THE PONTIFICAL
ACADEMY OF
SCIENCES

PLENARY SESSION

THE CULTURAL VALUES OF SCIENCE

8-11 November 2002

PONTIFICIA ACADEMIA SCIENTIARVM

VATICAN CITY
2002

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PRESENTATION

PROPOSAL TO DEVOTE THE PLENARY SESSION OF THE PONTIFICAL ACADEMY OF SCIENCES IN THE AUTUMN OF THE YEAR 2002 TO THE SUBJECT: 'THE CULTURAL VALUES OF SCIENCE'

WERNER ARBER

Research in the natural sciences has brought mankind many forms of enlightenment with regard to natural laws. The knowledge which has been acquired through such research has been, and is still, useful for numerous practical and technological applications which help to facilitate the daily lives of human beings, including their health and wealth. Acquired scientific knowledge also 'modulates' our world-view, our deeper understanding of what nature (both the inanimate and the living world) is and how it functions. The internalised world-view greatly influences man's multiple relations with his environment. This is true both of technological development and the psychological and sociological aspects of human behaviour. Indeed, the history of scientific discoveries and their impact on our world-view and on technological progress is closely bound up with the history of our civilisation. It could be the aim of the proposed debate at the Plenary Session to collect case studies and to propose general conclusions on the obvious cultural values of science in a broad context, both as regards the evolution of our world-view and the evolution of the opportunities and possibilities of our lives.

Many of the contributions could be made by Academicians but the programme might be complemented by papers and comments given by a few invited speakers who are experts in the field.

This debate could represent a contribution of the Academy to the follow-up to the World Conference on Science held in Budapest in 1999 and more specifically to the subject of the renewal of the social contract between science and society. The Academy might possibly aim to draw up an appropriate statement and a set of recommendations on the basis of the conclusions reached during this Plenary Session.

INTRODUCTION

A CONTRIBUTION TO THE PREPARATIONS FOR THE PLENARY SESSION ON 'THE CULTURAL VALUES OF SCIENCE', FOLLOWING THE DISCUSSIONS OF THE COUNCIL MEETINGS OF 18 NOVEMBER 2001 AND 17 FEBRUARY 2002

H.E. MSGR. MARCELO SÁNCHEZ SORONDO

The First Homes of Science

All anthropologists agree that culture should be seen as a set of *learned* ways of behaving and adapting as opposed to inherited patterns of behaviour or instincts. Aristotle writes: 'While the other animals live by impressions and memories, and have but a small share of experience, the human race lives also by art (τέχνη) and reasoning (λογισμός)' (*Metaph*. 980 b 21). Culture is a typical characteristic of man who is not rigidly guided by determining laws which establish him within a given horizon. On the contrary, he is a self-interpreting animal, a self-made man. He never ceases to express himself and to give himself a name, and this development, at the centre of which is to be found man's freedom, is called 'culture', which is different from nature. When did culture experience the transition to science? If by science we mean the sophisticated arts of mathematics, aesthetics, architecture, metallurgy, and the written documents that describe such disciplines and their philosophical significance, then it is possible to describe ancient Egypt, China and Greece as the first homes of science. The wonders that Plato and Aristotle perceived as the starting point for engaging in philosophical thought are still applicable to the knowledge of children and adults, and to science itself, only that science makes the subject of these wonders move from the outside to the inside of things and is dedicated to the discovery of new laws, at the same time answering old questions and raising new ones.

The Scientific Revolution

Perhaps the most important event in European culture during the sixteenth and seventeenth centuries, which indeed gave rise to the modern age, was the so-called 'scientific revolution'. The wish to obtain in all the sciences (astronomy, physics, chemistry, biology) the same kind of rigorous demonstration that was to be found in mathematics, led the first modern scientists to apply mathematics to the study of nature. They dedicated attention to those aspects that could be measured. Given that mathematical hypotheses did not in themselves ensure a direct correspondence with reality, these modern scientists tried to verify such hypotheses not only by simple observations which could at times be deceptive (e.g., the perception that the earth is stationary) but also by more precise instruments (the telescope, the microscope, and others, which were constantly being improved), and above all by experiments, that is to say attempts to reproduce phenomena in more rigorous and controlled conditions. The synthesis of these two procedures, i.e. mathematical demonstration applied to nature on the one hand, and experimentation on the other, was the experimental-mathematical method. Matter, indeed, because of its quantity, could demonstrate its intelligibility through mathematical calculations that expressed themselves in relationships of a formal identity of reality in an abstract way. For example, two cells and two elephants, because they were each two in number, were the same in their 'twoness'. But in reality things do not exist equally, not even individuals of the same species. Therefore, contemporary science affirms the plurality and differences of physical forces (mass, energy, space, time, nuclear and sub-nuclear electric charges) and the plurality of life energies (cells, chromosomes, genes, the genetic code, the teleomatic structure) in living things. Today, macrophysics and microbiology seem to be moving towards an awareness that quality is in a dialectic relationship with quantity and vice versa, although on the physical level they are co-existent.

The Impact of Modern Science

For this reason, modern science has been one of the most important factors in the evolution of our civilized world for at least three centuries. Indeed, it cannot be doubted that scientific knowledge has led to remarkable innovations that have been of great benefit to humankind. Life expectancy has increased strikingly, and cures have been discovered for many diseases; agricultural output has risen significantly in many parts of the world to meet growing population needs; technological developments and the use of new energy sources have created the opportunity to free humankind from manual labour; and technologies based on new methods of communication, information handling and computation have brought unprecedented opportunities and challenges for the scientific endeavour as well as for society as a whole.

Science and Values

The question whether the values by which 'improvement' is measured should come from outside or inside science (or a combination of both), that is to say whether they are purely scientific or philosophical, ethical, political, religious, etc. (or a mixture of the first and some or all of the rest), is a subject of primary importance in the contemporary debate. The determination of the character of an action with reference to the predicates of 'good', 'values' and 'obligatory', which represented a radical break with everything that had gone before, began for the first time in history with the tradition of thought generated by David Hume. For this tradition, one cannot derive an 'ought' from an 'is' and there can be no direct step from one to the other. Put in more contemporary terminology, no set of descriptive statements can entail an evaluative statement. Thus Bertrand Russell concluded 'that, while it is true that science cannot decide questions of value, that is because they cannot be intellectually decided at all, and lie outside the realm of truth and falsehood. Whatever knowledge is attainable, must be attained by scientific methods; and what science cannot discover, mankind cannot know' (*Religion and Science*, OUP, 1961, p. 243).

The Rejection of Ethical Neutrality

The rejection of ethical neutrality and the problem of the justifiability and objectivity of value judgements began to manifest themselves, under the impact of the circumstances of the time, after the end of the Second World War, when it appeared clear, as Russell was to write, that it was no longer possible to place on the same level a discussion of the goodness or otherwise of oysters and a discussion of the rightness or otherwise of torturing Jews. After what has been termed the capital sin of science, the atomic bomb, and the arrival of the greenhouse effect (which scientists are the first to recognise and strongly condemn) the most serious problem to emerge today is the relationship between the science of nature, in itself perhaps neutral in relation to values (in Max Weber's view 'without values', value-neutral and ethically neutral), and its freedom to engage in research, with all that this implies for the morally and socially relevant responsibility of science itself. This responsibility, which in the first instance concerns the technical and economic application of scientific results, also regards the planning and implementation, linked to both technical and economic assumptions, of research programmes.

Emerging Questions

There thus emerges first of all the strictly theoretical question of the relationship between what is and what ought to be, and the question of the relationship between ontology, deontology and teleology, or between scientific rationality and ethical rationality; and secondly, the question of how to compensate for the powerlessness of the responsibility attributable to individuals who become effective only within the context of institutions which themselves should be transformed so that science may do good. As is often observed, science is one of the very few human activities where errors are systematically criticised and fairly often, in time, corrected. This is why we can say that in science we frequently learn from our mistakes, and why we can speak clearly and sensibly about making progress. Naturally enough, the Pontifical Academy of Sciences, which has studied this subject on many other previous occasions, cannot but take part in this debate, and this plenary session seeks to make a contribution to its positive development. The new horizons generated by globalisation, a process which has acted to reduce the distances of time and space (in part because of the impact of science itself), cannot neglect the question of the sustainable development of the whole world but in particular of developing countries. Let us not tolerate the existence of a knowledge divide, in addition to an unacceptable economic divide which also includes a 'digital divide'. For, unlike the possession of material goods, knowledge, science, and values, when shared, grow and develop. Aristotle argued that it was a principal task of the wise man to expound what he knows to others (*Metaph*. 982 a 14). Today, in a world which is increasingly globalised and where communication travels almost at the speed of light, it is the task, more than ever before, of wise men not only to engage in research but also to teach, to advise, and to orientate.

The Aims of the Deliberations of the Plenary Session

To provide examples of the progress of knowledge acquired by scientists during the course of the twentieth century in the various scientific disciplines;

to observe that an expansion in knowledge in itself has an incontestable value for humankind: universality; an increase in life opportunities; and a strengthening of the bases of human dignity;

to uphold the wish to share these cultural values with all our fellow citizens and with all the peoples of the world;

to secure democratic agreement about the principles and values to be applied to experiments required by research and to the critical assessment of the consequences of research.

PROGRAMME

Friday, 8 November 2002

9:00	***Speech of Welcome*** Prof. N. Cabibbo, President of the Academy
9:15	***Commemorations of Deceased Academicians***: André Blanc-Lapierre (14.12.2001) by Prof. P. Germain Louis Leprince-Ringuet (23.12.2000) by Prof. P. Germain Jacques-Louis Lions (17.5.2001) by Prof. P. Germain Minoru Oda (1.3.2001) by Prof. N. Cabibbo Max F. Perutz (6.2.2002) by Prof. W. Arber Franco Rasetti (5.12.2001) by Prof. N. Cabibbo Victor F. Weisskopf (21.4.2002) by Prof. A. Zichichi
10:30	***Self-presentation of the New Academicians***: Prof. A.M. Battro, Prof. E. Berti, Prof. G. Blobel, Prof. T. Boon-Falleur, Prof. P. Léna, Card. Prof. C.M. Martini, Prof. J. Mittelstrass, Prof. R. Noyori, Card. Prof. J. Ratzinger
11:30	Break
12:00	Chairperson: W. Arber ***Que la science s'inscrit dans la culture comme "pratique théorique"*** Prof. P. Ricoeur Discussion
12:50	General Discussion
13:15	Lunch
15:00	Chairperson: P. Germain ***Science and Culture*** Prof. M. Iaccarino Discussion
15:40	***The Cultural Values of Science*** Prof. L. Arizpe Discussion
16:20	***Cultural Aspects of the Theory of Molecular Evolution*** Prof. W. Arber Discussion
17:00	Break

FRIDAY, 8 NOVEMBER 2002

17:30	Chairperson: N.M. Le Douarin ***Science and Dreams*** Prof. P. Germain Discussion
18:10	***The Facts of Life*** Prof. C. de Duve Discussion
18:50	General Discussion
19:15	Dinner

SATURDAY, 9 NOVEMBER 2002

9:00	Chairperson: W.J. Singer ***Modern Cosmology and Life's Meaning*** Prof. Father G.V. Coyne Discussion
9:40	***The Different Paces of Development of Science and Culture: the Considerations of a Demographer*** Prof. B.M. Colombo Discussion
10:20	***From World View (Weltanschauung) to Science and Back*** Prof. S.L. Jaki Discussion
11:00	Break
11:30	Chairperson: E. Berti ***Science Education in the Twenty-first Century: a Challenge. Summary of the PAS Workshop held in November 2001*** Prof. P. Léna Discussion
12:10	***Nouveaux paradigmes scientifiques et déplacement du sacré*** Prof. Father J.-M. Maldamé Discussion
12:50	General Discussion
13:15	Lunch
15:00	Chairperson: R.L. Mössbauer ***The Moral Substance of Science*** Prof. J. Mittelstrass Discussion
15:40	***Reconnecting Science with the Power of Silence*** Prof. T.R. Odhiambo Discussion

SATURDAY, 9 NOVEMBER 2002

16:20	***Towards a Culture of Scientific Excellence in the South*** Prof. M.H.A. Hassan Discussion
17:00	Break
17:30	Chairperson: R.L. Mössbauer ***Science as a Culture: a Critical Appreciation*** Prof. C.N.R. Rao Discussion
18:10	***Predictability of Crime Waves*** V.I. Keilis-Borok Discussion
18:50	General Discussion
19:15	Dinner

SUNDAY, 10 NOVEMBER 2002

9:30	Holy Mass celebrated by His Eminence Card. Prof. C.M. Martini, Church of St. Stephen of the Abyssinians (Vatican City)
10:30	Private Guided Visit to the Sistine Chapel
11:00	Closed Session
12:30	Award of the Pius XI Medal (Casina Pio IV) to Dr. S. Dehaene and Dr. J.M. Maldacena
13:30	Lunch at the Academy

MONDAY, 11 NOVEMBER 2002

9:00	Chairperson: G.K.M. Menon ***The Impact of Neuroscience on Human Culture*** Prof. W.J. Singer Discussion
9:40	***The Art and Science of Medicine*** Prof. A. Szczeklik Discussion
10:20	Break
10:45	Papal Audience and photograph with the Holy Father
13:15	Lunch
15:00	Chairperson: N. Cabibbo ***The Why and the How of Our Origins*** Prof. W.R. Shea Discussion

MONDAY, 11 NOVEMBER 2002

15:40	***Science Never Ends: a New Paradigm is Coming into Being in Biology*** Prof. R. Vicuña Discussion
16:20	***The Unique and Growing Influence of the Neurosciences on the Development of our Culture*** Prof. R.J. White Discussion
17:00	Break
17:30	Chairperson: Cabibbo ***Scientific Culture and the Ten Statements by John Paul II*** Prof. A. Zichichi Discussion
18:10	General Discussion
19:00	Dinner

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ABSTRACTS

CULTURAL ASPECTS OF THE THEORY OF MOLECULAR EVOLUTION

WERNER ARBER

Applications of scientific knowledge often refer to technological uses, but their impact on our world view can also be of great importance. Both of these kinds of applications have their cultural values. This view will be exemplified with recent developments in molecular evolution. Darwinian evolution resides on 3 pillars: genetic variation (or mutation), natural selection, and geographic and reproductive isolation. It is only since about 50 years that genetic information is known to be carried in DNA molecules. Molecular genetics and molecular evolution are the fruits of this knowledge. Molecular evolution is investigated by the comparison of genomic sequences and by the study of the molecular mechanisms generating genetic variations. Much of the available knowledge comes from microbial genetics. Genetic variation is brought about by a number of different specific mechanisms, which can be grouped into three different strategies, namely small local changes in the DNA sequences, rearrangement of DNA segments within the genome by recombinational processes, and the acquisition of foreign DNA by horizontal gene transfer. A few specific examples for these mechanisms will be presented. The three strategies to generate genetic variants have different qualities of their contribution to the evolutionary progress. The available data clearly show the involvement both of gene products (acting as variation generators or as modulators of the frequency of genetic variation) and of non-genetic elements in the production of genetic variation. There is no evidence that genetic variation would in general be a specific response to an identified need imposed by the environment which forms the basis for natural selection. Rather, genetic variation is to some degree aleatoric, and it is natural selection together with the availability of appropriate genetic variants which determines the direction(s) of biological evolution. In view of the activities of specific gene products to the benefit of biological evolution a dual nature of the genome becomes obvious. While many of its genes serve for the fulfillement of the individual life, others (the evolution genes) serve for the expansion of life, i.e. for a rich biodiversity. Cultural values of this knowledge and its impact on our world view as well as on technological applications of genetic research will be discussed.

THE DIFFERENT PACES OF DEVELOPMENT OF SCIENCE AND CULTURE: THE CONSIDERATIONS OF A DEMOGRAPHER

BERNARDO M. COLOMBO

The point of view chosen for this intervention is to deal on how culture does accommodate itself to innovations introduced by science and technology, with particular reference to demographic phenomena.

The meaning of culture is taken in the largest sense, with no reductionism, in an horizon possibly acceptable to a cultural anthropologist. For instance it includes progress in techniques of research, in performing economic activities, in roads for decision taking, in customs, up to ethic and religion. And it includes artistic objects, tools for work, facilities for elaboration, and so on.

Nowadays we see scientific discoveries and technological applications popping up at a more and faster pace. And we see their marked impact, direct or indirect, on many facets of our life. But culture is embodied in human beings, who have a history behind them. A history of personal experience, of habits, evaluations and choices with which the new horizon opened by those events has to be confronted before any decision is taken towards and eventual change.

We make about that personal experience when we re-orient our own lines of research in view of taking advantage of new techniques. This might mean, not only to be able to master the new techniques, but also to make ad hoc studies in new fields allowing to become possibly personally creative in new directions. Concerning economic activities may be mentioned problems debated in this Academy in the study group of January 1999 on 'Food needs' in the developing world. There was much discussion on the new approaches to their work from farmers – especially small farmers in developing countries – due to the impact of genetically modified products. The development of software for computers has magnified the problem of evaluation of intangible goods with its link with the constructions of framework for economic balance. And so on.

The demographer is confronted since a long time with the understanding, measuring, forecasting the relevance of changes in knowledge and applications. Life, birth, death, sickness, age structure, marriage habits, population movements, and so on have a history, and a future, on which the advancement of science and of technological applications continues to open new panoramas. There is a substantial difference between their initially restricted and localized happenings and the pace of the spread of their impact on societal culture and personal behaviour. Demographic developments follow their own road, characterized by the weight of an intrinsic inertia.

MODERN COSMOLOGY AND LIFE'S MEANING

GEORGE V. COYNE

Modern cosmology, as well as ancient mythologies, cosmologies and cosmogonies, bear witness to the immense power which drives us humans in our continuous search for a deeper understanding of the universe and our place in it. They also bear witness to the insufficiency of our search for understanding, of the need for something or someone out there, beyond oneself. From time immemorial we have always sought this further understanding in a person with whom we could converse, someone who shared our capacity to love and be loved and our desire to understand and to accomplish.

Our attempts, therefore, to understand the universe have as much to say about ourselves as they do about the universe. In fact, in us the universe can reflect upon itself and from our reflections there grows the conviction that we are part of that upon which we are reflecting. As soon as we set out with the powerful instruments for telescopic observations, together with those of mathematics and physics, to understand the universe and our place in it, we are made aware that we are standing on the shoulders of giants and that the path which has led to what we know today has been, with respect to a human lifetime, a long and arduous one and that many have gone before us. But, in comparison to the age of the universe, it has really been quite a short trek.

It makes us dizzy to contemplate billions of years in the evolving universe and then to think that we are on a little planet orbiting a quite normal star, one of the 200 billion stars in the Milky Way. And the Milky Way is just one galaxy and not anything special among the billions of galaxies which populate the visible universe.

Cosmology today is ever more human; it stimulates, provokes, questions us in ways that drive us beyond science in the search for satisfaction, while at the same time scientific data furnish the stimuli. In this context the best cosmology, to its great merit, does not pretend nor presume to have the ultimate answers. It simply suggests and urges us on, well aware that not all is within its ken. Freedom to seek understanding and not dogmatism in what is understood characterize the best of cosmology. It is, in fact, a field where certainties lie always in the future; thus it is vital, dynamic and very demanding of those who seek to discover the secrets of the universe.

I will attempt to read the data of cosmology more from a human than a scientific perspective without any presupposition, however, that the one precludes the other. In fact, it is altogether a very human endeavor to attempt to integrate rigorously scientific conclusions with those which are drawn from life's other experiences and from the very search for the meaning of life.

THE FACTS OF LIFE

CHRISTIAN DE DUVE

The last fifty years have witnessed immense advances in our knowledge of the nature, origin, and history of life on Earth. From the practical point of view, these advances have led to the development of new technologies that dramatically increase the power of humankind to consciously and deliberately modify living organisms, including the humans species itself. From the philosophical point of view, the advances impose a fundamental reappraisal of humankind's cosmic significance, which has yet to become incorporated into modern thought. These facts and the ensuing problems are briefly reviewed.

SCIENCE AND DREAMS

PAUL GERMAIN

This paper presents a few remarks on the following statement by two French biologists: 'Man, the distant cousin of the slug, who invented the integral calculus and dreamed of justice. Man and human society: the products (the distant cousins) and the producers (the integral calculus) of science. Man, the living being who has always dreamed of a better world, a world or peace, a world of purity and fairness'.

The first part of the paper draws attention to the marvellous gift that science is: science provides an incontestable understanding of life, the universe and their histories, and also offers a possible way of creating the wealth and goods that could ensure that people have a better life.

The second part of the paper describes the various positions and attitudes of scientists towards the dreams of society. Some of them think that everything must be done to hasten the progress of science and scientific achievements and they are ready not only to take action which opposes and contradicts such dreams but even to behave in a unworthy way towards humans. In contrary fashion, for other scientists, the progress of science appears to be the best way there is to realise these dreams. But during the last decades most scientists have not paid very much attention to such dreams. They have thought that they were not their concern and have seen them as the prerogative of other groups: politicians, philosophers, priests, sociologists.

The last part of the paper deals with the new situation now faced by the scientific community: today, scientists cannot ignore the efforts, the needs, the expectations and even at times the worries of societies. International meetings, the first held in Rio ten years ago, show that the problems created by the growth in the world's population and the development of communications are strongly affected by scientific activity and its technical applications and achievements. Science and scientists were more directly involved in the impressive Budapest meeting of 1999. This paper will describe a few initiatives taken at different levels which have tied to meet the present needs of societies.

TOWARDS A CULTURE OF SCIENTIFIC EXCELLENCE IN THE SOUTH

MOHAMED H.A. HASSAN

Experience has shown that no nation can achieve sustainable economic and social development without embracing a professional culture of scientific excellence, as part of the nation's overall social, cultural and ethical values.

Developing and sustaining such culture depends largely on carefully designed national strategies that ensure excellence and relevance in the conduct of science within existing cultural frameworks.

The enduring investment that countries of the North have made in encouraging the pursuit of excellence in science and technology largely explains their economic and social progress. Recent experiences in a number of developing countries – including China, Brazil, India and Korea – also show that supporting and maintaining high quality local capacities in science and technology yield substantial benefits to society.

In the majority of developing countries, however, there is an acute shortage of highly qualified and innovative indigenous scientists and technologists who, in addition to excelling in their own fields of research, are able to integrate modern science with traditional knowledge systems with the goal of addressing real-life problems and long-term sustainability issues.

The paper will discuss the ways and means of developing and maintaining a professional culture of scientific excellence in developing countries. This requires national S&T strategies that are fully integrated into economic and social frameworks and cultural values of the country. It also requires a paradigm shift in North-South partnership that is anchored on agendas designed by the Southern partners and supported by global efforts to establish and maintain networks of institutions of scientific excellence in the Least Developed Countries (LDCs).

ON THE FORTUNES OF CLASSICAL PHYSICS IN THE TWENTIETH CENTURY

RAYMOND HIDE

The twentieth century saw the rise of modern physics, one of the most stupendous developments ever to have occurred in science. Concomitant developments based on applications of the established laws of classical physics -of dynamics, thermodynamics and electrodynamics- to processes on length scales and time scales where both quantum and relativistic effects are negligible, were inevitably less impressive, though still very significant

When it comes to predicting future trends even eminent scientists seem to achieve no more than average success [1]. Knowing that the general circulation of the gaseous atmosphere of the Earth under the influence of differential solar heating must be governed by the laws of dynamics and thermodynamics, and emboldened by the great success of physicists in establishing these laws, one leading scientist in 1900 was rash enough to suggest that within 50 years routine efforts by meteorologists trained in physics and mathematics would enable the general public to enjoy highly accurate weather forecasts. He clearly overlooked the serious theoretical difficulties already besetting physicists, mathematicians and engineers in their attempts to apply the laws to real systems. These difficulties are especially severe in research on turbulent fluid flows and other complex processes encountered in the study of continuous media. The governing partial differential equations in terms of which the physical laws are expressed mathematically can certainly provide valuable theorems and diagnostic relationships between key variables [2]. But their essential nonlinearity renders the equations virtually impossible to apply in most prognostic work.

Classical physics understandably declined in popularity as modern physics advanced, although some talented young practitioners were prepared to pursue careers in the subject. Others kept a foot in both camps, at least to start with, including scientists of the calibre of Heisenberg whose well-known contributions to the theory of stability of parallel shear flow and turbulence in fluids [3] were outshone by his great work in quantum mechanics. With many new problems to be tackled in modern physics there was no strong temptation to spend time seeking explanations of natural phenomena such as the Gulf Stream in the Atlantic Ocean and the Great Red Spot in Jupiter's atmosphere. And many phenomena now investigated under the heading of "geophysical and astrophysical fluid dynamics" such as the magnetism of the Earth and the corona of the Sun remained completely enigmatic until pioneering work by Alfvén and others [4] created the new subject of "magnetohydrodynamics" (MHD).

MHD involves the application of all the laws of classical physics, for the (pre-Maxwell) equations of electrodynamics are also needed when treating the flow of an electrically-conducting fluid. Much material in the cosmos is both fluid and electrically conducting and on the scale of cosmical systems MHD phenomena abound. But underlying processes are impossible to reproduce.on the very much smaller scale of the terrestrial laboratory, owing to the difficulty with available fluids of achieving high enough values of the "magnetic Reynolds number" ULms (where U is a characteristic flow speed, L a typical length, m the magnetic permeability of the fluid and s its electrical conductivity). This obstacle to progress is now being overcome to some extent by the increasing use of powerful computers for integrating the governing equations.

Computational fluid dynamicists strive for breakthroughs in understanding turbulence and many other fundamental processes [5]. As in laboratory studies, basic general theorems and dimensionless parameters play a central role in the formulation of crucial investigations and the interpretation and application of experimental results. Dimensionless parameters are readily identified by expressing the governing equations in dimensionless form, but their successful use is less straightforward and remains something of an art [6]. Fortunately, experience shows that it is not always necessary or even desirable to insist on complete geometric and dynamic (and, where appropriate, thermodynamic and electrodynamic) similarity. We now see, for instance, albeit with twenty-twenty hindsight, that if physicists in the late nineteenth century and early twentieth century had made simple but systematic "curiosity-driven" laboratory investigations of flow phenonena in spinning fluids, unexpected dynamical processes, including chaos, of direct relevance to meteorology, oceanography and other areas of science and engineering would have been discovered much sooner [7, 8]. Whilst it is impossible in the laboratory to simulate a planetary atmosphere in all its details, much of our knowledge of fully developed "sloping convection" -the process that underlies many natural phenomena such as highly irregular waves and jet streams seen in the Earth's atmosphere and the more regular large and durable eddies in the atmospheres of the major planets- comes from laboratory experiments on thermal convection in rotating cylindrical (rather than spherical) fluid systems no more than several centimeters in size. These were started around 1950, long before computers became powerful enough to play a significant role in such research.

Historians must by now have a fairly clear picture of the main achievements of all branches of physics up to the middle of the twentieth century, but they are still evaluating the fortunes of the subject over the past fifty years. As a contribution to the 2002 Plenary Session of the Pontifical Academy of Sciences on "The Cultural Values of Science", this short paper offers comments on some of the fortunes of classical physics.

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SCIENCE AND CULTURE

MAURIZIO IACCARINO

Modern Science was born at the times of the Renaissance in Europe, but before that in all continents there has been an accumulation or knowledge concerning the comprehension of the world, accompanied, or stimulated, by technological development. Science deals with specific phenomena that are studied with an appropriate set of rules leading to the possibility of making predictions and generalisations. However, most observations on the behaviour of the world around us are empirical and there is much more to understand than what is studied by scientists. Nature is complex and we do not yet have today the appropriate methods to study it. The study of complex systems is a major challenge for the future and we cannot discuss the future of Science without taking into account the philosophical problem generated by the study of complexity.

The perception of the world in developing countries is different from that encountered in Western countries. Traditional or indigenous practices of developing countries are today studied not only with the aim of finding new drugs, but also in an attempt of deriving new concepts that help us reconciling empiricism and science.

EARLY DETECTION OF PRODROMAL SYMPTOMS AND TREATMENT OF EARLY PSYCHOSIS

PAUL A.J. JANSSEN

Frank psychotic symptoms rarely arise 'out of the blue' with no prior mental state changes or prodromal symptoms at all. Commonly observed prodromal features are reduced concentration, attention, drive, motivation, as well as anergia, social with-drawal, anxiety, suspiciousness, sleep disturbances, irritability, depressed mood, etc., most often in adolescents.

The inability of the brain to distinguish between relevant and irrelevant stimuli, – lack of Pavlovian 'internal inhibition' in other words – is as a rule the cause of these symptoms.

Perception is disordered as a result and this is caused by a dopaminergic dysfunction in the striatum.

Amphetamine e.g. which greatly increases the free dopaminergic concentrations, often induces a psychotic state indistinguishable from paranoid schizophrenia.

All potent and specific neuroleptics are very effective amphetamine antagonists.

At small and side-effect free doses these neuroleptics are also very effective in the treatment of prodromal symptoms and, when properly used, can prevent the onset of the first episode in psychotics for a considerable period of time.

In an effort to improve the diagnosis of prodromal symptoms in the pre-psychotic phase of the disease, we recently gained experience with a computerised stereotypy test apparatus. A subject is invited to press, at one-second intervals, any of 9 identical buttoms, 200 consecutive times, as randomly as possible. Bente's original observations were confirmed in normal and in schizophrenic subjects: in contrast to normals, schizophrenics are unable to avoid stereotyped patterns of pressing.

Available evidence indicates that most adolescents with prodromal symptoms also show a stereotyped pattern of pressing the buttoms.

Early ambulatory treatment with optimal doses of potent neuroleptics, as determined using the handwriting test of Haase, should be initiated in adolescents with prodromal features in order to prevent the occurrence of first-episode psychotic symptoms.

SCIENCE EDUCATION IN THE 21ST CENTURY: A CHALLENGE. SUMMARY OF A PONTIFICAL ACADEMY OF SCIENCES WORKSHOP HELD IN NOV. 2001

PIERRE LÉNA

Observing the many themes of Workshops or Sessions held over the last decades by *the Pontifical Academy of sciences*, it appears that none of them had directly dealt with *education* as a main title. In our days, the concern for education in science and technology blossoms all over the world in Science Academies, in Ministries of education, research institutions and in the scientific community. During the last two decades, a strong emphasis was placed on scientific information of the general public (mass media) and on informal science education (museums). Yet, after ten or more years of primary and secondary education in schools, the understanding of the nature of science, of its role is often mediocre among teen-agers. Accumulation of mere facts, results and formulae, admiration for technological 'black-boxes' do not suffice to build the basic roots of a scientific attitude towards the natural world, a proper use of reason and rationality, a capability to use adequate words and arguments in order to deal with concepts, causality, uncertainty with a critical mind. Such basic abilities, for every child on the planet, are not only desirable to address and solve the many problems facing the world, but are part of human development, in order to properly handle the new freedoms opened by the development of science and its applications.

The Workshop, held during three days in Nov. 2000, gathered thirteen Academicians and thirteen experts. Most parts of the world were represented, with the notable and regrettable absence of the Far East and Arabic countries. It led to a conclusion *Statement*, later approved by the PAS Council in Feb. 2001, and its whole content is published[1].

The basic agreement among the participants was that, in this new century, knowledge will be a fundamental basis for reducing global imbalance of development and to increase the stability of the world. Hence the issue of properly thinking, putting in perspective (historical, ethical, philosophical) and sharing the knowledge, built by research at an unprecedented rate, becomes vital. This requires to mobilize analysis and action on educational ressources, recruitment, role and training of teachers, their relation with the scientific community during the decades of their practice, the use of new information technologies, the understanding and rational evaluation of risks.

Most impressive was the convergence of analysis carried in countries as different in cultures and states of development as Chile, France, Germany, India, Italy, Mexico, United Kingdom, United States and others : they all showed the need for a deep reform, but also the success of experimental programs, carried with an *Hands-on* (*La main à la pâte* in French) approach to science and the active contribution of the scientific community (this seems to be a necessary ingredient for success). Clearly education in science goes much beyond imparting skills for the production of more science and technology. Several communications attempted to outline what is a scientific mind, a notion far from being understood by many science educators.

Another aspect barely touched on by the Workshop, but worth deeper analysis, is the impact of the cognitive and 'brain' sciences on the understanding and methods of education in science.

It would be fair to say that, rather than proposing exhaustive solutions, the Workshop made a lively inventory of issues and encouraging experiments, therefore calling for subsequent and deeper investigations. Specifically related to the globalization context, the question of how to merge in education the universality of science with the diversity of cultures arises.

The Workshop Statement

The immense and increasingly rapid development of science as an important element in culture bestows a new responsibility on the scientific community, beyond its traditional role of creating new knowledge and new technology. Ensuring proper education in science for every child in the world and, consequently, a better public understanding of science and what science stands for, has become both a necessity and a challenge.

As a belief in the constant capacity of humanity to progress, education requires caring for the children of today and preparing the citizens of tomorrow. Access to knowledge, therefore, is a human right, even more so in the knowledge-based society of the future.

The extremely uneven access to education in today's world generates profound inequalities. Let us not tolerate the existence of a knowledge divide, in addition to an unacceptable economical divide which also includes a 'digital divide'. For, unlike the possession of goods, knowledge, when shared, grows and develops.

Education in science for all girls and boys is essential for several reasons. In particular, this education helps :

to discover the beauty of the world through emotion, imagination, observation, experimentation, reflection and understanding;

to develop the creativity and rationality which enable humans to understand and communicate;

to contribute to moral development and sense of values : the search for truth, integrity, humility, and man's responsibility towards their neighbours and future generations;

to share the accumulated wealth of knowledge amongst all people, as required by justice and equity;

to be aware of mankind's interdependence with the environment and the Universe;

to enable contributions to the solution of the acute problems facing humanity (poverty, food, energy, the environment);

From the perspective of these objectives, it is our conviction that the present state of education in science is of great concern throughout the world, regardless of the local stage of development. In the case of developing countries, in particular, the magnitude of the problem is immense.

After consideration of a number of encouraging experiences in various countries, and the actions of several Academies, we conclude that the following initiatives should be taken without delay, both at a national and an international level. Moreover, they should be shared and integrated within the diversity of cultures found in contemporary societies.

The highest level of attention has to be given to science education in primary and secondary schools, including children with special needs.

Education in science must be seen and implemented as an integral part of the whole of a person's total education (language, history, art, etc.).

The most important contribution to improving education in science in elementary and secondary education lies in helping teachers and parents to cope with this difficult task. This will involve increased resources, partnership, professional development, social recognition and support for teachers.

Such a challenge cannot be met without the deepest commitment on the part of the various members of the world's scientific and technological community. Meeting this challenge must be viewed as a new moral obligation.

Every means should be used to convey the urgency of the situation to governments. They alone have the capacity to deal with the magnitude of the problem, to provide the necessary resources, and to implement suitable policies. Non-governmental organisations and financial institutions should also participate in such an initiative.

Relevant research on science education should be stimulated and encouraged, and should consider the potential of communication technologies.

What is being called for is a global commitment to revitalize science education at school level with support not only from the teachers, parents and scientists, but entire communities, organisations and Governments, for a better and more peaceful world to live in.

Success along these lines, pursued with perseverance and dedication, will constitute a decisive contribution to the socio-economic and cultural development of humanity, the achievement of social justice, and the promotion of human dignity.

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NOUVEAUX PARADIGMES SCIENTIFIQUES ET DÉPLACEMENTS DU SACRÉ

JEAN-MICHEL MALDAMÉ

La science moderne repose sur des procédures de vérification expérimentales, qui mettent en pratique des idées exprimées dans des concepts rigoureux. Ceux-ci dépendent de concepts premiers et plus généraux qui ne font pas partie de la science comme telle. Ils constituent des paradigmes. Les paradigmes eux-mêmes ne sont pas indépendants d'une culture qui implique attitude générale vis-à-vis de la Nature. Il y a donc par diverses médiations, une relation à ce que les sciences humaines appellent "le sacré". Celui-ci s'exprime par des symboles ou même des mythes qui ne sont pas totalement étranger à la science comme telle.

Lorsque la science change, ses concepts propres et ses procédures expérimentales se renouvellent en lien avec un changement de paradigme. Cette évolution (qui est parfois une révolution) mène à un changement d'attitude vis-à-vis de la Nature et donc déplace les catégories du sacré.

L'exposé montrera comment ceci s'est opéré lors de la naissance de la Physique quantique. Elle étudiera aussi ce qui advient aujourd'hui en matière d'embryologie où sont impliquées un vision de la Nature, de la Vie et de l'Homme. Ainsi la science actuelle participe-t- elle à l'élaboration de valeurs fondamentales qui définissent une culture.

Pour cette raison, il importe que la Communauté scientifique soit vigilante pour que les valeurs de raison et de vérité qui la fondent ne soient pas détournées de leur sens.

NEW SCIENTIFIC PARADIGMS AND CHANGING NOTIONS OF THE SACRED

Modern science depends on the practice of experimental verification, a procedure which makes use of rigorously formulated concepts. These concepts themselves depend on prior, more general concepts which are not a part of science as such. These more general concepts are known as paradigms. Paradigms are not independent of the culture in which they exist, nor of the general attitude towards Nature which is found in this culture. In various ways, this implies a relation to what the human sciences call 'the sacred'. A reality which is sacred is expressed in symbols or even by myths, and these are not entirely foreign to science itself

When science changes, its concepts and its experimental procedures are renewed as a shift in the paradigm takes place. This evolution – which can sometimes be a revolution – leads to a change in attitudes towards Nature and thus a changing notion of the sacred.

The paper shows how these various changes were brought about by the birth of quantitative physics. It will also consider what is taking place today in the science of embryology, where a vision of Nature, of lire and of man himself is at stake. Contemporary science has a role in shaping those fundamental values on which a culture depends.

As a result, it is vital that the scientific community be vigilant, and ensure that the values of reason and truth which of its own foundations are not robbed of their meaning.

THE MORAL SUBSTANCE OF SCIENCE

JÜRGEN MITTELSTRASS

When we speak of science, we mean as a rule either a particular manner of knowledge-formation, in other words the scientific formation of knowledge, which follows definite standards and methods of rationality, or again science as a (social) institution, for example in the form of universities and institutes. But this division is not complete. There is a third sense of the term, namely science as an idea that includes a moral form. The latter is expressed already in the usual standards of rationality, and above all when confining oneself neither solely to such standards as the reproducibility and controllability of scientific results and methods, nor merely to the conceptual clarity of scientific representation and justification, one thinks also of standards of selflessness, of veracity and of scepticism, as has been suggested by the sociologist of science Robert K. Merton.

This third meaning of science, which restricts science neither to purely methodological nor institutional aspects, was indeed its original and essential meaning. Greek philosophy, which we thank for the theoretical form of knowledge, spoke explicitly of the bios theoretikos, of the theoretical life, and not of theory in our modern, rather technical sense. According to Aristotle, theoria is a general orientation of life. Theory in this sense – and not in our textbook sense – is the highest form of praxis. The scientific and epistemological subject is here still at one with the 'moral' subject, so that theoria as a form of life involves making truth a form of life. Thus according to this division, theoria is assigned not to the methodological but to the moral form, or idea, of science. In this sense, both the work of the individual on his rational nature and the truth itself are moral.

THE DIFFERENT TIME SCALES FOR DEVELOPMENT OF SCIENCE AND OF CULTURE

MARCOS MOSHINSKY

Both scientific knowledge and cultural values change with time, but the first one does so much faster than the second. As an example we have the knowledge of the ultimate structure of matter which in the last seventy years has gone from its constitution in terms of three concepts the photon, the electron and the proton to a great number of quarks and gluons with different flavors and colors plus leptons and gauge bosons.

Which of these two pictures we would like to incorporate in the general culture of our population.

While the quark-gluon picture is, at the present time, the deeper one, the photon-electron-proton is the more accessible and its relative simplicity makes it a more convenient concept to incorporate it in the general culture.

We must distinguish between the knowledge of science that has been fully corroborated such as that the earth is round or that it moves around the sun, from those which are still in the process of development such as those indicated in the first paragraph.

Those concepts of science that are important and fully corroborated should become part of the culture of any educated person. Those that do not meet this criterion should remain in the province of the scientists that work on them or of those laymen that have a genuine interest in how science develops.

Science should be a part of culture but does not in compass all of it as it has nothing to say about moral values, artistic creation, religious beliefs or many other aspects of the human experience. Furthermore these other cultural aspects change more slowly, if at all, than scientific developments and thus we should be fully aware of their different time scales if we want science to play a more significant role in individual and social cultures.

In the present paper several examples will be presented of the mismatch of science and culture due to their different times scales of development.

SURGERY OF THE SOUL – REFLECTIONS ON A CURIOUS CAREER

JOSEPH E. MURRAY

This remarkable book is the autobiography of one of the 20th century's most honoured surgeons, Joseph E. Murray, winner of the Nobel Prize in Physiology or Medicine in 1990. In it, Dr. Murray describes his role in breakthrough research in human organ transplantation and his pioneering advances in surgical techniques to correct deformities of the head and face caused by birth defects or terrible accidents.

This book tells not only the author's story, but also the stories of many of his patients. One such patient is a 22-year-old aviator names Charles Woods. During wartime runs in the Far East, Wood's plane caught fire, and his attempt to escape, he was burned beyond recognition. His nose, eyelids, and ears were obliterated, and by the time Woods reached the States, he was barely alive. Over the next two years, Dr. Murray and the surgical team at a Pennsylvania military hospital performed 24 operations designed to build their brave patient a new face. Charles Woods survived and went on to a highly successful career, and to fly again.

Dr. Murray relates the story of another patient, Richard Herrick, whose kidneys were failing and whose life was saved when his twin brother Ronald, agreed to donate one of his healthy kidneys and made possible the first successful kidney transplant. Throughout his career, Joseph Murray travelled to other countries to help clinicians deal with patients suffering from craniofacial and other deformities, such as patients in India whose hands had been disfigured by leprosy but who, after surgery, were able to use their hands to work as artisans and thus become self-sufficient.

Dr. Murray also introduces us to a highly intelligent boy, Ray McMillan, abandoned by his mother because of a birth deformity and placed in an institution for the mentally retarded. At age 21, Ray's grandmother rescued him form this senseless incarceration. Dr. Murray, who was able to correct Ray's facial deformity, encouraged the boy to write what was in his heart. To read what this 'retarded' boy had to say, and about the joy he found in life, is to witness the transforming effect of Dr. Murray's care and skill in restoring not just bodies, but souls.

This book reveals the curiosity, tenacity, optimism, and humanity of a remarkable surgeon and scientist as well as the courage of his colleagues in their quest to understand the complexity organ rejection despite discouraging setbacks. It also reflects gratitude of the patients whose suffering Joseph Murray sought to relieve and to whom he has dedicated his life. It is a story about overcoming adversity and about healing – one that should interest any reader and that should leave no one unmoved.

RECONNECTING SCIENCE WITH THE POWER OF SILENCE

THOMAS R. ODHIAMBO

The rapid progress that Science has made over the last three centuries has originated principally from the rigour with which she has explored the organization and laws of nature through highly objective observation, experimentation, and rational thinking. In doing so, Science has skimmed off and incredible harvest of fascinating phenomena and a wide understanding of fascinating phenomena and a wide understanding of physio-chemical relations of the universe.

But the deeper mysteries of nature still remain untouched by the scientific methodologies and philosophical approaches that have been current over this period of rapid progress in Science. Has Science reached an invisible barrier to this more penetrating understanding? What, for instance, can Science say about the essence of Life? Or is Science, as we presently practice it, blind to or unaware of a more fundamental principle involved in evoking to vitality what we experience as Life?

The paper will examine these and related issues; and start the process of tentatively going beyond the imposed strict limits of the contemporary methodologies of Science.

SCIENCE AS A CULTURE: A CRITICAL APPRECIATION

CHINTAMANI N.R. RAO

Scientists have generally stood for certain principles that have provided traditions which go far beyond geographical boundaries. Scientists of the world do indeed constitute a supranational sub-culture and have evolved a value system of great relevance to society. Important qualities such as integrity, honesty and search for truth are taken as essential elements in the science sub-culture. Science also allows for aesthetics and has a place for beauty in science itself. What is not often understood, however, is the need for science in society or in one's life, other than for utilitarian purposes. Clearly, science also has a place in society just as poetry and philosophy.

While fully accepting the great values of the culture of science, I wish to point out that there are some aspects of this culture that need to be reexamined. Science has given birth to a language which tends to be impersonal and antiseptic, and scholarly articles are accepted only if this language is used. The very rigour of science often results in parochialism and narrow loyalties, promoting new ways of communicating with one another. It can also give rise to certain types of irrational reactions to scientific and societal problems. Under the facade of fundamental study, there is a tendency amongst many scientists to refuse to constructively scrutinize established styles of research and curricula. Science generally thrives where there is generosity, humility and selflessness. However, the practice of science in recent years, quite often being recognition-oriented, market-based or based on financial considerations, has gone against these very important qualities that are crucial ingredients of the science culture. While science actually requires that we look at nature dispassionately and search for universality, one often loses objectivity and interdisciplinarity. This is particularly true in the teaching of science.

It seems possible that science culture may result in a new form of arrogance in certain situations where scientists feel that they can explain anything, including human emotions, based on science. I believe that such arrogance may not be conducive for a meaningful life.

While promoting science culture, it is important to give due attention to the existing cultures in the world. These cultures have survived for centuries and have created languages, traditions and a variety of other important treasures of humankind. It is possible that as the science culture spreads, it may favour a common language which may slowly wipe out the importance of many important languages and cultures that exist today. Looking at the performance of human beings in the last century, we see that many important cultures, as exemplified by those of many tribes in Asia and Africa, have been wiped out. Many of the dialects and languages have been disappearing. This may happen over the next one or two centuries to the major languages and cultures of the world which may gradually lose their identity. This would be very unfortunate because the very diversity of this world is what makes it interesting and exciting. We have the responsibility to protect cultural diversity. At this juncture, I must also mention the cross-cultural effects that play a role in teaching science in the villages of Asia or Africa. We have to examine the importance of cross-cultural effects in science education and in the spreading of the culture of science.

When we think of science of the future, we have to be concerned as to how the culture of science will develop and influence the future of mankind. In order to protect and preserve the good features of the science culture, scientists would have to bear social and moral responsibility for situations arising from scientific pursuit. While scientists undoubtedly will continue to be interested in the discovery of new knowledge, it is important that science involves the minds and hearts of the peoples of the world and includes a component that leads to enlightenment. The culture of science could indeed help to make the practice of science a spiritual experience under favourable circumstances.

THE WHY AND THE HOW OF OUR ORIGINS

WILLIAM R. SHEA

Why are we here? is a religious question. How did we get here? is a scientific one, but the two questions are not unrelated.

The belief that we are here for a purpose and that the universe was designed for the emergence of human life is a persistent theme in both the Old and the New Testament. The Christian tradition has developed the idea and stressed that the wisdom and benevolence of God is discernible in the intricate design of Nature and its particular fitness for human, and generally organic, habitation.

This paper argues that the theological interest in the purposeful thread running through cosmic history has contributed to the rise of the modern scientific story of creation where all life forms on our planet are made of atoms that originated in the interior of stars. As a pop song puts it, 'We are stardust; We are golden; We are Billion year old carbon'.

Our existence, which is tied to the physical properties and the prior history of the universe, is only possible because the universe has a very special structure. Within the flexible constraints of that structure, some very special things occurred to make us possible, and there is a strong scientific case for saying that we are not 'accidents'. The meaning that we find in human existence is not mere dust thrown in our eyes. Another creation story, with which we are all familiar, says we are made from 'the dust of the earth', and are meant to occupy a special place in the scheme of things. Might it be possible that, 'In the beginning God created the heavens and the earth', is the ultimate answer to the puzzle of our how got here?

Our generation, like those that have been before us, needs a creation story that combines fact and value, and tells us why we are here and how we should live. The old biblical story of creation is timeless and will continue to inspire, but cosmology may at last be in possession of some raw material for a postmodern creation myth. If design can be integrated with biological explanations of human origins, and the result joined to the traditional biblical story, there emerges the possible recovery of a religiously traditional, yet scientifically coherent, creation story for our time.

THE IMPACT OF NEUROSCIENCE ON HUMAN CULTURE

WOLF J. SINGER

Progress in the Neurosciences has led to deep insights into the neuronal substrate of human behaviour including mental and psychological phenomena. Neuronal correlates have been identified for developmental processes such as the refinement of cognitive functions and the acquisition of social skills, for cognitive functions such as learning, remembering and forgetting, for emotional states such as disgust, fear and pleasure, for our ability to control selective attention and, finally, for the decline of all these functions with aging.

These insights will have repercussions on numerous domains of our cultural activities. They will have an impact on the significance that we attribute to education and on the way we structure educational programmes, on our judgements of the reliability of reported observations and experiences, on our concepts of guilt, punishment and reeducation, on our distinctions between conscious and subconscious determinants of behaviour, and on our management of problems arising from long evity. Last but not least the insights into the functioning of the brain have opened up multiple options for the manipulation of brain processes, for the substitution of brain functions by technical systems and for the implementation of brain specific functions in artificial devices. These developments confront us with ethical problems of unprecedented complexity that need to be dealt with urgently. These latter issues require a new culture in the discourse between science and humanities and hence have consequences on our culture at a meta-level.

THE ART AND SCIENCE OF MEDICINE

ANDRZEJ SZCZEKLIK

Medicine, throughout most of its recorded history, must be seen more as an art than a science. Together with art it emerged from the same source i.e. magic, characterized by the omnipotent power of the word. It was the word that , if pronounced properly, could expel the disease or cause it, bring rain or drought, disclose the future or bring back the dead relatives. The pre-modern medicine set great store by highly personal clinical relationship between the doctor and the patient and emphasized personal experience in diagnosing and treating the individual case as the royal road to successful healing. A radical transformation of medicine rapidly occurred over the last century with medicine becoming specialized, high-tech endeavor with ever increasing aspirations to be a science, or at best, a science-based art.

It is, therefore, relevant to appreciate the differences between science and art, which in some ways can be seen as opposite sides of the same coin, the one illuminating self-knowledge, the other public knowledge. Medicine embraces both science and art with its magic. They are bridgeable only by recognizing their differences and complementary characters. The issue is important since science – and technology has become the new religion. It is seen to be the origin of all sorts of freedom and all sorts of material goodies. There is growing belief that medical science will ultimately take away all the ills of the world. Acceptance of science's involvement in the spheres of morality follows naturally. It is essential to realize not only exceptional power of science but also its fundamental limitations. Medicine with its both insights, scientific and artistic, provides a unique opportunity to unveil these issues.

The medicine commitment to the patient is being challenged by external forces within our societies. Business ideology infiltrated health care when costs spiraled and governments reconsidered their long-standing commitment to the welfare states. But medicine is governed by an ethos, not a balance sheet, and physicians both in Europe and in the USA have very recently developed a set of principles to which all medical professionals can and should aspire. It reaffirms the fundamental and universal principles and values of medical profession and provides a new insight into medicine as both an art and science.

SCIENCE NEVER ENDS:
A NEW PARADIGM IS COMING INTO BEING IN BIOLOGY

RAFAEL VICUÑA

The spiraling advances in our knowledge of the natural world appear to drive the paradox that sooner or latter science will no longer have questions left to answer. Notable scholars such as Albert Michelson and Lord Kelvin believed that this transcendental moment had already arrived during their era. In modern times, one of the paladins of this 'end of science' is Dr. Gunther Stent, molecular biologist, neurobiologist and philosopher of the sciences at the University of California, Berkeley.

In 1969, Dr. Stent published *The coming of the golden age: a view of the end of progress*,[1] work which develops the hypothesis that reality possesses limits and therefore soon nothing important will remain to be discovered. Dr. Stent utilized the fields of anatomy and geography as examples of scientific endpoints. As for the discipline of biology, according to Dr. Stent, there would remain only three prominent questions worth exploring: the origin of life on Earth, embryonic development and the processing of information by the brain. The remainder of the great wonders in the biological sciences would have been cleared up with the publication of Darwin*'s Origin of the Species*, by the elucidation of DNA structure by Watson and Crick and the deciphering of the genetic code. These latter two discoveries seemed not to have left room for new advances in the field of the molecular biology, a premise which would lead Dr. Stent to publish in the journal *Science* a provocative article entitled: *'That was the molecular biology that was'*.[2] In the first paragraph of this article from 1968, Dr. Stent declared '*...the approaching decline of molecular biology, only yesterday an avant-garde but today definitely a workaday field*'.

Slightly more than 30 years later we can reflect on this prediction, specifically in regard to the field of molecular biology. The extraordinary complexity that is present in the process of DNA replication, with the identification of novel enzymes that alter the topology and helicity of DNA, the emergence of exceptions to the universality of the genetic code, the editing of RNA which modifies the message written into the genes, the reverse transcription of RNA, the splicing of both RNA and protein, the amazing discovery that DNA and RNA may possess catalitic properties, among many others, constitute impressive discoveries that suffice to reject the pessimistic prophecy of Stent. However, despite these marvels, without doubt it is the field of functional genomics where the more striking innovations are being uncovered, possibly to the point where we can glimpse a dramatic change of paradigm in the biological sciences.

The initial wonderment in this field was the revelation that a linear relationship does not exist between the quantity of DNA present in a given species and the level of evolutionary progression of this species in the biological scale, which constitutes the so called c-value paradox. Yet more amazing still is the lack of correspondence between the number of genes and the morphologic complexity of the species, as observed from the comparison of several completed genomic sequences. The human being appears to possess only 50 percent more genes than a roundworm that measures only millimeters in size and the same gene number as the mouse. The fact that the genomes of yeast, the roundworm and the fruitfly share a 46%, a 43% and a 61% similarity with the human genome constitutes likewise an unexpected surprise. Furthermore, studies using minimal genomes have shown that the knockout of supposedly essential genes produce strikingly different phenotypes than anticipated. In brief, what research is making more and more evident is that although the gene number is a key factor in account-ing for phenotype, it is the combination of environmental and inter-genetic interactions that are responsible for the patterning and development of the organism. Therefore, a univocal relationship does not exist between genotype and phenotype, as a given genome constitutes a complex system, whose expression is the result of multiple intertwining factors.

These few although convincing examples in the field of molecular biology confirm that science has no end. Dr. Stent made the error in assuming that we know all the questions, when in fact we cannot predict the questions which will arise with every new turn in scientific investigation. There have always been more questions than answers and most probably there always will. Molecular biology, far from finding the endpoint declared by Dr. Stent almost 30 years ago, has gained more vigor than ever and is giving birth to a new paradigm that is displacing the current thinking in the field of genetics.

[1] Stent, G.S. The coming of the golden age: a view of the end of progress. The Natural History Press, Garden City, New York, 1969.

[2] Stent, G.S., Science 160, 390-395, 1968.

THE UNIQUE AND GROWING INFLUENCE OF THE NEUROSCIENCES ON THE DEVELOPMENT OF OUR CULTURE

ROBERT J. WHITE

The subject selected for examination at the 2002 Plenary Session: 'The Culture Values of Science' acknowledges the critical and growing importance of the acquisition of scientific information in the format and development of our culture in and of its forms. This concept must include those scientific discoveries that have had, and will continue to have, a significant impact on our understanding of human behavior and sociological performance.

This presentation will emphasize the value of recent neuroscientific research in defining and interpreting the essential role of human intelligence operating within the framework of our evolving civilization which is constantly being modified and refined by achievements in the natural and biological sciences.

A special thesis will be presented in which it will be argued that it is the human brain/mind that forms the central element within the hierarchal structure of all human existence. It is this humanized biological unit that is, in the final analysis, absolutely necessary for the appreciation and application of all knowledge especially that gained through scientific inquiry in the formation of man's culture.

Obviously, as a consequence of this thesis, the latest neuroscientific research defining neurofunctioning and its relationship to our evolving culture will be reviewed.

SCIENTIFIC CULTURE
AND THE TEN STATEMENTS OF JOHN PAUL II

ANTONINO ZICHICHI

The ten statements of John Paul II have given life to a Scientific Culture that lies in communion, and not conflict, with Faith. In the 80s, this Culture strove to make a real contribution to overcoming the risk of a Nuclear Holocaust. Then, with the fall of the Berlin Wall came the need to avoid the danger of an Environmental Holocaust created by the political and economic violence that fired the undeclared War between the planet's North (the rich) and South (the poor). Once again, Scientific Culture in communion with Faith took action to avoid the latent danger of an Environmental Holocaust, by implementing pilot projects related to the Planetary Emergencies, through the scientific volunteering of its community.

Atheist Culture, using as its arm public dissemination of what is passed off as Science, has instead wanted all to believe that Science and Faith are enemies. It has always confused Science with Technology, has never explained that the three towering conquests of Reason are: Language, Logic and Science, never mentioned the Galilean distinction between the three levels of scientific credibility, and has laid at Science's feet the responsibility for the Planetary Emergencies – responsibility that instead belongs to political violence (planet stuffed with chemical, bacteriological and nuclear bombs) and economic intemperance (unaccountable industrialisation). Atheist Culture too has acted as spokesman of ideas, such as scientific materialism, that lie in utter contradiction with the conquests of scientific thought, and has endorsed as frontiers of real and true Science, research activities that still lie below the third level of scientific credibility (for example: biological evolutionism of the human species: BEHS).

Had Atheist Culture itself discovered Science, then the ten statements of John Paul II would never have been conceived. These represent the cultural guide to the concrete deeds of which the Holy Father has been author, right from the very first days of his Pontificate. And it is this guide that has made possible the birth of a Scientific Culture in communion, not antithesis, with Faith. The influence of the Great Alliance with Science and its values has enabled the danger of the Nuclear Holocaust to be overthrown (Erice statement), and allowed creation of scientific and technological foundations from which to confront issues of the Environmental Holocaust (pilot projects for the Planetary Emergencies).

The 20th Century will take its place in History for having seen the fall of the Berlin Wall and the undeclared War between North (the rich) and South (the poor). The third millennium has need of a Scientific Culture resulting from the Great Alliance between the two most important conquests of Reason, which are, in the Immanent, Science, and in the Transcendent, Faith. We are the only form of living matter that has been granted the privilege of the gift of Reason. Let us seek to use it.

The third millennium must open up man's heart to hope through a Scientific Culture in communion with Faith, not in antithesis. This is why, as this great Pope teaches, Science must do all in its power to ensure the triumph of the values of the Galilean Scientific Culture.

STANDING RULES FOR MEETINGS

1. The Academy invites a number of illustrious scholars who have especially studied a given question and have arrived at different conclusions to meet in Rome at its headquarters, the 'Casina di Pio IV', situated in the Vatican City, so as to make a joint examination of all the data on the question.

2. The chief aim of these discussions is to endeavour to reach a common view on the subject of the meeting, but when this is not possible to formulate precisely the reasons for this inability. The scholars invited to these meetings undertake in advance to concentrate their efforts on this.

3. A critical examination of these reasons should lead either to agreement on a partial or provisional solution or else to the conclusion that, on the basis of the information presently available, it is impossible to establish unity on the question concerned. In the latter event the scholars involved will be called upon:

a) to define the reasons why agreement appears to be impossible for the present;
b) to specify the kind of research work it would be desirable to undertake in order to solve the problem.

4. The invitation will be addressed by the Academy to only a small number of representatives of each branch of learning: these will be selected from scholars who are not connected with the Academy. These representatives will be joined during the discussions by members of the Academy who are experts in the same discipline. This invitation, moreover, will apply only to the study of one precise question by each branch of learning.

5. The debates will be strictly private and will take the form of papers and talks in the presence only of a few members of the Pontifical Academy of Sciences who have special knowledge of the subject under discussion. Interpreters will be made available to the participants.

6. The conclusions arrived at will be published in the form of a 'Statement' (to which may be added individual notes) mentioning:

a) the points on which agreement was reached;
b) the points on which it was impossible to reach agreement;
c) the reasons why it was not possible to reach agreement;
d) suggestions about the research work that appears most appropriate in order to arrive at a solution of the difficulties.

7. The 'Statement' arrived at will be immediately printed and transmitted by the Pontifical Academy of Sciences to all the centres of learning which might be interested in them.

MEMORANDUM

1) Every day a bus will leave the hotel (8:45) for the Academy fifteen minutes before the beginning of the morning session (9:00). At the end of the morning session a bus will take the participants to the hotel for lunch. After lunch it will take them from the hotel to the Academy for the afternoon session (14:50). A bus will also depart from the Academy following each afternoon session (about 19:00) to take participants back to the hotel.

2) On Sunday 10 November (9:30), Holy Mass will be celebrated by His Eminence Cardinal Carlo Maria Martini at the Church of St. Stephen of the Abyssinians. A private guided visit to the Sistine Chapel has also been organised for the participants (10:30). On the same day, lunch will be served at the headquarters of the Academy (as indicated in the programme).

3) On Monday 11 November, Pope John Paul II will grant a Papal Audience to the participants (11:00), and a bus to the Apostolic Palace will be ready at 10:40 (at Casina Pio IV).

4) The cost of travel will be covered by the Pontifical Academy of Sciences. If you purchase your travel ticket yourself (which is normally the best policy), you will be refunded for a sum equivalent to the economy class fare.

5) A map indicating the location of places within the Vatican which are of importance to the participants is to be found printed in the accompanying document.

Note:

a) The price difference between a single and double room is Euro 77,47 per night (meals included).

b) Please give your form for the refunding of expenses to the secretariat of the Academy at least one day before your departure so that you can be refunded immediately.

PONTIFICIA ACADEMIA SCIENTIARUM

PLENARY SESSION

The Cultural Values of Science

(8-11 November 2002)