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BIOLOGY, POWER AND RESPONSIBILITY

Science is at present passing through a credibility crisis*. One could almost say a moral crisis. As a matter of fact we are standing at a turning point in the relationship between science and society, a turning point marked by the change from a social evolution characterized by high productivity and growth, into an evolution which might lead humanity to a new balance between individuality and collectivity.

At the beginning of the 20th century and during its second half the scientific world had suffered the impact of two significant revolutions: first of physics and then of biology. The basic discoveries in the field of physics led to applications in realms of energy, transportation, communication, electricity, electronics, and data processing.

The most important biology discoveries were made in a fairly short and relatively recent period. They are only beginning to be applied today. As physics has effected profound changes in

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the 20th century so biology will exercise a decisive influence on the 21st.

One can try to discover and to analyze the roots of the crisis through which science is passing in the "biological revolution" and in its consequences. This analysis then helps us to understand better the evolution of relationships between science and society, seen from the point of view of science's social role, of the responsibility of the scientific establishment and of its powers. Considering all this we may ask ourselves whether it will ever be possible, by evolving a new scientific attitude, to surmount the contradictions created by the modern science crisis. These three stages: analysis, evolution and *possible* solution of the crisis constitute the general plan of the present article.

Physics played a fundamental role in the development of the crisis; the role of biology is more recent and generally less known. The most important events resulting from the fundamental research of both branches of science can be symbolized in physics by nuclear energy and the atomic bomb and in biology by genetics and "genetic engineering" as the public calls it nowadays.

We will mainly follow the leading thread of biology without underestimating the importance of physics for the new types of interplay of powers between science and society.

The biological revolution of the 'fifties and the beginning of the 'sixties can be divided into four basic stages. These stages prove the importance of the knowledge derived from the theories of information, communication, or programming.

The first stage of this revolution is symbolized by molecular biology. This branch of science tries to understand the mechanisms of life on the level of molecules and of their intracellular interaction. Molecular biology was born out of the meeting of the physiologists who explored the life structures of the whole organism down to the tiniest cell; of physicists and chemists who passed from the molecule to the cell's microstructures; and of the genetists who deciphered the language of genes. For the first time in the history of biology the molecular interpretation of the basic life mechanisms allowed us to identify the important chemical code necessary for the transmission and translation of genetic information.

The second stage consists of cellular biology. The problem is not only the study of *intra*cellular relationships, but also, and mainly, that of *inter*cellular connections. The cells form a "society" within the tissues. They communicate with each other exchanging signals recognized by receptors placed on their surfaces. The understanding of these "conversations" among the cells during their "social" life is fundamental for the interpretation of the mechanism of differentiation, long range cellular communications or cellular recognition; and those mechanisms regulate the functions of the nervous, hormonal and immune systems. As we see, cellular biology leads the way to other important discoveries: that of the transmitting and the receiving molecules.

Neuro-endocrinology constitutes the third stage of the biological revolution. Here we are not dealing only with *intra*cellular or *inter*cellular communications, but with inter-organs, with the regulation and integration of the whole system of signals exchanged between the cells by way of molecules acting as cybernetic regulators, the hypothalamus or the pituitary directing the orchestra. Therefore the cybernetic regulation of the organism forms the general subject resulting from the research work of neuro-endocrinology.

The fourth stage of this revolution, the most recent but also the most fascinating one and at the same time the most controversial one, is represented by the breakthrough of genetic engineering, also called recombinant D.N.A. technology. This new bio-technology offers, as we shall see, the possibility to "re-program" the molecular and cellular interactions discovered during the preceding stages of the biological revolution. Through genetic engineering, science is enabled to act directly on life, heredity, and the species.

What about the applications, implications and consequences of such a scientific revolution? At this point it isn't any more a matter of considering the pratical applicability in the medical or industrial field; the problem is to valuate its influence on our thought and our action. There have already been great public debates on biology. Behind the battle about abortion lurks the great question: when does life begin? About euthanasia: when does death begin? For the transplant of organs: what is biological individuality? Everybody feels himself to be directly involved in the biological discoveries, which are speeding up and becoming more threatening every day. Here are three examples illustrating the techniques of genetic engineering, of "cloning," or of operations on the brain.

Genetic engineering consists in transplants from one organism to another of series of genes either reproduced from an original cellular "messenger" or obtained by chemical synthesis, or even cut up at random, thanks to special enzymes. These sequences of genes are then introduced into a molecular carrier, the "vector," which can be a virus or a plasmide, a kind of bacterial minichromosome of circular form. he "rearranged" or engineered gene is then "cloned," that is multiplied within a host bacteria. This gene is "translated" by the host cell into different proteins. The sequence of genes may also be introduced, always by way of proper vectors, into nucleate cells (eucaryote cells) belonging, for example, to mammals. In a short time the technique of genetic engineering made possible the production, by way of bacteria, of human hormones such as somatostatin, insulin and the growth hormone; or of proteins such as chicken egg albumen or interferon, an anti-viral and antitumoral protein. Reprogramming life is a basic research tool which will render possible a thorough understanding of the functional organization of the genes and of their expression; but it could also represent a powerful tool in the service of the young bio-industry for the production of raw materials for chemistry, medicines, biocombustibles, foodstuffs, or for rendering innocuous the dangerous substances present in our environment.

Cloning* practised on multicellular beings presents serious ethical and philosophical problems. Here indeed we face the question of a uniform biocopy of a live being. This method consists in taking the nucleus out of any cell extracted from a living individual, and introducing it in the place of the nucleus of a female egg. This egg divides immediately, exactly as if it were fertilized by a spermatozoid. The egg is then reintroduced into a female's womb. The embryo which develops can be carried up to the proper time and will become an individual biologically identical with the donor of the first cell. These cloning experiments have been made on frogs and recently on mice.

* From the Greek *klon*: twig.

We can also act on the "noblest" organ in the body: the brain. The researchers have recently discovered hormones called "endorphines" (endogenous morphines) which probably play an important role in the regulation of instinctive functions such as hunger, thirst, sleep, pleasure, pain, sexual instinct or aggressivity. It is presumed today that analgesic acupuncture might stimulate the endorphine production in the brain which would explain the painless operations performed by Chinese medicine. Could we imagine electronic systems programmed by a micro-processor and able to modulate in the brain the synthesis of endorphines, producing sometimes extraordinary pleasure surpassing that induced by drugs, and sometimes sensual stimuli, affective or intellectual, caused today by external events? Experiments in electronic brain stimulation made in California have already resulted in a paraplegic monkey regaining the use of its right hand by voluntary command—thanks to the other hand pressing the buttons of a computer, of coded electric impulses causing movements of the arm, the wrist and the fingers, and enabling him to grab "artificially" the food lying before him and carry it to his mouth.

An artificial arm receiving radio impulses emitted by the stump of an amputee sitting in a neighbouring room reproduces exactly the gestures about which this person thinks: close the fingers, turn the wrist, lift the forearm. There are today blind people who see and deaf who hear thanks to the microcomputers placed in special spectacles and transmitting to the brain, by way of electrodes implanted in the sensory areas.

As you see, biology has succeeded in acquiring real and disquieting power in a very short time. The relation of science to society is again upset. Following physics—which for the first time rendered science morally guilty—will biology, touching the deepest sources of life, establish definitively the basis for a long scientific crisis?

In this modern crisis the relationship between science and society evidently constitutes the heart of the matter. In three giant steps science has passed from the age of innocence to a state of concrete responsibility and then of latent guilt. Science was at first innocent, neutral, naive, almost a hobby or a game. The scientists, alchemists, inventors, enlightened amateurs, lived isolated in their ivory tower. As Krzysztof Pomian notes, they never left it except to fight disease, to promote inventions benefiting humanity or to oppose secular prejudices. This attitude enabled Henri Poincaré to write in *Valeur de la science* in 1905: "There cannot exist an immoral science, just as there cannot exist a scientific morality."

From innocent, neutral and naive, science became responsible. At the beginning of the century the growing industrialization caused a proliferation of industrial research laboratories. Science left the universities just in the period in which the effects of militarization and state centralization became ever more evident. In the face of such an evolution, represented by the soaring development of heavy chemistry in Germany during the 1940s and by the new techniques applied in the war industry, the problem of the scientist's social responsibility became rampant. However, it remained limited to the responsibility of the researchers for the use that others—politicians, generals, industrialists—made of the result of their work. The scientists assuaged their conscience by signing petitions or manifestos. But they were not yet fully conscious of their responsibility.

After Hiroshima the international scientific community began to have doubts about its influence and the efficacy of the means employed to convince the people responsible for the pratical use of scientific discoveries. Science felt guilty. It found itself—as A. Cournand noticed—"in a state of siege." It was discovered with sadness mixed with astonishment that—contrary to Poincaré's assertion—an immoral science *could exist*. There were, on the campus, secret research programs financed by the army, prestige programs due to the requirements of some politicians, industrial pressures on fundamental research. The scientists decided they must organize. This was the "campus revolution" of the early '70s, the foundation in the United States of the "Union of Concerned Scientists" and of "Science for the People." In 1975, at Asilomar the genetists and molecular biologists assembled in order to establish the rules of an international code for genetic engineering and to avoid what the physicists could not, or knew not how to, prevent: the highjacking of their research by political and military power. The Asilomar meeting can be considered an exemplary event: the scientists becoming for the first time fully conscious of their responsibilities and meeting to establish international rules for the future, designed to control the practical application of their own discoveries. In various countries the protesting and contesting movements concerning the responsibility of scientists of international fame outgrew the limits of biology or physics and interpellated the governments on nuclear weapons, civil use of nuclear energy, environmental degradation. We have witnessed a return of real doubt as to the scientist's role in contemporary society. Among young scientists this crisis reached unprecedented depths, sometimes surpassing even the intentions of its originators. Jacques Monod said that in some of them it became a kind of science masochism, young researchers doubting even whether they should continue their research; whether they should not, rather, render the discoveries already made useful for social goals and purposes. It was evidently a profound crisis, a malaise, a disorientation which characterized the sudden responsibilization of the scientists. However, their power also changed. The magic and then occult power becomes extended, diffused, revealed by the mass media; it influences greatly public opinion leaders, in depth intellectuals, the general public.

The scientist's power over society was exercised at first in an almost magic form. It was the power of the alchemist, of the medicine man over his tribe, of the high priest who could predict solar eclipses from a special arrangement of stones, of the healer. Besides, these enlightened scientists had always known how to excite the avidity of rulers, of the holders of real power.

From magic, the power of the scientists becomes occult at the very moment of the militarization of science, of its industrialization and subjection to state pressure—the hidden power of the man summoned by the powerful as an adviser: the "wise man" of the government, the consultant of industry. So certain great scientists become real "grey eminences," but in this subtle and sometimes intoxicating game they lose a certain trait of purity. The scholar in his turn looks for power, for a quicker way to reach glory than the one leading through his scientific work. Often he also seeks material gain. Indeed, the "consultant," the government adviser, the industrial adviser represent another type of scholar, a scholar who will not play any more according to the rules approved by "scientific" ethics;

since he bases his influence and his success upon criteria different from those according to which he accepted, and sometimes submitted to, the judgement of his peers.

This hidden power, which reached its peak in the '50s and '60s and which continues today, is changing into a more diffuse form: the "mediated" power exercised through publicity by the media: television, the press, the radio. Suddenly we see scientists becoming high priests celebrating a kind of televised mass; an evolution particularly important in the fields of biology and of medicine. When biologists speak on television, it strengthens the power of the medical world. When physicians express themselves through medical TV programs, their influence on the public is very great: the patients want to be examined and tested for the illnesses described on television. This direct relationship between biology and medicine reinforces the mandarins, the power of the few men running the establishment. This biology-medicine interrelationship seems to have replaced the religious ritual, ever more falling into disuse. The analogies are striking: the priestly vestment—the white coat. The benediction or absolution are replaced by the physician's prescriptions; the Latin by the complicated medical jargon; and the penitence by the medicine administered to the patient.

Next to the "high priest" scholar stands the incomprehensible one. This widespread attitude merits some consideration. Why are some scientists often so incomprehensible to the layman even when using mass comunication media? Doesn't this attitude hide a deliberate intent not to be translated? Indeed, a scientific discipline resembles a "territory" in Lorenz's sense. Every specialist owns his territory. He employs all the means in order to prevent an invasion of it by any intruder. The foxes define their territory by urinating on the tree trunks; the birds by constant chirping. Does the scientist "define" his "territory" by means of a language incomprehensible to non-specialists? The more complicated the language, the fewer intruders would risk defying him on his own territory. This is probably the means many specialists use to wield their power. Therefore they do not at all try to translate their language, since "popularization" really constitutes a loss of power. In fact to popularize means to divest oneself of a certain power. It means to speak like all the others, to render oneself accessible, to come down from one's pedestal. This might be the origin of the conflict we see nowadays between the scholar and the journalist: the journalist is always "in too much of a hurry" and the scholar "too cautious." This contrast, sometimes quite sharp, this reciprocal mistrust, is typical of our time. As a result, we are observing a basic contradiction between the powerful means of demultiplication provided by the press and the television on one side and the retreat of scientists behind the screen of language to escape, like the octopus behind an ink cloud, or to protect a theatened departmental territory.

The responsibility of the scientist also underwent an evolution. It has changed radically as a result the context of the rapport between science and society. The scientist is responsible above all to the community of scholars, a small exclusive world speaking a coded language, emanating very strict rules, which constitute a real code of morality. This code of the scientists was composed in 1942 by Robert Merton, an American sociologist. It contains four principles.

1. *Universalism*: scientific works should by judged everywhere according to their merit and their scientific value.

2. *Organized scepticism*: a scientific work can be evaluated only temporarily. This evaluation rests on irrefutable proofs which, however, must be put in doubt after a certain period of time.

3. *Detachment*: the scientist should be motivated only by the advancement of knowledge.

4. *Communalism*: the scientist must immediately inform the community about the results of his work.

Since this responsibility was obligatory in a cloistered world, it was "the others" who were responsible for the misuse of science: the politicians, the generals of the industrialists.

The scientist's responsibility changes radically as a result of the great national choices caused by the centralization of budget programs in the industrialized countries. The scientists suddenly feel that they are personally concerned in the costs of scientific, military or prestige programs, whose priorities slow down or prevent other fields of research. The conflict between the basic and the applied research becomes acute. The direct intervention of big business in university research, the problems posed by the deterioration of natural resources, the possibility of atomic of bacteriological warfare, force the scientist to come out of his enclosure and to speak in and to the city. By and by even the framework of the city or of the nation seems to become too narrow; international science senses a planetary responsibility. And so we hear them intervening for the defense of the species, for the respect of the ecological, or climatic balance. They make statements concerning the energy policy and the proposed means of production, aid to underdeveloped countries, the Soviet dissidents and human rights.

How can one try to reconcile the multiple facets of the relationship between science and society and surmount such contradictions?

As a result of the rapid analysis we have just made of the social role of the scientific establishment, of its power and responsibility, we can truly see its role and its functions questioned. It appears surrounded by an aura of power amplified by the media, but at the same time it suffers from the difficulties in communication with the public. It participates actively in the great debates on energy environment, the hunger in the world; but its influence on the policitians remains limited. Therefore the actual crisis could well be based on a deep-seated contrast: science might be suffering from a kind of dual personality. As Krzysztof Pomian very rightly observes, there is indeed a divergence between science's cognitive and productive functions. As a matter of fact, to understand and to know means also to be able to produce. Let me give a typical example taken from the techniques of genetic engineering. Some time ago, in the United States, small industrial companies were founded for the exploitation of genetic engineering techniques on an industrial basis. The founders of these industries are famous scientists who invested their savings in their enterprises but who in the meantime continue their research career. The "know-how" they possess enables them to produce a new strain of bacteria in a few weeks. This strain can then be used to inoculate a large fermentor which in its turn will become a chemical factory able to produce a precious pharmaceutical substance to be sold at a high price to industry. There exists, as we see, a direct connection between a "know-how" translatable into immediate action and the act of production. This creates an even more bitter debate between basic and applied research. The cognitive, abstract, creative function of fundamental research against the productive function of the applied one, the daily conflict between university and industry, between the publication and the patent.

Only by surmounting such contradictions could the malaise of modern science be mitigated, allowing it to forge a new kind of interplay with society, freeing the scientist of the dualistic antagonism in which he finds himself imprisoned. These contradictions could be surmounted in particular by complementary dialectics, a new kind of reasoning, no more linear, but appealing to the many facets of reality which strenghten each other through an interplay of combinations of interdependent means.

Some examples of such an approach could open up roads which would enable us to bypass the present conflicts. The first example seeks to show how we might abandon the linear reasoning which often imprisons our thinking. We might consider, from the traditional point of view, the relationships between basic research, applied research, development, and industrial realization and accomplishment (see Fig. 1).

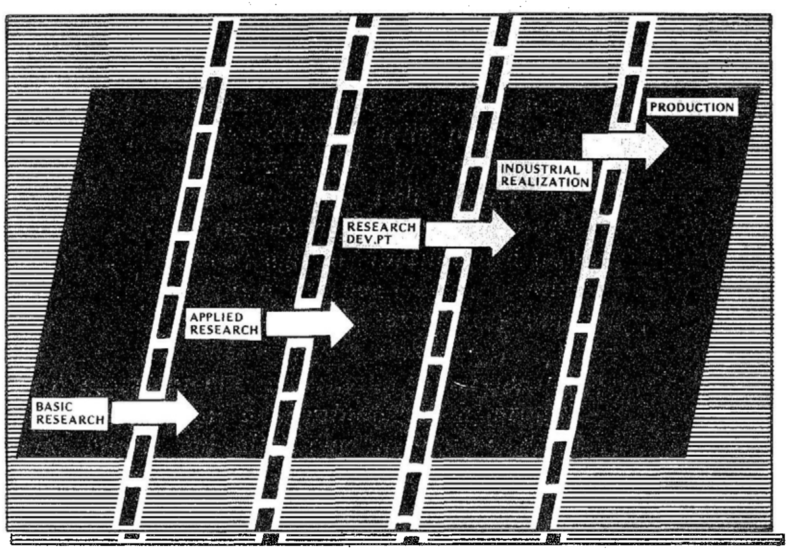

Fig. 1

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For some authors the basic research "precedes" the applied one. It is the upstream flow. Such a reasoning introduces theoretical borders between basic research, applied research, research-development, pilot production and industrial production. Indeed the scientists will tend to place themselves on the one or the other side, "upstream" or "downstream." That way they imprison themselves in unsolvable dualism. As a matter of fact, the relationship between basic and applied research can be illustrated schematically by a diagram on which we put "basic" research on the ordinate and its "applicability" on the abscissa (Fig. 2).

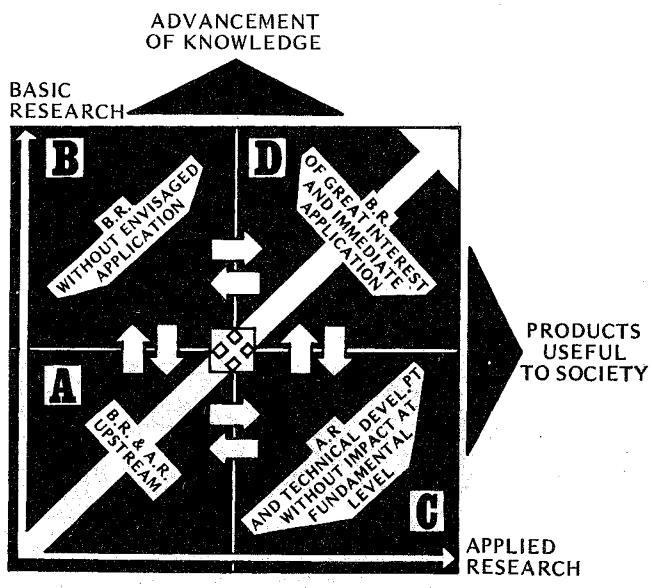

Fig. 2

Thus we distinguish many domains: in field A, a basic research and an applied one at the upstream point, multipotential. In field B, a basic research without immediate hopes of application. In field C, an applied research and technical development without any impact at the fundamental level. In field D, basic research of great interest and immediate practical value (application). The communications among the researchers can be realized in the interfaces of the fields ABC and D. The arrow on top of the diagram represents the advancement of knowledge; at the right, the technological innovations leading to industrial and economic development. The central axis is interesting because it leads to scientific progress and still leaves free the road for production useful to society. Looking at this diagram we cannot any longer think that the scientists place themselves strictly along the axis of basic research → applied research; but rather that they move from one field to another in the course of their careers. The contradiction between the cognitive and the productive functions can thus be eliminated, especially when considered from the point of view of society.

The second way of surmounting the contradictions consists of using the complementarity between two languages: the one of knowledge and the one of meaning. On one side the scientific language and on the other the language spoken and understood by artists and poets and in certain measure by philosophers. The complementary use of both languages would enable us to create a meta-language (so named by Michel Serres) by using the various symbolic tools available in order to "transfer" a message in two or more registers at once: a metaphoric, analogical or schematic language, a language which speaks in examples, in patterns. Only by using such combinations may we hope to avoid the irreconcilable dualism and open our minds to a better interpretation of basic discoveries and of their more concrete applications.

The third means which could be proposed consists of avoiding the focalization on a few individuals of general scientific success and of the criteria that go with it. It would be a matter of a kind of "depersonalization" of scientific success; a process that could be considered a desacration and a de-mythicization of the great scientific prizes which could be conceded to institutions rather than to individuals. Indeed, these prizes and the success criteria that go with them, in many cases dictate research subjects or research programs and sometimes the "conformist" attitude of some great scientists. Another means that could contribute to the "de-individualization" of scientific research would be to temper the effects of the "Peer Review System": this consists, particularly in the Anglo-Saxon countries, in the assessment of scientific results by experts who judge their colleagues. Of course, this system has been extremely useful and its role fruitful. However, in France the concentration of too much power in the hands of a few threatens to become a bottleneck for the young talents. Indeed, we often find the same scientists on the committees appraising young research men, on the editorial boards of the most famous international scientific journals, or on the committees distributing research funds. The fact that the same people decide whether a young scientist climbs one step higher on the career-ladder; whether he receives a scholarship or grant that will enable him to continue his research or whether he will be able to publish its results, tends to favor the students of the *gran-patron* and therefore to maintain unchanged the ideas of scientific "schools"—I would almost call them "chapels." An isolated scientist, even a brilliant one, has little chance to get known if he doesn't go through the "proper channels."

The proper sharing of scientific power also constitutes one of the ways of getting science out of its cloisters and of helping a new scientific spirit to emerge. As we have mentioned, the incomprehensible scientific language is one of the means of maintaining intact the power over one's well defined territory (the particular scientific discipline). We receive this language as we receive all expressions of power: from the top of the pyramid to its base. One way of making people participate in scientific progress and its results is to begin with a network organization in which every "node" receives and also transmits information. Today's scientist can contribute a lot to this redistribution of power by participating in the editions of scientific information to the general public and of course by teaching his students or lecturing before wider audiences.

These various examples of combined methods might bridge the conflicts which we find at the basis of the present crisis of science. The new approach to the scientist's role in modern society expresses itself more in terms of reciprocal complement and interdependence than in the power or domination relations of yesteryear. The analytic approach has led to a distribution of departmental territories ruled by "schools." The system approach

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introduced the opening up and the reciprocal fecundation of these territories. In this way all the facets of social life are being penetrated by the new scientific sbpirit; the pure knowledge conceded or withdrawn at will is substituted by "know-how," art of doing, productive ability and also the gift of plain speaking. This "enlightened" attitude leads inevitably to a modernization of scientific ethics. The ethics of knowledge as described by Jacques Monod is not sufficient any longer: "The only goal, the supreme value, the sovereign good in the ethics of knowledge is not—let's confess it—the happiness of humanity, and even less its earthly power or its comfort, and not even Socrates' "know yourself," but only the objective knowledge... The new ethic will be a strict and demanding one; although it respects man's right to knowledge, it ascribes a still greater value to Man himself."

Neither does the newborn scientific ethic go back to the development ethic and the scientist's role in technological, economic and social progress, as it was practiced by a certain technocracy of the sixties.

Finally, the strictly personal ethics—intellectual integrity, scientific objectivity, devotion to duty, unselfishness, values thought to be on a high moral level—are no more sufficient, since they center on the individual.

The emerging scientific ethic composed of a renewed (modernized) sense of individual and collective responsibility and of a mind opened to the whole world, has been considerably enriched by group and species morality. It is closely associated with bio-ethics (so called by Bronowski). It becomes a wisdom of the spirit.

This new wisdom will be indispensable for the difficult passage into the third millenium: if we really want science, particularly biology with its new power, to help us to cross that bridge without destroying ourselves in the process.