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NIELS BOHR, PHYSICS AND THIRD WORLD DEVELOPMENT :

THE NEED AND FEASIBILITY OF A NEW SCIENTIFIC PARADIGM

by

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(The views expressed by the author do not necessarily
reflect the standpoint of Unesco.)

NIELS BOHR, PHYSICS AND THIRD WORLD DEVELOPMENT :
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Contribution of Prof. MALU wa KALENGA

"The importance of physics for general philosophical thinking does not come only from the contribution that it brings to our continuously increasing knowledge of nature, from which we are part ourselves, but at least as much from the fact that it leads us to verify and to refine ceaselessly our conceptual apparatus".

Niels Bohr
(Excerpts from "Atomic physic and human knowledge,
Gonthier edition, (1961), p.5);(1)*

I. INTRODUCTION

We propose, as our contribution to the centenary of the birth of Niels Bohr, to dwell on the implication of this Bohr's statement, in the light of the emerging consensus that the socio-economical crisis of Sub-Saharan countries result, for a good part, from a poor overall conceptualisation of the Process of development and sometimes from a mistaken approach to the application of science in support of that process.

Doubless, many things have been said and will be said about Niels Bohr's accomplishment in physics.

Indeed as one of the initiator of the body of knowledges regrouped under the name of "quantum physics", Niels Bohr can rightly be considered to have contributed immensely to a truly scientific revolution by fostering a truly new scientific paradigm, (2).

In spite of the debate, and may be on account of it, quantum theory has had a tremendous impact outside the narrow branch of the physics of particles.

In the basic sciences, one of the greatest impact of quantum theory is perhaps through its epistemological consequences. It has corroded the concept of basic predictability and simple visualisation which has been the mainstay of the imposing edifice of physical science since the Newtonian scientific revolution.

But the most dazling success of quantum theory, to which Niels Bohr has contributed directly and indirectly, having the most staggering impact on our live and on our civilisation, pertains more to technology than to basic science. It concerns of course, the understanding of the mechanism of nuclear fission and its use as a source of energy for the best, and hopefully not for the worst, of mankind (3).

The impact of this great technological breakthrough that constitutes nuclear energy is such that we are now living in a transitional age of particular importance, which differs profoundly from any previous epoch of transition in at least two ways.

* The numbers between parenthesis refer to the bibliography and notes at the end of the paper.

The first constrast lies in the rapidity with which changes are being carried out in the scientific, technological and industrial sectors. The rapid pace of technological change can easily be related, in part, to the implementation of nuclear fission as a source of energy.

The second contrast lies in the choice facing our age since the first atomic explosion in 1945 : either "peace through development" or "Barbarism through the rule of the mighty", or even "extinction through the foolness of a few ones".

Bohr has recognized this early enough, (1950), and has tried hard in various forums to foster the course of "peace through development".

If we have not progressed very far along this avenue it is in fact because we have not yet devised enough "confidence-building" measures through the right type of social control over our empire of more and more powerful and intelligent machines.

As the industrial revolution continue to unfold, going from the area of simple mechannical divices to the area of artificial intelligence, it is becoming more and more evident that the disparity between material and non-material factor of our culture is wideming dangerously.

This disparity between the material and the non-material culture is also rendering the development problematic in the Third World particularly complex.

Indeed, science and technology can contribute immensely to the solution of many problems facing Third World nations. This is particularly true in the general area of what one can call "the logistical support" of material development.

But if one press on and try to apply the same approach to socio-economico-political problems, one is bound to find himself in the situation of a man "groping in the dark".

The "scietific key" available in natural sciences is obviously not truly fitted to solve complex societal problems, for example in the field of economic development or social behaviour.

Social ills thus keep croping up everywhere, poisoning international relations, in spite of various prescriptions that are given but who seems to generate more ill-feeling and debates, than good solutions. Obviously it is becoming imperative to bring together in a different fashion than has been tried before, social and natural scientists in order to make then work together more effectively to promote a more human World.

To facilitate such undertaking a new scientific paradign encompassing social and natural sciences will certainly help.

We propose in this talk to find out if such a reconceptualisation of science is possible, and if it can be conceived as an extrapolation or an enlargement of the thoughts and perspectives that underlie the quantum formalism which Bohr so successfuly applied to foster a truly new scientific revolution in physics.

II. THIRD WORLD DEVELOPMENT PROBLEMATIC

By the right application of the body of scientific and technological knowledges already at hand, Third World nations can go a long way into mastering fairly quickly their physical environment in order to make it more conducing to a better material well-being.

Such endeavour is however constrained by the fact that the modern man is experiency a non-material cultural lag.

In order to really use science and technology to promote an overall well-being, material and non-material, through peace, security, prosperity, man must bring social thoughts and institutions into harmonious relation with its material culture.

History shows clearly enough that too much discrepancy or maladjustement between material and non-material cultures can lead to insuperable tensions that end up destroying the fabric of society if not the entire civilisation, (4).

This cultural lag is too often in evidence to-day. This can be seen for example in the poor overall management record of the African continent which are producing economic waste, under-or mal-consumption, low standard of living in spite, sometimes, of rather big monetary investment, high unemployement, unnecessary disease, hunger and death.
The failure of many projects in Africa can be traced to an inadequate understanding of the socio-cultural reality of the people they most directly affect; to a lack of participation of these people in project planning, implementation and evaluation, and to a poor understanding of the two ways interaction between man, society and technology.

Unfortunately social scientists can not agree on how socio-cultural factors should be incoporated into the planning process. Furthermore these factors are seldom adequately understood by development project planners. This situation can in part be traced to an inadequacy of the analytic process and on the theoretical framework that can be applied to the assessment of very diverse and complex events and processes such as charge in the natural environment, local economy, the impact of the dominant technology, (5),(6).

This is happening in Africa while in the industrialized world one is witnessing a quickening pace of the industrial revolution. One sees the emergence of a new and truly "creative society", whose principal resource is the "intelligence", and which requires a bigger collectivisation of the development process with man at its centre; (7).

Third World nations are thus facing a truly gigantic challenge. They must at the same time build the basic infrastructure needed to "bootstrap" their economy, master the current and new "dematerialisation" of technic, as examplified by the "information revolution", and insure the delicate blending between the technical, material and social conditions of production that to-day development of society requires.

This has to be done when the two ways interactions between "potential resources", "means of production", the "economic structure of society" and the "political and ideological superstructures" are not well understood, (8), let alone measurable, (9). Change in one of those factors of production is contrained by all the others in a way that must be ascertain more properly if one wants to solve for example the problem of hunger in the World, particularly in Africa.

To understand the multifactorial complex and global problems of development, the early reductionistic approach that relies on single disciplinary approach has long be replaced by an holistic approach as examplified by the now common interdisciplinary undertaking.

However, interdisciplinarity is more often than not mere multidisciplinarity, (10). This is because the plurality in values, interests and methodologies also means that in practice there is irreconciliable difference in the views of what might be the basic causes of the problem and the best solution to solve it. The wide difference in the perspectives and opinions means in practice, more often than not, either the impotence of the group or some useless middle of the road solution.

That is why it is of interest to know how to transform multidisciplinarity.undertaking into truly interdisciplinary one.

One method is the interparadigmatic dialogue, (11). The result of such interparadigmatic dialogue can certainly be enhanced if a natural consensus does exist at a higher hierarchical level among different disciplines; that is if they can share at some hierarchical level the same major principles of conjunction and disjunction.

The need of a common paradigm at a higher hierarchical level arise first because, interparadigmatic dialogue is constrained by the high, (and getting higher) fragmentation of knowledge which renders communication very difficult amongst scientists, even of the same discipline, let alone between social scientists and physicists for example.

There is also the fact even if, in theory, the members of an inter-paradigmatic group can share the same view of what may be exactly the problem to solve and its probable causes, they will tend to propose reductionistic recommendations that are more often than not irreconciliable. This is because each membre address a different aspect of the problem, with different tool, different conceptualisation, differents criteria as to what constitute the truth, and finally difference in the degree of confidence in the findings.

This situation is compounded by the fact that the difference in the addressed aspect of the problem means in practice a difference in the complexity of the system being considered, (12). For a given problem social scientists will be, for all practical purpose, addressing a system of greater complexity than will be the case of natural scientist, (13).

Finally the interparadigmatic aporoach does not suppress the fact that social philosophers and social scientists find themselves ill at ease in a World where science, since the Newton revolution, was defining the fundamental laws of nature as being deterministic and reversible, irreversibility (and thus a certain dimension of "historicity") and randomness (which permeate social facts by way of the freedom of choice of individual) being considered as either anomalies or the result of science provisional lack of knowledge and (or) of control over variables, (14).

But for social scientists to adopt without modification the methodological principles and criteria for evaluating the truth of natural sciences means interfering in an inacceptable way into the complex social or human systems they are studying. Such is the case for example if one wants to extract the observer from the observed, this condition being the prerequisite of classical science methodology.

On the other hand, to renounce the exacting discipline and methodology of classical science which has shown its tremendous success, based among other things on the principle that only the strict, individual verification of the concordance of the theory with reality is the deciding factor to ascertain the truth, is to confine social science to the uncertain value of a simple rethorical science, (15).

As seen from the above discussion the problem is not an easy one. However the "new alliance" through a common paradigm at a sufficiently high hierarchical level, encompassing all other paradigms as special cases is not complete fantasy, (16).

Bohr and quantum formalism can be shown to play an important role in support of that statement.

III. BOHR, QUANTUM FORMALISM AND THE FEASIBILITY OF A NEW SCIENTIFIC PARADIGM.

When studying the history of science and particularly the evolution of the paradigm that inderlies scientific thinking, one cannot miss to notice a global shift that affect the concept of determinism, of causality, of time, of divisibility, of order, of certainty...,(17),(18),(19),(20).

In classical physics, strict determinism and thus strict causality was the order of the day, (21).

Starting with quantum mechanics, particularly with the celebrated Heisenberg's uncertainty principle and the statistical interpretation of Schroedinger's wave function by Born, one comes slowly to the realisation that there is a natural limit for the improvement of our information, and that uncertainty and hazard are integral part of mechanics itself.

This result combined with recent outpour of scientific evidences in fields ranging from biology, to physico-chemistry through social science suggest at least one statement : determinism and reversibility do not constitute by themselves fundamental characteristics or laws of nature, (22),(23). This does not imply that hazard and irreversibility do constitute by themselves fundamental laws of nature, although most human and social processes exibit such characteristics.

The reality, as usual, must lies in between which suggest that the most suitable scientific paradigm is the one that makes way for the introduction of the logic of inclusion or "con-junction" along the logic of exclusion or "dis-junction" that has been at the core of classical science since the Newton revolution, (24).

This statement does not detract from the fact that the method and tool of the 18th and 19th reductionist sciences have been successful. The scientific revolution fostered by the success of Newton has provided man with the power to master his environment. Unfortunately, it has not impart him with the skill to know himself better or to learn more closely the full consequences of his action on the complex systems encountered in the domain of biology, ecology, socio-economic, culture...

There is to-day a consensus that man must take more fully into account the tremendous complexification of the developement process, (25),(26).

To accomplish this, one needs more effective models and tools of global scientific investigations which permit to take fully into account the basic facts emerging not only in biological and social science but in physico-chemistry science as well. Amongst them one can list :

1) The decider is not totally free outside the system; the observer is not longer completely outside the system he is observing, (27);

2) Isolated or closed systems composed of entities behaving like automata, pursuing predictable, rational paths is a crude is not completely erroneous assumptions or approximations, (28);

3) Instead of isolated or closed systems, one is more likely to deal, at least at the macrolevel, with open systems subject to flows of energy, matters and informations that develop into complex forms and organisations following an essentially evolutionary and adaptative course punctuated by essentially undeterministic choice and thus more or less undeterministic behavior ; (27),(28);

4) There exist an hierarchy of relations and interactions between the pertinent key factors of a system. This hierarchy can be used to explain the past but not necessarily all the future path the system will take or can follow because of the "noise" in the system. This noise is tied not only to the presence of the "choice" factor, which instill uncertainty in the development process of the system, but also to be basic uncertainty underlying the interaction process itself. Indeed the decision or choice process is not truly free but is dependant : on the interplay between internal and external circumstances; on the emerging collective values and their relative acceptabilities; on the weight of the past; on the anticipated value or usefulness of possible future; on the adaptive response to anticipated consequence of to-day decision;(42).

5) The global nature of phenomena or system; that is the essentially non-divisibility "ad infinitum" of system, particularly biological system; (28),(42).

It is clear from the above consideration that the physical laws of conservation of energy, masses and moment that characterise classical physics can not be used alone to model social, economical and biological systems. It turns out that they do not even render the true complexity of new emerging physico-chemistry phenomena far from the equilibrium;(29);(30).

One is thus confronted with the following fundamental question : "How to situate (and thus to be able to model) biological and social systems with regard to the general laws of organisation of sciences in general and of thermodynamics in particular ?"; (31).

In other words : "How to integrate randomness and determinism in order to explain (and thus, hopefully, to be able to model) the development of biological and social structures ?"; (32).

The old position that consisted of simply discarding the problem by assuming that there is a basic separation between the living and the non-living systems is not longer acceptable. Choice and freedom can be visualized in physical system as examplified by the "dissipative structure";(33), (34).

It become therefore imperative to ascertain the feasability of an all embracing scientific paradigm in which the following conjunction can be fully integrated :

1. Conjunction of the "observer" and the "observed";
2. Conjunction of "order" and of "disorder";
3. Conjunction of "reversibility" and of "irreversibility";
4. Conjunction of "separability" and of "non-separability";
5. Conjunction of "certainty" and of "uncertainty";
6. Conjunction of the "autonomous or self-governing" and of the "interdependent";
7. Conjunction of the stable and of the "unstable";

8. Conjuction of the "project" and of the "situation";

9. Conjuction of "equilibrium" and of the "non-equilibrium".

One can list many other conjuction; (24). Some of those listed here are obviously redundant. Redundant or not, they can be viewed as a step toward a partial answer to the following question put forward by Niels Bohr, (35) :

"To recognize the significance for the function of living organisms of their essentially atomistic features is not sufficient to explain biological phenomena. The decisive point is the following question : aren't we missing an essential point of view when we try to understand life using the experience of the physical science in our analysis of natural phenomena ? Even if one does not take into account the practicaly unlimited wealth of biological phenomena it seems impossible to answer the question without digging more deeply into the problem of the nature of the physic explanation than we have been forced to do from the discovery of the quantum of action".

The problem remains however to know if the new emerging ideas and views of the importance of stochasticity, uncertainty, adaptative behavior..., which seems to characterize in many scientific disciplines what are perceived as essentially evolutionary systems, can truly lead to the grand unification of human and natural sciences through the formulation, at an appropriate hierarchical level, of a new, all embracing, scientific paradigm such as the so called "EVOLUTIONARY PARADIGM"; (36).

In other words, and as expressed by Prigogine, (37) :

"Does it exist an evolutionary paradigm which can be applied at the same time to the relative simple phenomena of physics and to the complex phenomena which are the rule in the living and the social ?".

Of course, if such a formulation is possible, then by the epistemological application of Bohr's principle of correspondance, it must integrate as special cases all other paradigms; (38), (39).

That such a formulation is desirable has been made sufficient clear. It follows not only from new discovery in physico-chemistry and other related sciences but also from the imperative of sound socio-economic developement, particularly in the Third World.

The problem of modelling "choice", "freedom", "adaptative behavior" remains however a formidable task. This task is rendered somewhat essier by ideas, methods, models that have been introduced in quantum physic by a fine line of outstanding scientists amongst which stand taller Bohr and his Copenhague School of physicists, (40).

Indeed some of the listed conjuctions can be viewed as application of ideas introduced by Bohr, amongst which one can list the characteristic of totality and the theory of complementarity. Some others conjunctions can be related to well known results and paradoxes of quantum physics, (42).

The theory of complementarity is this form of description introduced in 1921 by Bohr, which includes two mutually exclusive aspects of the complete experiment, that show themselves to be non contradictory when one changes the frame of reference, that is of the measuring instrument or more generally of the situation of the observer, (41).

It can be shown that the need to integrate the observer to the system being observed, that is the first conjuction, can be related epistemologically to the theory of complementarity,(42).

The essential point of the argumentation consist in noting the fact that, for an objective description and an harmonious synthesis, it is imperative in almost all domains of sciences to pay a particular attention to the condition of the observation.

The conjunction of "separability" and of "non-separability", that is conjonction n°3 above, can be related to the well known paradox of the lack of individuality of particles in physics, (42), (43),(44).

It should be noted here, that conjonction n°1 above, that is the need to integrate the observer to the observed, which is a perequisite in social science, is a consequence of the non-applicability of the postulate of unlimited divisibility.

What should be also stressed is that the same constraint arise in quantum physics as well, (42), (45).

This "character of totality" wich seems to constringe scientific studies of biological and social systems has been put in evidence not only in quantum physic but also in recent developments in physico-chemistry, specifically in the thermodynamics of irreversible phenomena where long distance correlations in dissipative structures have been shown to exist, (46),(47).

Conjuction n°2 and n°5 can be expressed more generally as the conjuction of the "hazard" and the "necessity", and thus be related to the intrusion of probability in science, particularly in quantum physics (at the microscopic level) and in the thermodynamics of irreversible processes (at the microscopic and macroscopic level).

The meaning that have the most fascinating connection with epistemology and philosophy are the statistical interpretation of Schroedinger's ware function by Born and Heisenberger's uncertainty principle; (42),(48),(49).

This evolution in quantum physics toward less determinism and more randomness is duplicate in a particular and very interesting way in the recent development in the thermodynamics of non linear systems far from the equilibrium.

In the so-called thermodynamics of irreversible processes one witness a reconceptualisation of physico-chemical science characterised by the realisation that the distinction between "simple" and "complex", between "order" and "disorder" is much narrower than usually thought. One sees the emergence of complexity at the macro physical level as a valid topic of study. The new theory stress the fact that irreversibility, dissipation, distance from equilibrium and non linearity can generate order out of the underlying disorder; (50),(51). Complexity is not longer associated only with biological of social systems, it is part of physical science, Einstein notwithstanding. The interesting aspect of the new theory and of dissipative structures which seems to appear in many fields such as optics, metallurgy, medecine, chemistry and biology is not only the fact order can emerge from disorder but that the underlining mechanism need random fluctuations, that is disorder, to work in the microscopic as well as macroscopic level; (42),(53).

The conjunction n°3 is related to the dimension of "historicity" which is a fundamental characteristic of the "living" (living organism as well as human behavior). To this conjunction can be added conjunction n° 7, as well as conjunction n° 2 through an adequate interpretation of Boltzmann intuitive interpretation of the second law of thermodynamics; (42). Overall these conjunctions can be expressed more generally as the conjunction of "entropy" and "neg-entropy"; (42),(52).

The reversible and irreversible description of nature can also be viewed as difference in the way "TIME" is used as a descriptive variable in science; that is either as an intrinsic or an extrinsic variable, making the dissymmetry "past-future" an intrinsic or extrinsic propriety of the system; (42),(55).

Classical mechanics, thermodynamics and quantum mechanics can be used to show example of both reversible and irreversible systems; (42).

In classical mechanics one can list the planetary motion and the K-systems as example of respectively reversible and irreversible systems; (53),(54).

In thermodynamics one can define a rich assortment of irreversible systems by virtue of the second principle. Irreversibility appears not only at the macroscopic level of description but also at the microscopic level. At both levels of description irreversibility and probability are related through Boltzmann formula; (52).

Finally, one has in quantum physics the paradox of observable events obeying laws of chance while their probabilities spread according. to laws which are in all essential features causal laws, (60). This raises the problem of "reality": the problem of what constitue the "real" things,(42).

Taking into account all the previous considerations, one comes to the conclusion that somehow reversibility and irreversibility coexist at the macroscopic. and microscopic level of scientific description of nature. The problem then is to know exactly how to integrate the two concepts at both levels of description of nature and accross the two levels. Therefore the conjunction of reversibility and irreversibility constitue a problem not only for the sake of finding an overall, all-embracing, scientific paradigm but also in term of the quest for basic laws in physics itself.

This quest has also to consider the applicability of the conjunction to the variable "Time" itself; (42),(55).

IV. CONCLUSION

It is appropriate to open the conclusion by a quotation from Niels Bohr again :

"The essential point to which one must pay attention is that every knowledge appears in a conceptual framework adapted to the past experience, and that such a frame, whatever it is, can appears too tight when the question arises to take up new experiences. The scientific research has shown many times and in many fields of knowledge the necessity to abandon or to reform point of view which was considered, because of their fecondity and of their applicability without apparent limit, as indispensable conditions of every rational explanation", (56).

This quotation rejoints the one presented at the introduction of the present talk. The necessity to revise the conceptual apparatus to deal more effectively with the complexity of social and biological processes and phenomena is obvious in many scientific quaters. The reason is that to become operationnel in the social and biological fields of knowledge one has to simplify, somehow, complex situation without losing essential informations needed to render precisely the complexity one is studying.

Furthemore it turn out that physicists believe that there exist universal basic laws observed by any entities under the same conditions, (57). This belief has led to a pervading mechanical description of nature in science.

Talking into account the impossible idealisations that govern the mechanical description of nature in the narrow fields of physics, one can rightly question the relevancy of applying the results obtained in physics in order to understand the subtle character of the enigma of life and the horendous complexity of human behavior. How indeed to use mechanical concepts and laws to simplify without losing essential informations, the complex processes and phenomena one encounters in socio-and biological fields of knowledge. As expressed by Bohr, (58) :

"To-day this old problem has regain a new interest because of the recent development of the atomic theory which has given us the unexpected proof of an essential limitation of the mechanical description of nature".

It is important to retain from the above quotation "the essential limitation of the mechanical description of nature", in order not to discard altogether this description but in order to probe more deeply the conditions under which it can be applied along other scientific descriptions to foster a better understanding of the complexity of socio and biological phenomena and processes.

We have been of the opinion that this aim can be achieved by finding a new paradigm that is based on a suitable conjunction of concepts that one finds in the field of physics but which appears, more often than not, as exclusive of each other.

All things equal and by analogy with quantum formalism, one has to find in fact the equivalent of Bohr's theory of complementarity, that will allow one to render in a more appropriate and simple way the complexity of social and biological phenomena. That this can be achieved is of course an open question. Some will think that the whole entreprise is doubtful, bordering the impossibility to say the least. One can take confort, however, on the way that Prigogine's mechanism has been able to combine in a elegant way the concepts of irreversibility, reversibility, determinism and randomness, (53).

From the above discussion, one can list two basic attitudes for physicists, concerned with the problem of developement in the Third World.

The first attitude is to wash one hands. As stated by a well known french saying : "A chacun son métier et les vaches seront bien gardées". Physicists must confine themselves to doing good science, which is already and herculean task, in developing countries at least, and forget the idea of involving themselves with problems, such as people starving to death in Africa, which are outside their expertise let alone their (immediate) solving power potentialities.

The other attitude is to swim against the tide and not to wait for the "spill over" mechanism, from whatever discovery physicist can be credited with, to help somehow in the future starving people, or whatever the development problem is.

I have taken the second attitude all along the present exercice, may be in a too subtle way.

Whatever the attitude however and whatever the merit of it, one thing must be clear at least : on must discard both the "Scientific certainty" and the "arrogance of the intellect" that come with it. They have more often than not, multiplied the blunders rather than the achievements in too many parts of the World. Certainty and arrogance are not the order of the day. This is perhaps the best lesson that one can drawn from Niels Bohr's life. Indeed if Bohr was able to build and to lead the "Copenhague School" composed of outstanding physicists, it is in great part because he was a modest man, ready to learn from other and not afraid to be shown "a fool " in the face of young scientists as reported by S.T. Belyaev, (59). The beautiful thing is that Bohr was not a fool, far from it.

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(8)
- "Potentiel ressources" : represent technical Know-How, professionalism, imagination, will power and ideas that are condition of production;
- "Means of production", are the existing tool, technology, available ressource;
- "The economic structure of society" : represent the social condition of production such as ownership, access to the means of production, division of labor, power structure. The "social conditions of production" reflect the relation between operator and the mean of production.
- "Political and ideological superstructures" : represent culture per se, ideology, religion, morale, (pré)-conception.

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(28) Prigogine L., Lecture du complexe; communication à l'Académie Européenne des Sciences et des Lettres; (1982).

(29) Bohr, opus cited (1961); p. 100.

(30) See reference in note (28). It should be noted that there is fundamental incompatibility between the postulat of conservation of energy and impulsion and the possibility of a precise description of the state of an atomic system; that is its localisation in space and time; see :Bohr, opus cited, p.34, for example.

(31) *"For we all think, in accord with Newton, that science is based on the certitude that nature always obeyes the same laws in the same conditions".* Bohr, opus cited,(1961), p. 19.

(32) According to Bohr (opus cited,(1961), p. 37.).

"The only way to renoncile the laws of Physics with the concepts adapted to a description of the phenomena of life is to examine the essential difference between the conditions of observation in physics and in biology".

The problem, here, is how and where to establish the clear cut, distinction between the "subject" and the "object" of a scientific investigation that allows the universal use of the universal concepts of classical physics necessary for the univocal and universal communication of the results of the observation.

(33) Allen P.M., The evolutionary paradigm of dissipative structure; in "The new evolutionary vision", edited by E. Yantsh; AAAS Selected symposium; Colorado, Westview Press Boulder, (1981).

(34) Nicolis G. and Prigogine I., Self-organisation in non-equilibrium system : from dissipactive structure to order through fluctuation; New York, Wiley, (1977).

(35) Bohr Niels, opus cited; (1961),(p. 18-19) and (p.37).

(36) Allen P.M.; opus cited.

(37) Prigogine I., En guise d'introduction, monde à découvrir; dans : "Nouvelles des Sciences et des technologies; opus cited, p. 9.

(38) Belyaev S.T., L'exemple de Niels Bohr. dans Niels Bohr et l'infiniment petit", Revue Impact, science et société; n°137; (Vol.36,n°1),. Paris, UNESCO; (1985), p. 39-50.

(39) Bohr's principle of correspondance, expressed at the origin Bohr conviction that there exist a profound structural similarity between quantic regularities and the laws of classical physics.

(40) The task is not an easy one. As stated by Born (opus cited (1961); p. 127-126) :

> *"We can correlate it (free will) with other phenomena in order to transform it into an objective relation, as the moralist, sociologist, lawyers do (...). After this transformation into a sociological concept, free will is a symbolic expression to describe the fact that the action and reactions of human being are conditionned by their internal mental structure and depend on their whole and unaccountable history. Whether we belive theoretically in strict determinist or not we can make no use of this theory since a humain being is too complicated, and we have to be content with a working hypothesis like that of spontaneity and responsability of action. If you feel that this clashes with determinism, you have now at your disposal the modern indeterministic philosophy of nature (where) you can assume a certain "freedom", i.e. deviation from the deterministic laws, because these are only apparent and refer to everage (...) Yet if you believe in perfect freedom you will get into difficulties again, because you cannot neglect the laws of statistics which are laws of nature (p. 126)".*

(41) Bohr Niels, The quantum postulate and the recent development of atomic theory; Atti del Congresso internationale dei fisici, Come, (1927).

(42) Malu wa Kalenga, Some epistemological consequences of Bohr's work in quantum physics; Monography, Kinshasa, édition C.G.E.A.; (1985); (in print).

(43) Born Max, Experiment and theory in physics; opus cited, p. 27

(44) O. Costa de Beauregard; Quanta et relativité; Cosmos et conscience; UNU Conference on "The praxis and management of complexity", Montpellier, France, (1981).

(45) Bohr Niels, opus cited (1961); p. 160 : "

> *"I .one wants to subdivise a quantum phenomena then one is obliged to modify the measuring instrument in a manner that is incompatible with the appearance of the original phenomena".*

(46) Nicolis G., Irreversible thermodynamics, Rep. Prog. Phys., Vol. 42 (1979), p. 227-267.

(47) Nicolis G., Bifurcation, fluctuation, [illegible] and dissipative structure. in "Nonlinear phenomena in physics and biology", edited by Richard H. Henns and alls, Plenum Press, n° 5, (1981), p. 185-308.

(48) Born Max, Experiment and theory in physics; opus cited, p. 23.

(49) In spite of this probabilistic interpretation, a ghost of predictability survive because the probabilities associated with the unpredictable motion (by virtue of Heisenberg principle of indeterminacy) flow like wave and obey strictly causal laws. (see: Banesh Hoffmann, the quantum revolution, in H.E.Barnes "An intellectual and cultural history of the Western World; Dver Publication, (1965), p. 1120). This insure that at the macroscopic level the law of great number restore a high degree of predictability; that is probabilities merge into virtual certainties.

(50) Prigogine I. and Nicolis G., Self-organisation in monequilibrium system : Towards a dynamics of complexity; in "Bufurcation analysis; ed. M. Hazewinkel and alls, Reider Publishing; (1985) p. 3-12.

(51) Lefever Rene ant Erneaux T., On the growth of cellular tissues under constant and fluctualing environmental conditions; in "Non linear electrodynamics in biological system", edited by M. Ross Adely and A.F. Lawrence; Plenum Publishing Corporation, (1984) p. 287-296

(52) Boltzmann most celebrated result was the microscopic interpretation of the increase of entropy under the form : S = K ln P,
Where S = entropy; P = probability; K = Boltzmann universal constant.
The technical definition of an "Information" (I) is the same as that of entropy except for a change of sign (neg-entropy); that is one has : I = -S.

(53) Prigogine I, Only an illusion; The Tanner lectures on human values delivered at Jawaharlal Nehru University; December, (1982).

(54) For K-systems the trajectories related to two initial conditions as near one can make it but not identical can diverge in time for a particular class of initial conditions in spite of the fact that the system is described by deterministic equations. Such systems can be viewed as intrinsically random (see : A.N. Kalmogorov, la théorie générale des systèmes dynamiques et la mecanique classique, Amsterdam Congress I (1954), p. 315-333).

(55) Costa de Beauregard O., Temps, Génèse de la notion; Encyclopédie universelle, Vol. 16, p. 925-932.

(56) Bohr Niels, opus cited, (1961), p. 109-110

(57) Bohr Niels, opus cited, (1961), p. 19

(58) Bohr Niels, opus cited, (1961) p. 9

(59) Belyaev S.T., L'exemple de Niels Bohr, opus cited, p. 45

(60) Born Max, opus cited, (1964), p. 103.