have contributed to throw a new light on these premises and revolutionized, at least in our Western culture,

the way of thinking and of envisaging these existential questions. It has to be stressed and recognized that main characteristic of scientific methodology is rationalism.
Summarizing the present analysis, we distinguish the following steps:
The first question has to do with the place and position of the planet Earth in the universe and directly related to it the place of mankind in this universe. Physics has given a clear answer to this fundamental problem. The shift from a geocentric to a heliocentric view had a tremendous impact on the thinking in the Western world. Scientific rationalism proved to be a powerful instrument to understand reality and continues since to contribute to modify and enhance our views on universe. In a second part of this problem the question of the origin of the universe: what can science say about the origin and eventually about the end of our universe? Once again physics has brought some answers and new insights on the evolution of the universe.
The second question concerns the origin of species. The theory of evolution has modified the perception of the origin of man. The theory provides a vision and interpretation on how the evolution of species can be understood. The importance of this scientific approach, in the context of the present analysis, is that the evolution shows to be a continuous process and therefore that the origin of man is to be seen as the result of an ordinary activity of nature. As a result, man, is not to be seen as a special species. Therefore, and once again, the answers given by science modify profoundly the perception about man himself. The representation of creation by some religions and their interpretation do not correspond with reality and careful observation. Another vision appears to be necessary and is the result of scientific thinking.
The third question has to do with the fundamental question about the origin of life. It is perhaps the most challenging one. The power of this analysis indicates that the concept of discontinuity between the living and non-living world vanishes. The strong relationship between structure, pattern of organization, and processes of living systems leads to a total integration of physical components and cognitive activity. Matter and mind are no longer separate entities. Historically this separation did fit in a concept of creation and was a useful presentation for religious purposes. The importance of such insight is easily understood in the sense to throw further light on evolution theory and about the origin of life itself.

3. Technology and Progress

3.1 Historical Evolution. Enlightenment

Technology has been present from the very beginning of the appearance of mankind on earth. Everyone has seen images and representations from

primitive cultures, dating from thousands of years before our era. The Egyptian civilization has been able to build constructions which have our admiration of technical knowledge and ability. In the Western culture, modern science and technology, as they are practised today have their roots in the 16th and 17th century, in the period of the Enlightenment. Among thinkers about the phenomenon of technology, one of the philosophers of the period of Enlightenment, who has written about science and its application, is most certainly Francis Bacon. He wrote the novel *The New Atlantis*, which unfortunately has been unfinished and was published in 1624. In this novel he describes the perspectives of how sciencific knowledge and its applications will bring about solutions for problems encountered in daily life. The perspectives he develops in this novel are representative of the state of knowledge of that time and concern almost domains of science: heat transfer, optics, botanics, biology, energy podruction, etc. From this vision has been derived the concept of techno-optimism or the almost unlimited believe in technological progress. It is certainly unquestionable that the concept of progress through science and technology has provided society quite a number of advantages. In this respect technology has relieved to a large extent man from heavy work and heavy duty activities, has brought forward healthcare and has modified his way of living, housing and mobility. Technological progress and innovation, indeed, have provided humanity considerable comfort in different respects. In the 19th and above all in the 20th the industrialization of the Western world took place.
In the previous chapter on science, a desciption has been given about a number of domains where science has definitely influenced the thinking of man. In case of technology, the number of inventions and applications it has brought forth is about infinite. They contributed to modify substancially the way of living of society and the perception of the relation between mankind and nature and environment of the planet earth.

3.2 Technology and Industrialization

The start of the industrialization of the Western world has been based on inventions in the field of thermodynamics with the production of heat and mechanical energy, on inventions in the field of electromechanics with the application of electricity, on inventions in the field of materials with the application of steel and many others which are today of common use in our daily life. Unlimited energy and resources were the premises for the industrial development, which took first place in Britain and afterwards in Europe and the United States of America. Today one recognizes that by the end of the 19th century, the industrialization has changed tremendously the social structure of society.

It is useful to mention a few of these modifications and evolutions of society due to technology and industrialization:

* The first one concerns the interest in mobility. To be mentioned here especially is the importance of *transportation* and the interest shown for the mobility in the Western society. The railroads date from the beginning of the 19th century in Europe and from the beginning of the 20th century the automobile has been produced on large scale. The model -Ford T- stands as an example of technological skill and innovation. With the industrial expansion the rural society decreased very fast in number and has continued to do so all over the 20th century. An urban society emerged with a new social structure. Technology and industrialization are at the foundation of new social structures.
* The second one is a consequence of the industrialization process. The social changes are merely the result of the financial implication -or the availability of *capital means*- of the industrialization process. In fact technology is related to financial means through the investment in infrastructure and industrial production processes. Indeed, the social consequences of industrialization, at least in the 19th century, have to be considered as almost catastrophic. They have been corrected due to the cration of unions and massive actions from the side of workers in the factories.
* The third group to be mentionned concerns the benefits of technology in the field of *agriculture* through extensive mechanisation and use of mineral fertilizers. The production of food has been dramatically increased and has helped populations of regions where hunger and food security was a tremendous challenge. The green revolution in agriculture was made possible by technological input.
* The fourth field concerns *medical care* and medical technology. Medical practice accompanied with the availability of clean drinking water and other hygienic measures, have increased dramatically, in all regions of the world, the life expectancy of the populations. One can only be delighted about such results. Technology has definitely contributed immensely to improvement of living condition and extended its impact on society.
* The fifth field concerns the field of *communication technology*. It started to be developped in the beginning of the 20th century and has been since then in constant expansion all over the world. In the last three decades, with the advent of microelectronics, a renewal takes place which will transform our society considerably and will go on in the next 20 to 30 years. Communication and information are among the most advanced forms of technological applications.
* The sixth domain concerns the domain of *space research* and *technology*. Space exploration has become of great interest since the sixties. In that period, first steps into space have been designed and it has been in the beginning of the seventies that fast exploration of space has been set up. Today an immense amount of information and knowledge e.g. by the Hubble Telescope, about our

solar system and the universe has been gathered. Also space technology is contributing to understand the evolution of our planet in different domains of interest for the world community: climate change and global change about environment, forestry, water management, etc. It is not exagerated to state that due to the exploration of space, man has completed his perception about himself and the status of the planet on which he is living.
* The seventh field concerns the very important orientation which takes the *microbiology* and especially *genetical engineering*. The break through of microbiology is dated in the second half of the 20th century with the discovery of the molecular structure of RNA and DNA by Watson and Crick. The development of this science and technology will be of the utmost importance for the coming years in respect with: therapeutic innovations, the production of food taking into account the dramatic increase of the world population in the next fifty years.

3.3 Critical Reflections about Technological Progress

The pace at which technological innovations and developments has taken place since the beginning of the industrialization, especially in the second half of the 20th century, has led to questions about the sense of this course and about the future of the planet. At one hand philosophers had already in the thirty years indicated the importance of technology and its tremendous impact it exercises on Western society. Also in the late sixties a few individuals -which became later *The Club of Rome*- from industry and involved in the development of technology asked themselves the question about the availability of resources. They felt that if the pace of material and energy use remained as high as it was, industrial development would some day face the problem of scarcity. To clarify this problem, they decided to use a mathematical model. The expectation was that it should be able to describe the dynamics of the evolution of the ongoing process and, hopefully, to give some answers about the outlook of the long term future. With the help of a dynamic simulation model, the WORLD3 model, developped at MIT, it appeared to be possible to make some predictions and forecasts about world resource depletion. Five parameters with multiple dynamic interactions were use in the model. The evolution of the planetary demography, the production of food, the use of materials inclusive energy, the environmental pressure and soil erosion as a result of these activities, were calculated. It appeared that the forecasts of this model produced a new vision and insight: suddenly the industrial Western world and humanity as well, realized that human activity took place on a planet with limited amount of resources and limited carrying capacity in regard with its natural environment. The availability of resources had to be seen in a different way, especially, the almost tripling (at the moment of the simulations) of the world population by the end of the 21st century had to be taken into account. Limited availability in th elong run of fossile energy, massive deforestation, the climat change due to greenhouse effect were at the time not yet recognized as planetary problems. Limited usage of nature in terms of biodiversity and environmental pressure, etc. have to be taken seriously, especially by industrialized and consumption driven societies. All these considerations and findings have somehow to do with the future of a liveable planet. As a result a collective awareness grew.

One of the topics raised by the model concerns the evolution of the world population. In the 19th century, Thomas Malthus had already put forward a model about the evolution of the population in relation with available food. The conflict between these two trends results from the observation that the population growth follows an exponential curve and the food production only a linear one. The consequence being that a correction in the population growth has to occur from time to time. Fortunately, up to now the predictions made by Malthus have not been verified, execept in some regions in the developping world. This means that up to now the food production was able to follow the demographic evolution. Nevertheless, the demographic development cannot follow indefinitely an exponential expansion, a demographic transition has to occur -and is hopefully taken place now- in order to decrease the growth and to reach a stabelized world population of about 10-12 billion people by the year 2100. Nevertheless a doubling of the world population, an increase of about 5-6 billion people, will still happen.

Through the physical obligation that mankind has to live on a finite planet and that man has to share the available space -in average, compared with today, half the space by the end of the 21st century- increases the urgency for the world community to search for a new world vision. Additionally there is the common intuition that through the continuous increase of industrial expansion of modern society its impact on the environment will have on the long range a disastrous effect. The awareness of this threat has grown slowly through the appearance and actions in the sixties of ecological movements in the Western societies. The biologist Rachel Carson is generally considered today as the foundster of the ecological movement. Her publication *Silent Spring* (1962) was an alarming message to the entire society: politicians, industrialists, scientists and engeneers. Looking back in the recent past -about half a century- one has to accept the fact that industrial output has increased tremendously. On one hand, the production of large amounts of goods occured without questionning about the origin of materials and the effects on the environment. On the other, the awareness of the limits of resources and of the carrying capacity of the planet has grown constantly within the civil society. A new world vision has to be elaborated and corresponding institutions to be created to manage the construction of a liveable planet and society on it

3.4 Sustainable Society

When looking for solutions to orient the world community with a fast growing demography on a finite planet it seems necessary to search for new concepts and new visions. Such a new concept has been formulated a decade ago and has became the name *sustainability* or *sustainable development.* It has been described for the first time in 1987 by The World Commission on Environment and Development of the UN. The commission was presided by Gro Harlem Brundtland. The concept of sustainability is a very generous one. It starts from the idea that the activities of the present generation should not endanger the development of the future ones. This means that the rich countries of the Northern hemisphere should restrain themselves in the use of the planetary resources. Indeed, today these countries often use these resources several times more than the populations of the Southern hemisphere. It is beyond imagination and reality to think that it will be possible for mankind to spend the same amount of resources as the rich countries do today. A redistribution has be looked after. Sustainability does contain a solution of the problem, though extremely difficult to implement. It represents in the long term a de facto *paradigm shift* and new world vision.

However, the implementation of the concept is not without challenges. Sustainability has the following characteritics:

1. the rich countries of the Northern hemisphere get along very cautiously with the usage of natural resources;
2. this generation brings forward respect to nature and the planetary ecological system: environment, forests, oceans, soil and land, air, etc.
3. the next generations should have the chance to develop themselves according to own social structure and culture.

This concept represents a major evolution of our society and economy. Indeed one may speek of a paradigm shift. The international community is becoming aware of its necessity. In a recent publication from our colleague and distinguished member of this Academy, Ernst Ulrich von Weizsäcker, with the title *Factor Four: Doubling Wealth, Halving Resource Use* gives a description of the possibilities of technological innovation. This new approach is a challenge for technology to innovate in a way that a more effecient resource use by a factor four or even ten is feasable. The concept of Factor Four joins a techno-optimist vision, where technology becomes the mission to design and contribute to the realization of a sustainable society. At the same time, if it succeeds, it refutes the analysis of the philosophers who stand for an uncontrolable autonomous behavior of technological progress.

A sustainable society should become the objective of the world community. Keeping the demographic evolution and the limits of our planet in mind any realistic and feasable solution should therefore be taken seriously. At the same time one cannot imagine today that Western society would, in normal circumstances, voluntarily restrain itself from the materialistic advantages technology has brought forward since many decades, even centuries. It seems therefore that the approach of Factor Four appears to be a reasonable solution. However, the consequence will be that an even more technology oriented society will emerge.

3.5 The Phenomenon of Technology. Philosophical Considerations

Technology moves very fast, penetrates all domains of society and modifies the basic activities of man. It will continue on the same way in the future as it did in the past and will change the social structure of society, the concept of the family, the way of doing business. In fact, the list of examples is endless.
The analysis of a number of philosophers, social thinkers does bring another approach to the perception of technology and its significance for society. Several philosophers of technology have expressed severe criticism on the evolution of technology and the place it takes in society. This orientation has been called the *autonomous character of technology*.
According to this approach, technology is in the first place a large system and its autonomous character means essentially that technological development and innovation have to be attributed to the internal dynamics of the system. It is progressing along its own guidelines which are not predetermined. The progress is in itself not good as was defined by the thinkers of the period of the Enlightenment, nor bad. It is *ambivalent* and neutral in respect with the society in which it is operating. Contemporary philosophers of this tendency are: Martin Heidegger, Jacques Ellul, Langdon Winner and others.
Especially, Ellul considers technology as being a system similar as we know it from cybernetics. During the dynamic behavior of a cybernetic system the observer or operator can act upon it by means of feedback information the observer gets from the system. Such a system can be monitored, the feedback is used to steer the process in the direction desired by the observer or operator. However, with technology the situation is quite different according to him. In the first place technology is a *large system* and it is more than the sum of separated techniques. It behaves is a whole system, an *ensemble*, in which each specific technique is an element. The technology system has a number of characteristics such as: it is universal, it behaves as a united system, it has its

own pace, it is ambivalent, etc. Secondly, it appears that there can be no feedback from its evolution. The observer, in this case, man and society, are part of the system. It means that the scientist, the engineer and technician, the production manager, the consumer are at the same time the operators and the builders of the technological system. As a consequence, there is no possibility of having feedback and therefore it is impossible to steer the technological system in one or other direction.
Evidently, the conclusions of this approach are enormous. Therefore, it is not given that the objectives of technology are systematically for the benefit of mankind since technology evolves on itself neither for the good of man nor for the worse. Technology does not have predefined values in itself. Additionally, technology behaves as a *system-out-of-control* (L. Winner) and therefore there exists no possibility to control and steer its progress. The system escapes all democratic control. The latter consideration evidently has an enormous signification to concept of our society.

One may wonder if a similar tendency occurs in our economical system. Is the phenomenon of globalization, we are now observing as a major trend, behaving also as a system-out-of-control escaping all democratic control? The dominant situation of transnational companies leads to the situation that their decisions about world wide operations –investments, capital flows, environmental use-, do escape from this control.
The analysis of the thinkers is generally described as a *techno-pessimistic* vision of society. The trend of the last two to three decades,in which the pace of technological innovation takes place and the way technology is embedded in the market driven economical system, suggests that some caution for the future developments and orentation makes sense. One might wonder, even when the autonomous character of technology is not as pronounced as these thinkers have described, if our society will be able to guide and direct technological development. It remains questionable if in the near future such an attitude will be possible. Climate change, depletion of resources, ecological pressure, are all domains where some restraint by the civil society is recommended. It is already doubtful that some international committments agreed upon in nineties in the field of environment and climat change (Rio, Kyoto) will be fulfilled by 2010. As a consequence it will be very difficult to arrive to a new world vision in which technology plays the role to work towards a sustainable world community.

3.6 Integration of Technology in Culture

Another approach in the philosophy of technology starts from the observation that in society a certain reluctance towards technology exists. The objective of

technology is to design and produce objects or *artefacts*. Compared to the objective of science, which searches to understand nature, the objective of technology is entirely different. Man is at the origin of the artefacts he has designed and build of which ultimately he remains master of them.
Several philosophers, among them Gilbert Simondon, Lewis Mumford and others plead for a much better integration of technology and of its products in our culture and cultural activities of society. This means for example that technology should be considered by society as an activity which man should not be afraid of. Machines replace labor frequently and therefore the perception persists that technology as such is a threat to man. Automation and robotization in production processes replace labour on large scale. It does not mean however that in the long run the machine would be able to take the role of man totally over. According to these thinkers, man will remain master of the devices he designs and produces. Therefore it seems necessary, rather than being afraid of them,that they should be incorporated much deeper in our culture. The question is whether modern devices such as personal computers (PC) and the mobile phone, can still be regarded by man as a threat to his activity or not? The forecasts are that they will reach almost total penetration by 2010 in our Wetsern society. These devices and their use will be regarded as standard items of society and thus be part the usual human behavior. The same reasoning can be made for other devices now usual in the daily picture of society e.g. cars, household devices etc. Further scenarios mention for example that the PC will become the usual briefcase for the students and pupils. Learning and education will be applied through the use of the PC. This looks a realistic vision about the way our school system will evolve. Last but not least the *Internet* being already an important source of information will further be used for the acquisition of knowledge.
These examples tend to indicate that technology is increasingly linked to our activities. They also show, that technology is becoming closely related to intellectual activity and therefore, it may well be, that its integration in our culture is in the process of being realized.

4. Perspectives for the Future. Conclusions

Looking in the future is always an interesting and intellectual activity. It is however impossible to do exact and long term forecasts in the domain of sciences, for, discovering the unknown is the objective all scientific endeavor. In the frame of the present analysis, we will limited ourselves to few perspectives. In fact we are looking for some answers to the fundamental question, painted by Paul Gauguin, *où allons-nous? (where are we going to)?* Eventually one may ask where do we want to go?

4.1 The domain of Sciences

The first field concerns the *science of genetics*. We all have witnessed the great progress that was made the last decades analyzing the genomes of all kind of organisms and recently of worms and the fruit fly. The deciphering of the human genome is progresssing at high pace in academic laboratories as well as in highly specialized enterprises. The more knowlegde we gather the better it is. To dispose about this knowledge is absolutely interesting and will contribute to understand a number of mechanisms about the functioning of nature. The latter is of great interest for therapeutic purposes.
In respect with our existential question, it seems that the understanding of the systematic structure of the elements -the genes- with which nature is built will be an important step in the comprehension of the living world as a whole. Therefore, the understanding of the genome of a large number of organisms -going from the one cellulars up to humans- will clarify of how nature is functioning and structured. In a similar way, as it has been argued about the possible continuity between the living and the non-living world, the understanding of the structure of the genome will answer the question of continuity or discontinuity between the different species. This knowledge contributes to the understanding of the fundamentals of the composition of nature and therefore, to the understanding of the origin of mankind.

The second one concerns the field of *space research* and *technology*. This domain of scientific research is evidently very close to the possibilities offered by technological innovation. The importance of the discoveries in space consits, on one hand, in the understanding of the universe, its origin and evolution, and the position of our planet with life on it. The field of astrophysics has innovated some of the research about the composition of matter and related metaphysical problems. On the other, space research contributes also to the observation of our planet. The knowledge about the evolution of climat change and global change are essential to mankind. Satellite observations allow to follow up the effects of human activity. With the help of mathematical models, projections and forecasts can be made and, in the long run, will be of great interest for the world community.

And thirdly, many *other* field*s* of science and research which are not discussed, remain of great importance in the search for answers of our 'existential' questions. Paleontology, antropology, biology, etc., all bring light about the origin of life, species and humans.

All these endeavors deal with knowledge and understanding of nature and life. The science of genetics allow scientists to intervene in very basic structures of nature and life. It will allow him to design and modify some of the characteristics of nature. It is not the subject of this presentation to analyse this totally new situation of mankind. Remains to indicate that the problems related to such interventions do have important ethical dimensions which should be considered all a long the research progress with the greatest care

4.2 The domain of Technology

Technology will continu to change profoundly the social structure of society. Firstly the importance of *information and communication technology* ICT is obvious. It will change the way of working. Urban industrialized society will undergo profound modifications. Solutions have to be worked out for the mobility problem. One of the solutions is found in the use of intensive communication in professional life - tele-working- as well as in daily activities e.g. commerce. Tele-learning is another domain of profound change in society. School and education systems have to adapt to the new technical opportunities. Permanent training has to be incorporated in the professional curriculum and communication technology will help to organize it on a large scale. The shadow side of these technological innovations is that apparently the pace at which they should be introduced in society in order to be effective, will be in many cases much too high. One may wonder to what extent societies are capable to assimilate these technological progresses. A social consequence will be most certainly that there will appear societies with two or more speeds. Will the world evolve along the line of: 'those who know and those who do not know' rather than a world with 'the have and the have not' is a real question.

Secondly, large expectations are put forward in the progress of *biotechnology.* It is frequently stated that biotechnology or life sciences will become the same place in the 21st century as physics had in the 20th century. This is most likely correct. The life sciences and technology will considerably alter the way man is looking at nature. His position will evolve profoundly. In the past, nature was considered as a gift to be used without restriction by (Western) society; in fact nature has been misused. Apparently two new directions appear for the future: firstly, biotechnology will change some of the constituents of nature. The engineer intervenes in the living world; the engineer being the biologist, the microbiologist, genetist, etc.And, secondly, the ecological movement stands for a more ecocentric approach of nature. A renewal of respect for nature is likely to happen and belongs to real tendency of society.

Thirdly, of course many *other* technological innovations in the field of renewable energy production, material use, agriculture, etc., will contribute to the evolution of society.

These are, in a condensed form, some of the perspectives of the future developments in science and technology.
I am aware that these 'forecasts' and perspectives are very general. Nevertheless, I hope, they have given some vision of the future and how they will influence the thinking and the behavior of mankind.

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