THE PONTIFICAL ACADEMY OF SCIENCES

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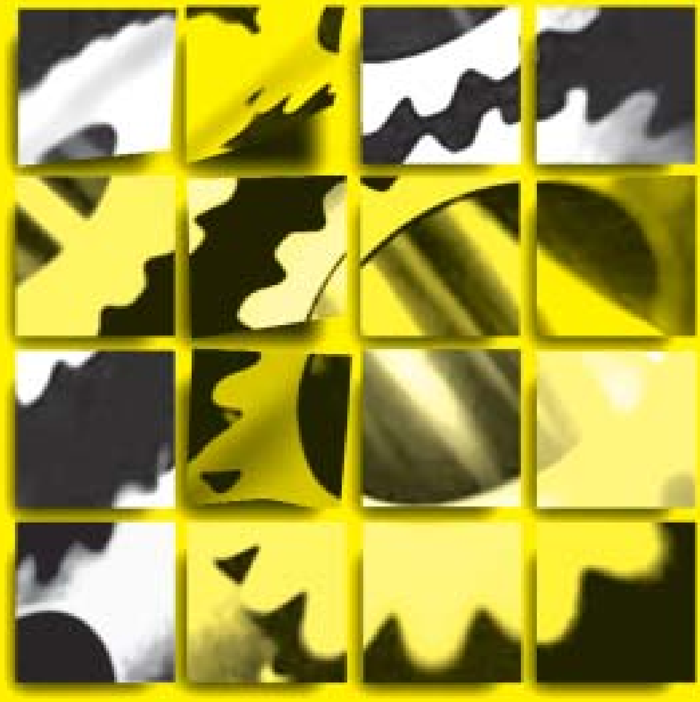
THE CULTURAL VALUES OF SCIENCE



Plenary Session
8-11 November 2002

VATICAN CITY
2003

THE CULTURAL VALUES OF SCIENCE

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PONTIFICIAE ACADEMIAE SCIENTIARUM SCRIPTA VARIA

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EX AEDIBVS ACADEMICIS IN CIVITATE VATICANA

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The opinions expressed with absolute freedom during the presentation of the papers of this meeting, although published by the Academy, represent only the points of view of the participants and not those of the Academy.

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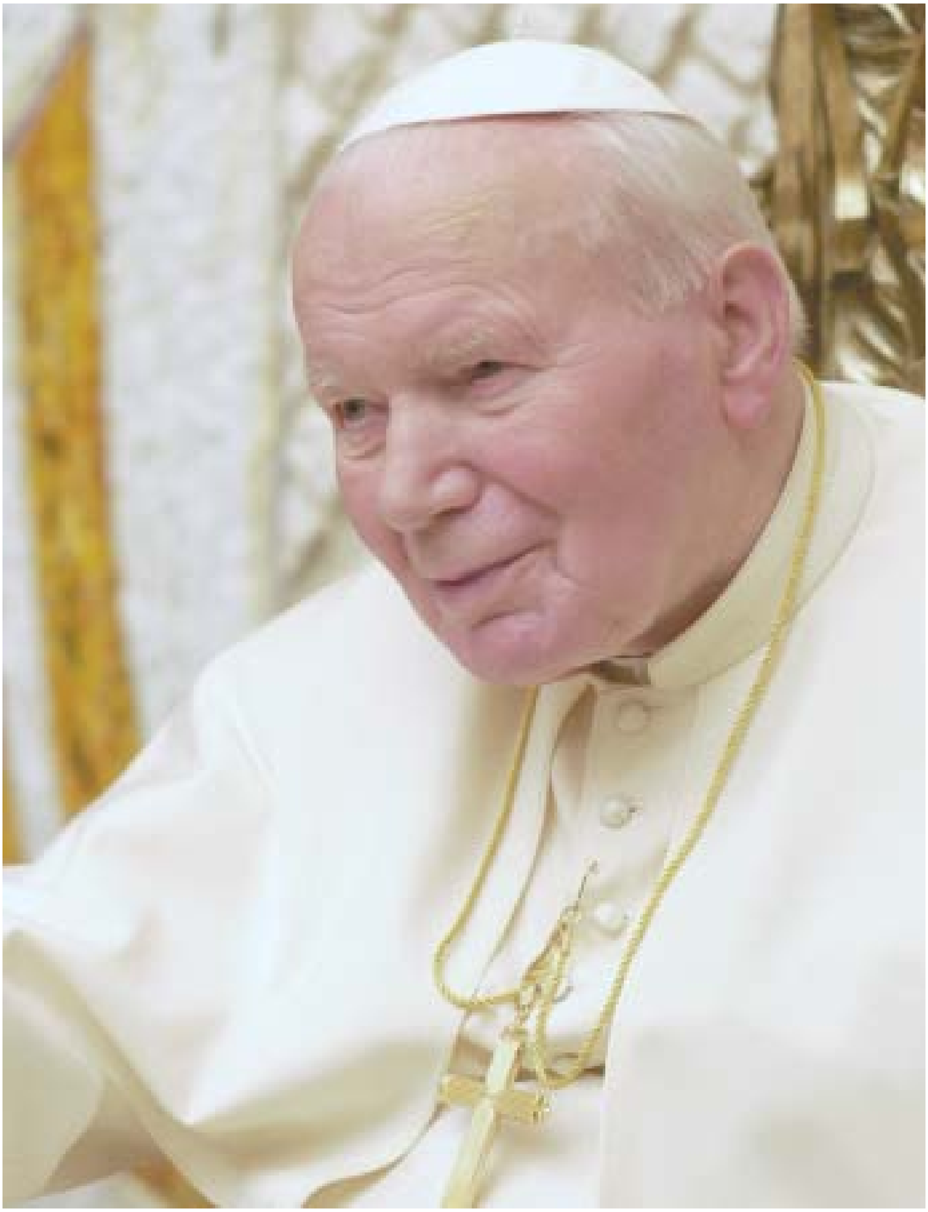

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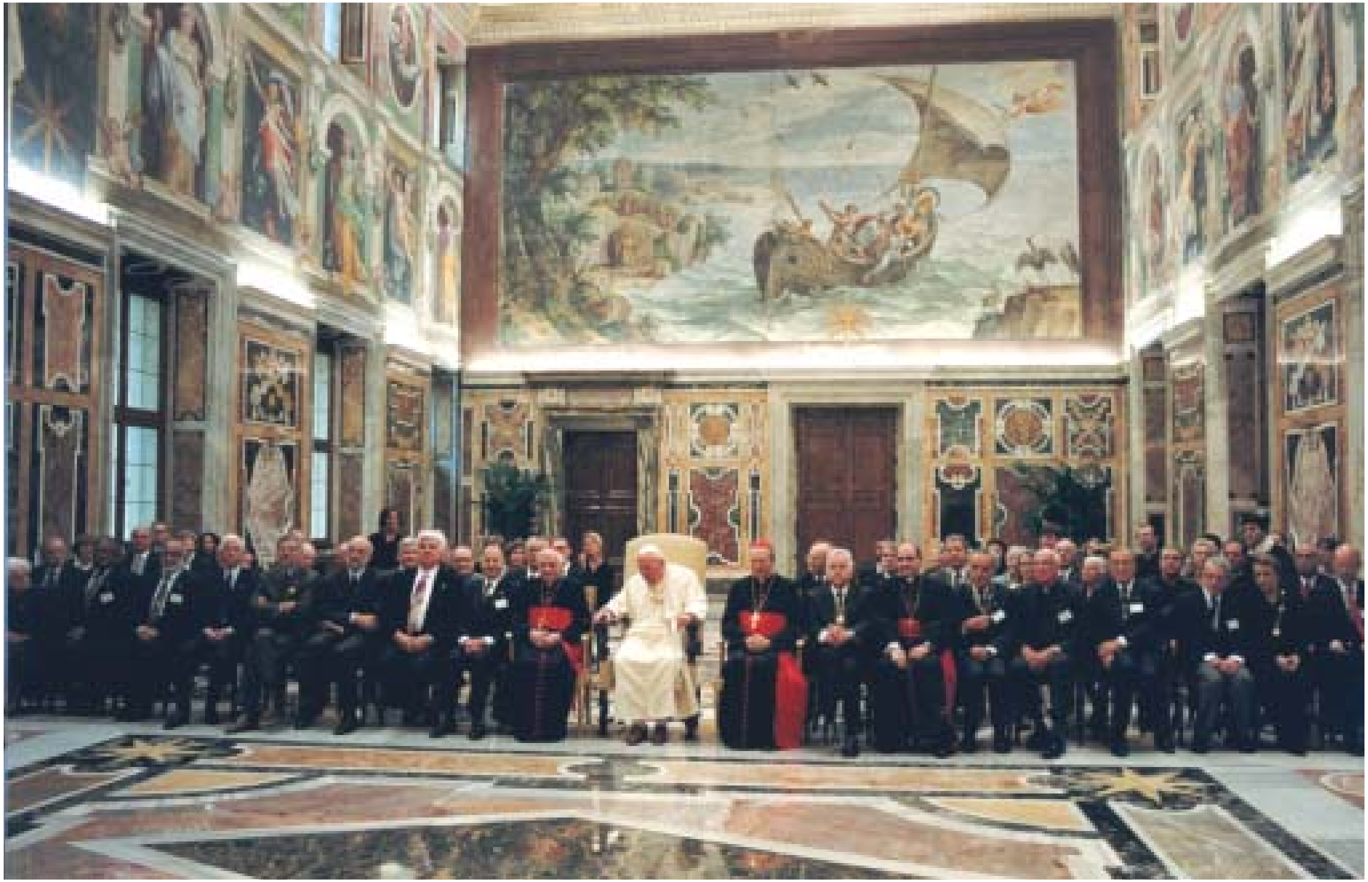

The Participants of the Plenary Session of 8-11 November 2002

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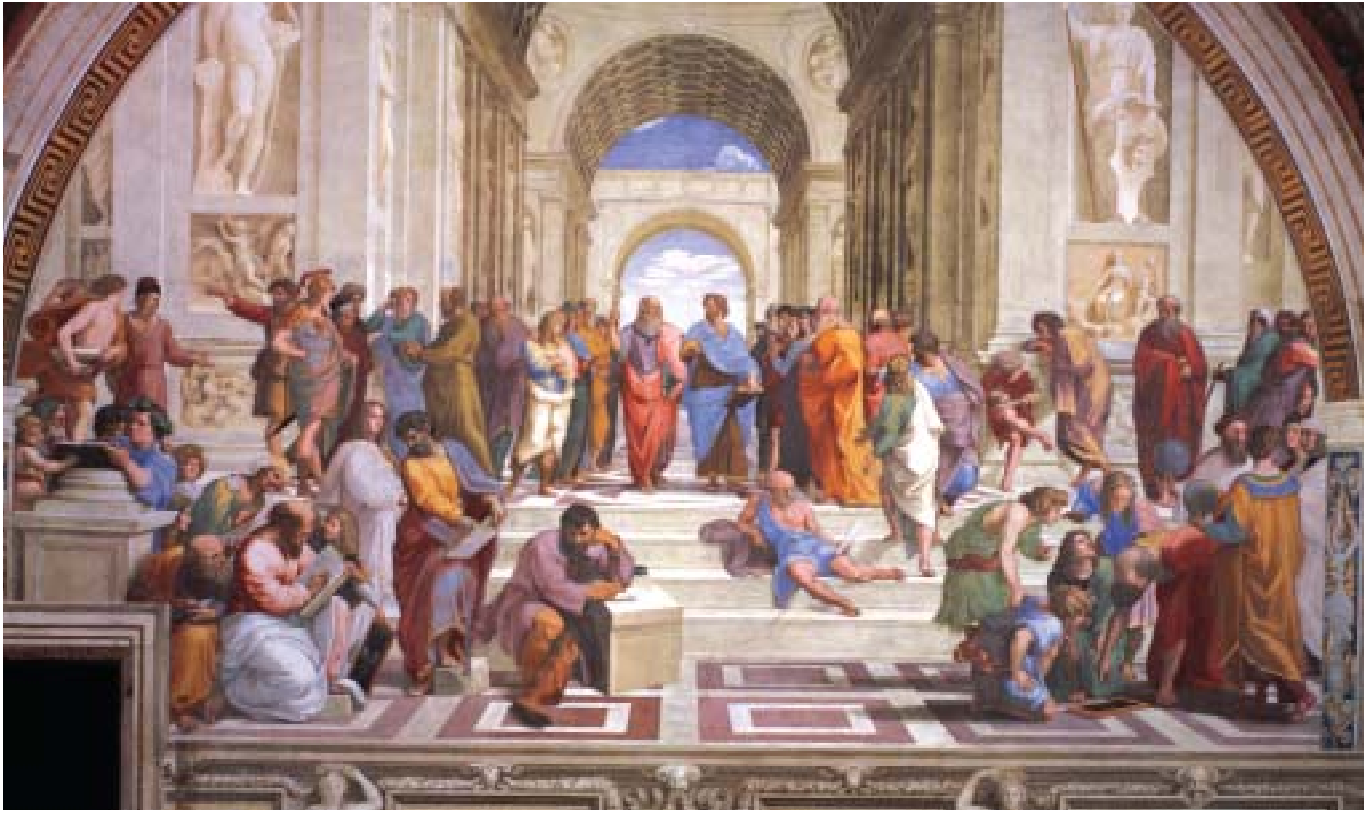

The Academy or *The School of Athens* by Raphael, in the Vatican Palace
'In those people you will have recognised your oldest predecessors in the investigation of both matter and spirit'
(Pius XII, Address to the Plenary Session of the Academy, 3 December 1939)

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SCIENTIFIC PAPERS AND DISCUSSIONS

ADDRESS TO THE HOLY FATHER

NICOLA CABIBBO

Holy Father,

It is with profound gratitude that the scientists convened for the plenary session of the Academy of Sciences, where we are discussing 'The Cultural Values of Science', have received the invitation to this audience.

The Academy was founded by Federico Cesi in 1603 in the very heart of the Catholic Church, and had in Galileo Galilei one of its first and most illustrious members. Next year will mark the four-hundredth anniversary of its foundation and we are preparing to commemorate and honour this important event.

The history of the Academy is coeval with the history of modern science. In 1623 the Academy published *Il Saggiatore* by Galileo, a book that was to become the manifesto of the scientific renaissance. The great book of nature, Galileo wrote, is written in mathematical symbols, in an alphabet that should sit side by side with the alphabet of philosophy or with that of the Holy Book.

The lesson of Galileo becomes even more important today: science that abdicates its cultural values risks being perceived as an extension of technology, an instrument in the hands of political or economic power. Humanity that disavows science risks falling into the hands of superstition. These very concerns led the Academy to organise in 2001 a workshop on 'The Challenges for Science: Education for the Twenty-First Century', when we discussed the central role of science education for all children, especially those of the less developed countries where the inequality in access to knowledge is more acute, a phenomenon that is a grave peril in today's knowledge-based society.

The Academy has this year acquired nine new members, all well known in the scientific world and representative of the main scientific disciplines and geographical regions. I would like to mention their names: Antonio Battro from Argentina, Enrico Berti from Italy, Günter Blobel from the USA, Thierry Boon-Falleur from Belgium, Pierre Léna from France, Jürgen Mittelstrass from Germany, and Ryoji Noyori from Japan. The Academy is very grateful to you for your appointment of two illustrious members of the College of Cardinals, Carlo Maria Martini and Joseph Ratzinger. These appointments renew an old tradition of the Academy, which had the glory of having as one of its members Cardinal Eugenio Pacelli, who was later to become Pope Pius XII.

I would like to ask you to kindly present to Professor Stanislas Dehaene the Pius XI medal for the year 2000, and to Professor Juan Martín Maldacena the medal for 2002, who have been awarded these medals for their exceptional contributions to neuroscience and theoretical physics.

Lastly, I wish to thank you for the essential support which you have given the Academy in all its activities, which has also allowed the restoration of the Casina Pio IV in preparation for next year's four-hundredth anniversary celebrations.

ADDRESS OF JOHN PAUL II TO THE PLENARY ASSEMBLY OF THE PONTIFICAL ACADEMY OF SCIENCES

MONDAY, 11 NOVEMBER 2002

Dear Members of the Pontifical Academy of Sciences,

It gives me great pleasure to greet you on the occasion of your Plenary Meeting, and I offer a particularly warm welcome to the new members among you. Your discussion and reflection this year focuses on 'The Cultural Values of Science'. This theme allows you to consider scientific developments in their relation to other general aspects of human experience.

In fact, even before speaking of the cultural values of science, we could say that science itself represents a value for human knowledge and the human community. For it is thanks to science that we have a greater understanding today of man's place in the universe, of the connections between human history and the history of the cosmos, of the structural cohesion and symmetry of the elements of which matter is composed, of the remarkable complexity and at the same time the astonishing coordination of the life processes themselves. It is thanks to science that we are able to appreciate ever more what one member of this Academy has called 'the wonder of being human': this is the title that John Eccles, recipient of the 1963 Nobel Prize for Neurophysiology and member of the Pontifical Academy of Sciences, gave to his book on the human brain and mind (J.C. Eccles, D.N. Robinson, *The Wonder of Being Human: Our Brain and Our Mind*; Free Press, New York, 1984).

This knowledge represents an extraordinary and profound value for the entire human family, and it is also of immeasurable significance for the disciplines of philosophy and theology as they continue along the path of *intellectus quaerens fidem* and of *fides quaerens intellectum*, as they seek an ever more complete understanding of the wealth of human knowledge and of Biblical revelation. If philosophy and theology today grasp better than in the past what it means to be a human being in the world, they owe this in no small part to science, because it is science that has shown us how numerous and complex the works of creation are and how seemingly limitless the created cosmos is. The utter marvel that inspired the first philosophical reflections on nature does not diminish as new scientific discoveries are made. Rather, it increases with each fresh insight that is gained. The species capable of 'creaturely amazement' is transformed as our grasp of truth and reality becomes more comprehensive, as we are led to search ever more deeply within the realm of human experience and existence.

But the cultural and human value of science is also seen in its moving from the level of research and reflection to actual practice. In fact, the Lord Jesus warned his followers: 'everyone to whom much is given, of him will much be required' (*Lk* 12:48). Scientists, therefore, precisely because they 'know more', are called to 'serve more'. Since the freedom they enjoy in research gives them access to specialized knowledge, they have the responsibility of using it wisely for the benefit of the entire human family. I am thinking here not only of the dangers involved in a science devoid of an ethic firmly grounded in the nature of the human person and in respect of the environment, themes which I have dwelt on many times in the past (cf. *Addresses to the Pontifical Academy of Sciences*, 28 October 1994, 27 October 1998 and 12 March 1999; *Address to the Pontifical Academy for Life*, 24 February 1998).

I am also thinking of the enormous benefits that science can bring to the peoples of the world through basic research and technological applications. By protecting its legitimate autonomy from economic and political pressures, by not giving in to the forces of consensus or to the quest for profit, by committing itself to selfless research aimed at truth and the common good, the scientific community can help the world's peoples and serve them in ways no other structures can.

At the beginning of this new century, scientists need to ask themselves if there is not more that they can do in this regard. In an ever more globalized world, can they not do more to increase levels of instruction and improve health conditions, to study strategies for a more equitable distribution of resources, to facilitate the free circulation of information and the access of all to that knowledge that improves the quality of life and raises standards of living? Can they not make their voices heard more clearly and with greater authority in the cause of world peace? I know that they can, and I know that you can, dear members of the Pontifical Academy of Sciences! As you prepare to celebrate the Academy's Fourth Centenary next year, bring these common concerns and aspirations to the international agencies that make use of your work, bring them to your colleagues, bring them to the places where you engage in research and where you teach. In this way, science will help to unite minds and hearts, promoting dialogue not only between individual researchers in different parts of the world but also between nations and cultures, making a priceless contribution to peace and harmony among peoples.

In renewing my warm wishes for the success of your work during these days, I raise my voice to the Lord of heaven and earth, praying that your activity will be more and more an instrument of truth and love in the world. Upon you, your families and your colleagues I cordially invoke an abundance of divine grace and blessings.

COMMEMORATION OF ACADEMICIANS

André Blanc-Lapierre (1915-2001)

André Blanc-Lapierre received his first education in an 'Ecole Primaire Supérieure' and at the end of this scholarship, he got a 'Brevet Supérieur'. He was an excellent pupil and he joined the classical lycée, to obtain first his 'Baccalauréat' and then became a student of the 'Ecole normale supérieure'. The special upbringing he received in his family and his training in these schools gave him distinct characteristics, very elegant handwriting and other very good habits in organizing his life and work.

After graduating from this last school, his scientific activity may be described by four periods. The first one covers approximately the decade 1940-1950. He joined the Physics laboratory of the Ecole normale and prepared a thesis under Georges Bruhat's supervision. His dissertation, accomplished in 1944, was devoted to the study of the shot noise and to its influence on the measurement and amplification of very small photocurrents. The existence of background noise was known; but it was not known at that time how it would be possible to give a description that went further than a qualitative one. He was the first to be convinced that, to make progress in understanding the phenomenon, it would be necessary to use the tools provided by probability theory. But at that time the concept of stochastic processes was not known. He started to attack the problem and his analysis was so successful that he was in the position to uphold a new dissertation and to add a second doctorate, in Mathematics, to the one he had achieved in Physics. It is exceptional in France for anyone to have two science doctorates in two different fields. This work was the starting point of a great number of papers devoted to stochastic processes applied in various domains of physics and information theory. In 1953, with his colleague Robert Fortet, he published a book of seven hundred pages on random functions which shortly became a classic.

The second period is roughly the decade 1950-1960. He was then Professor of Physics at the University of Algiers. He founded a theoretical physics laboratory; a very active one. He encouraged young physicists to explore new areas where probabilistic methods could be applied. Among many developments, his suggestion to transpose to optics ideas known in radioelectricity deserves to be mentioned. He was the first to show that the concept of coherence in optics must be described by using appropriate correlation functions. His papers written in French remained unknown and the validity of his ideas became clear later with the development of lasers and coherent optics.

The third period covered approximately the decade 1960-1970 and was mainly devoted to nuclear physics. In fact, it started at the end of the previous one, with the creation in Algiers of an 'Institut de Physique Nucléaire' which was, for Blanc-Lapierre, the occasion to show his talents for managing such an operation. It was on the basis of his achievement there, that he was chosen as director of the linear accelerator-lineac of the faculty of Orsay in 1961, succeeding Hans Halban who had just resigned. First, he decided to upgrade the electron lineac energy from 1 GeV to 2.3 GeV, thus allowing the undertaking of K meson experiments. Moreover a positron beam was set up, a facility that proved to be crucial for the storage rings to come. Then he proposed in 1962 to start work on electron-positron collisions which presented great technological challenges which had to be faced. Two years later, such collisions were observed for the first time in a storage ring. In 1964 he invited a group of bubble chamber physicists, led by André Lagarrigue, who were working at the Ecole polytechnique, to move into his laboratory. Then jointly with this school, CEA Saclay and the CERN, the Orsay laboratory of Blanc-Lapierre participated in the Gargamelle bubble chamber program under the leadership of André Lagarrigue. This heavy liquid chamber turned out to be the most effective in neutrino interactions and allowed the famous discovery in 1973 of neutral currents.

During the last period he was the director general of the 'Ecole supérieure d'Electricité'. He showed, once again, his talents as high class administrator and manager. He succeeded in expanding the number of buildings for the school and its developments. Moreover he gave a great impulse to research in this school, in particular by the creation of a new laboratory in cooperation with the CNRS: the 'Laboratoire des signaux et systèmes' where he was working until his retirement.

André Blanc-Lapierre was a tireless worker who had a fantastic level of activity. He liked to build new schools, new offices, new laboratories for his students, his co-workers and for the people involved in the activity he was running. He was a very good supervisor, always available for those who needed help or advice. He was one among a few scientists who have contributed to the renewal of science in France. He was ready to take on successfully high responsibilities, for instance as the President of the most important Committee in the sixties, in charge of the preparation of Government decisions concerning the scientific development, its budget and its organization. Member of the French 'Académie des sciences' since 1970, he played an important role in 1983 in the creation of the CADAS, 'le Conseil des Applications de l'Académie des Sciences', which has recently become autonomous under the name of French 'Académie des Technologies'. He was President of the French Academy in 1985 and 1986, a very active one who brought many improvements to its organization. He was elected to the Pontifical Academy of Sciences in 1979 and was a very active member, as member of the Council and also as the leader of a very successful study week on energy. When he accepted a responsibility, he would take it on fully.

André Blanc-Lapierre was a warm personality, very open minded, very helpful to everybody. He was very attached to our Academy, very happy to be able to work for its development. This good Christian was convinced that our Academy would have a very important role in making science better understood and appreciated by the Church.

Paul Germain

LOUIS LEPRINCE-RINGUET (1901-2000)

Louis Leprince-Ringuet was born in March 1901. His father was an engineer who graduated from the ‘Ecole Polytechnique’ and was even a member of the ‘Corps des Mines’ composed of the best former students of this school. Louis was not an excellent student. Nevertheless, he too graduated as an engineer from the ‘Ecole Polytechnique’ and also from the ‘Ecole supérieure d’Electricité’, and became member of the ‘Corps des PTT’.

Birth of his vocation as a scientist

For five years he worked in an undersea cable Company. He spent eight months each year at sea on missions to check the good general state of the communications network. He liked this outdoor activity. In addition he had personal experience of the hard conditions in which the workers operated. In 1928-1929 he was fortunate to meet Maurice de Broglie – the elder brother of Louis de Broglie who received the Nobel prize. Maurice was an enthusiastic physicist who ran in his town house, in Paris, his own laboratory working on X-rays. The young Leprince-Ringuet was fascinated by Maurice de Broglie. He decided to quit his first job in order to accept Maurice de Broglie’s proposal to work in his laboratory as a research assistant. It was the start of his scientific career, a very modest beginning. The laboratory had only a few permanent physicists, around three or four, who consequently worked very closely with the ‘boss’.

Physicist on Cosmic rays

When Louis Leprince-Ringuet joined this team, their research topic was undergoing change, passing from X-rays to nuclear physics. They began to be interested in the structure of atomic nuclei and in the particles produced on breaking these nuclei. At that time, it was impossible to obtain particles with an energy of more than one GeV. That is why Leprince-Ringuet decided to work on cosmic rays. These rays consist of high-energy particles which bombard the earth. Mostly, they are protons. On collision with the upper atmosphere, they create new particles which arrive on the ground. In 1933, with another young physicist, Pierre Auger, they sailed on a ship from Hamburg to Buenos Aires with an array of detectors, Geiger counters, in order to investigate the variation of intensity with the latitude and to prove that, effectively, protons were predominant. Over two decades, cosmic rays were the best source of fundamental constituents of nuclei. In order to have better conditions, physicists built laboratories on high mountains. Leprince-Ringuet, who had been appointed to a new laboratory at the Ecole polytechnique, worked frequently at the 'Pic du midi' observatory in the Pyrenées. Many new fundamental particles have been discovered by this method: the positron, the muon, the pion, the kaon, the hyperon, using a Wilson chamber and, after the war, a double Wilson chamber. Leprince-Ringuet, who became Professor at the Ecole polytechnique in 1936, had the possibility to attract many bright young students who were to become outstanding physicists, such as Lagarigue, Gregory and Astier.

Towards physics of high energy particles

After 1953, Leprince-Ringuet decided to reorient his laboratory's activity towards the physics of accelerators in order to take advantage of the first synchrotons with their intense and precise beams of particles with an energy exceeding one GeV. In conjunction with Saclay, his laboratory designed new 'bubble chambers' in order to replace the Wilson chambers and made a bright use of CERN which very often led to important discoveries.

Member of the French 'Académie des sciences' in 1949, he succeeded Frederic Joliot in 1959 in his chair at the 'Collège de France'. For more than ten years, he was the head of two famous laboratories working in particle physics. He had a great influence on the rapid development of this discipline as a member of important committees, in particular those running the CERN programme. He used it in order to give young physicists wanting to work in this field the best conditions. Leprince-Ringuet may be considered one of the greatest scientists working in particle physics in the twentieth century, not so much for his personal discoveries – although they were important – but especially for his exceptional ability to encourage bright young talent to work in this field and also to persuade the decision-makers to favour its development.

Extraordinary diversity of talents and interests

So far, I have shown that Louis Leprince-Ringuet was a great scientist. This has long been recognised by our Company with his election as member of the Pontifical Academy of Sciences. But he was not an exceptional student. He spent many years in a job which gave him the possibility to sail for two thirds of the time. He became a scientist not through special studies or reading, but through meeting and talking with a man who was a living epitome of scientific research and who devoted a part of his house and of his wealth to scientific activity.

The theme of Leprince-Ringuet's work was a very attractive one: observation of many particles which come from the universe. To capture them, he sailed for two months; he built an observatory on a mountain summit. He spent the best part of his energy in developing his own laboratory and helping create this 'marvellous cathedral' which is the CERN.

However, this scientist was fascinated not only by the particles which came from breaking the nuclei, but also by people. One of his books, the one I prefer, is called *Des atomes et des hommes*. He experienced and described beautifully the particular friendship and brotherhood among the scientists working on the same adventure. He organized for many years in September meetings of his collaborators and colleagues in his own private property in Burgundy to discuss the new discoveries or topics he wanted to present in his course at the 'Collège de France'. But what is for me the most remarkable was his gift for talking to people, to explain to any public not only scientific achievements, but also his personal views on topics of interest for the listeners. He developed this natural capacity when he was a student as member of the 'équipes sociales', an institution devoted to the organization of meetings and exchanges of views between young workers and students. He was invited over many months to give a regular prime-time television programme: 'le quart d'heure de Leprince-Ringuet', which was very successful and in which he talked about various topics, not necessarily scientific.

He had many centres of interest. He was a ranked tennis player. He was a painter whose works have often been on public display in good Parisian art galleries. He was a music lover and had been chosen to be President of the 'Jeunesses musicales de France', a very famous and popular institution of the country. He was very cultured, elected of course to the 'Académie des sciences' but also to the 'Académie française', in 1966, rather exceptional for a scientist. He did not like philosophical or abstract discussions. He was a man of action.

He was a strongly active supporter of Europe, very enthusiastic, a committed Christian, not so much attracted by theology, but deeply rooted in the Gospel which shaped his intense spiritual life. With his remarkable wife, they brought up a wonderful family, being great-grandparents of a lot of children. He was a very happy man. At ninety-five, he wrote a marvellous book: *Foi de physicien – Testament d'un scientifique*. The introduction is entitled 'the happiness of being a scientist'. The last chapter is: 'Why I am an optimist'.

Paul Germain

JACQUES-LOUIS LIONS (1928-2001)

Jacques-Louis Lions was a very bright French scientist endowed with many skills and moral qualities. He showed these on many occasions and in many responsibilities; for instance at fifteen during the war, as chairman of INRIA ('Institut National de Recherche en Informatique et Automatique'), as a President of the CNES ('Centre National d'Etudes Spatiales'), as the President of the French 'Académie des sciences' in 1997 and 1998.

But above all, he was a remarkable mathematician who, I think, deserves to be recognized as the best in applied and industrial mathematics during the second half of the twentieth century. Consequently, in order to keep this notice as usual at a reasonable length, I will concentrate on a few highlights of his wonderful mathematical work.

To characterize the field of his achievements, I will quote Philippe Ciarlet writing that 'it concerns partial differential equations in all their states: existence, uniqueness, regularity, control, homogenization, numerical analysis, and of course, their applications to mechanics, oceanography, meteorology'.

When he was a student at the 'Ecole normale supérieure', he was already considered among his schoolmates as the most hardworking. After receiving his diploma, he was appointed by CNRS as a researcher at the Nancy group of Laurent Schwartz, who had just received in 1950 the Fields Medal for his creation of the distributions theory. Jacques-Louis Lions worked on applications of this theory to various differential equations and gained his doctorate in 1954. He immediately became professor in the mathematical department of Nancy which was at that time very famous thanks to the high standard of its professors and of its research students. From the very start, Jacques-Louis was attracted by the applications and strongly encouraged by two fellow workers of the same age: Robert Lattes, also a graduate from the Ecole normale who was later director of the SEMA ('Société d'Economie et de Mathématiques Appliquées'), and Robert Dautray, a prominent graduate from the Ecole polytechnique, who had a high responsibility in the most advanced research department of the CEA ('Centre de l'Energie Atomique').

In 1962, Jacques-Louis was elected Professor at the Sorbonne, the Sciences Faculty of Paris University. He immediately created a seminar in numerical analysis which was soon very famous and, a few years later, the 'Laboratoire d'analyse numérique' which has been one of the best departments of this discipline in Europe. In 1973 he became at the same time, Professor at the 'Collège de France' in the chair: 'Analyse numérique des systèmes et de leur contrôle' and member of the French 'Académie des sciences'. In the 'Collège', his course, new each year, as required by tradition, and the weekly seminar on 'Mathématiques Appliquées' were both followed by many people, colleagues and research students. Professor at the Ecole Polytechnique between 1966 and 1986, he created in this famous school a new course of Applied Mathematics which was highly appreciated by the students. Many of them decided to work in this field after getting their diploma.

Despite all these highly time-consuming responsibilities, Jacques-Louis Lions succeeded in being a fantastic author: more than twenty books, some of them in collaboration with colleagues or students; most of them have been translated not only into English but also into many other languages. Moreover, he wrote more than five hundred papers. These figures are completely unusual in mathematics. Most of these works found a systematic presentation in a monumental treatise of four thousand pages entitled: 'Analyse mathématique et calcul numérique pour les sciences et les techniques' published in 1985 by Jacques-Louis Lions and Robert Dautray which, very often, has been rightly considered as the contemporary version of the famous Courant and Hilbert.

Let us mention briefly some of the new concepts and topics he introduced and developed. Since 1954, his collaboration with Magenes, Stampacchia, de Giorgi and Prodi gave rise to a three-volume treatise entitled *Problèmes aux limites non homogènes*. A little later, he became interested in problems of mechanics and physics, and in 1972 with Georges Duvaut, he published *Les inéquations en mécanique et en physique*. This book showed how fruitful were the functional methods for solving difficult problems arising from Bingham fluids, viscoelasticity, plasticity.

So far, the numerical solutions were obtained by methods of 'finite differences'. They were not easily applicable to many situations, for instance in a domain of complex geometry. Lions brought his attention to new methods, introduced by engineers, called 'finite elements methods'. With his co-workers, he succeeded in giving to these methods a highly satisfactory mathematical presentation. It can be found in the book *Calcul numérique des solutions des inéquations en mathématiques et en physique* written with Roland Glowinski and Raymond Trémolières. One must also mention the book *Quelques méthodes de résolution de problèmes aux limites non linéaires* in which Lions introduced systematically the methods of compacity, of monotony, of regularisation, of penalisation which are essential tools for studying for instance Navier-Stokes equations, von Karman equations, Schrödinger equation, Korteweg de Vies equation.

Many useful theories in Mechanics investigate the properties of solutions when some parameters remain small: they lead to what may be called 'asymptotic analysis of these problems'. Methods were introduced: boundary layer theory, singular perturbation, multiple scales, homogenization. Again, Lions wrote a mathematically satisfactory presentation in at least two books.

It would be important to report on all the works and books dealing with control theory, a field to which Lions gave special attention right up to his death and in which his contributions are of fundamental importance. Even if I cannot do it here, I hope that what has been said above proves how exceptional was this mathematician. He was a genius who has often been compared to Henri Poincaré or to John von Neumann.

Paul Germain

MINORU ODA (1923-2001)

Minoru Oda was born in 1923 in Sapporo. He studied physics in Osaka, where he graduated in 1944. After a few years spent in the construction of Japan's first radio telescope, he moved to MIT, were he started a long collaboration and friendship with Bruno Rossi, working first in the field of cosmic ray showers and, starting from 1962, in the study of extra solar X-ray sources with the help of satellites. Minoru Oda made important contributions to the study of X-ray sources, and in 1965 devised an original method for the localization of these sources through the invention of the modulation collimator. These collimators played a crucial role in the optical identification of the first X-ray source, Sco X-1. X-ray astronomy and space science became the lifelong mission of Minoru Oda. In Japan he became a professor in the newly founded Institute for Space and Aeronautical Sciences (ISAS) at the University of Tokyo, an institute that he directed from 1984 until his retirement in 1988. Under Oda's direction ISAS had an enviable record of successful missions, probably unequalled by other agencies, among which Hakucho and Tenma, as well as the Japanese-British satellite Ginga.

After retiring from ISAS, Oda was appointed president of RIKEN, an important Japanese research institute. When he died last year he was still very active as president of the Tokyo University of Information Sciences.

Many scientists in Italy and elsewhere will remember Oda's friendship and generosity, especially to young people. Many of us will remember Minoru through his delightful watercolours of flowers collected in different parts of the world.

Nicola Cabibbo

MAX F. PERUTZ

I feel honoured to speak in memory of Max Perutz. I appreciated him extremely, both as a very competent scientist and as a lovely person. What also linked me to him was that twenty years ago, in 1981, we became members of this Academy at the same time. Looking back to these twenty years of having had meetings here, I still see him sitting for a short while in the – at that time – very hard seats, and then standing up and remaining standing because he had obvious back pains, but his face was with us and looked very happy. I think that he overcame his pain just by loving to talk about Science with us.

Max Ferdinand Perutz was born in 1914 in Vienna, where he grew up and studied chemistry. Doing his chemical studies, he started to pick up interest in applying his knowledge to investigating the structure and functions of proteins. This was at a very early time, in 1936, when he decided to go for his Ph.D. degree to Cambridge, England, where there was a well established X-ray crystallography group. At that moment very little work was done with bio-molecules, but that was his aim. Max Perutz chose a very particular protein which is relevant for all of us and for many other living organisms, namely haemoglobin. Haemoglobin is a rather complex molecule, and Max Perutz devoted enormous efforts and time to find access to its structure. This was not easy, because he had first to develop methodology which was not yet available; he had first to elaborate it, and I think that it is his merit together with some colleagues, to have found a way to introduce heavy metal atoms into the proteins under study and then to compare responses to X-ray irradiation of crystals with and without metal inclusions. Mathematical treatment of the obtained data allowed them to draw a picture of the three-dimensional structure of the protein. You can imagine that this gave a very big impulse to comprehend protein function. This development can be seen as a forerunner of what we now call proteomics.

On the way to his scientific breakthrough, Max Perutz spent some time in the Swiss mountains to study the formation and structure of ice crystals in glaciers. This best illustrates his efforts as a scientific investigator to find novel approaches to overcome difficulties of methodology in order to gain insight into the structure of complex biomolecules.

It was shortly after the war in 1947 that the Medical Research Council of England decided on the proposition of Max Perutz and his colleagues to create in Cambridge the MRC unit for studies of molecular structures. This institution later became the Laboratory of Molecular Biology. Max Perutz was its first Director until 1979. During those 32 years of scientific activities a remarkable amount of novel knowledge was acquired in this laboratory. I shall just remind you of a few names of investigators like Francis Crick and Jim Watson, describing the DNA structure, Fred Sanger exploring protein and later DNA sequence analysis, Sydney Brenner unravelling elements of gene expression and so on, and a big number of young investigators who received their doctoral and postdoctoral education.

The scientific success of research done in the laboratory of Molecular Biology may, in part, be due to its attraction of highly qualified investigators, but it might also be linked with the readiness of these scientists to develop new methodologies and research strategies, as exemplified by Max Perutz. From 1945, he closely collaborated with John Kendrew, joining at that time the laboratory with the aim of unravelling the structure of myoglobin, a protein related to haemoglobin. Both projects led to successful results. This found its highest recognition in 1962 when Max Perutz and John Kendrew were awarded the Nobel Prize in Chemistry for their studies of the structures of globular proteins.

Max Perutz's interests were not limited to structure, he wanted to find out the functional mechanisms of proteins. He thus investigated the binding of oxygen to haemoglobin. He was able to show that in this complex molecule the binding of different atoms of oxygen is cooperative. This important finding led him to look at differences between oxyhaemoglobin and desoxyhaemoglobin. In the same context he also studied abnormal forms of haemoglobin, such as those of some haemoglobin mutants. Following the same line, he also started to compare haemoglobins of different animals, and this gave him some insight on how these molecules must have evolved in the course of long-term history. The resulting knowledge offered explanations on how some particular adaptations to very specific life conditions, life styles, must have occurred. For example, he compared the haemoglobin of migratory birds that fly very long distances at very high altitudes requiring much energy, with that of sedentary land animals. This led Max Perutz to a deep understanding of protein functions and how living organisms can evolve to carry out their required functions.

The career of Max Perutz as a scientist, starting as a young doctoral student in Cambridge, lasted sixty-five years, until his death, which occurred last winter at the age of eighty-eight years. We still remember his reports in recent years on novel aspects of his research concerning studies of the electrostatic effects of proteins and their medical implementations as for example seen for

Huntington's disease. Thereby, he pointed to relations between stereochemistry and biological functions, such as those in aggregates of polyglutamine fibres. These are questions at the forefront of today's research.

So Max Perutz kept up with scientific progress as a passionate researcher until the end of his days. His personality was impregnated by that passion, and his influence on his colleagues and certainly on all his students is enormous and long lasting.

Lastly, in order to show the high regard and affection that he had for our Academy I would like to read out the letter that Max Perutz sent to the Chancellor shortly before his death:

'Dear Monsignor Sorondo,

It seems that my days are numbered and I feel like expressing to you and the President my deep appreciation of having been a Member. I received the Pope's telegram appointing me to the Academy at the same moment as the news of the attempt to assassinate him. It roused a terrible conflict of emotion in me, on the one hand my great pleasure about this Honour, and on the other hand my deep sorrow at that tragic crime.

I first attended a study-week in 1961, in fact organized it myself, which you could almost call 'The Birth of Molecular Biology'. People presented an extraordinary series of exciting new discoveries, and I first met some of the protagonists from other countries. Since then I have attended and organized other study-weeks and much enjoyed that privilege, but the greatest privilege was being a Member of that unique body, a truly international Academy, covering all the natural sciences. I came across there many more people whom I would never otherwise have met, such as the Indian physicist Menon, and then there was the wonderful setting, that Renaissance court, looking over the back of St. Peter's like the view of the Matterhorn from Zermatt. I think that the Pontifical Academy is a unique institution and I very much hope that the Holy Father and his successors will continue to give it their support.

I should be delighted if you were able to communicate any of this letter to the Holy Father and assure him again how much I appreciated my Membership.

With kindest regards to you and the President.

Yours, Max Perutz'

Werner Arber

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14 January 2002

Monsignor Marcelo Sánchez Sorondo
Pontifical Academy
Casina Pio IV
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Rome
Fax: 0039-06 698 85218

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With kindest regards to you and the President.

Yours,

Max Perutz

Figure. Facsimile of Prof. Max Perutz's letter.

FRANCO RASETTI (1901-2001)

Franco Rasetti started his career as a physicist in Pisa and then in Rome since 1927, where he was called by Orso Maria Corbino to be a member of the famous Via Panisperna group led by Enrico Fermi. Although he was for a long time identified as Fermi's collaborator, Rasetti is to be considered one of the great experimental physicists of the last century. I presume that everybody remembers the experiments of the Panisperna group which led to the discovery of the properties of slow neutrons and paved the way for the exploitation of nuclear energy, but other results by Rasetti have given important contributions to the development of modern physics. In 1928-29, while working at Caltech, he determined the statistical behaviour of nitrogen nuclei. This result definitely proved that the atomic nucleus cannot contain electrons, and opened the way for the discovery of the neutron and for Pauli's neutrino hypothesis and Fermi's theory of beta decay.

After emigrating to Canada in 1938, where he accepted an appointment to the Catholic University of Laval, Rasetti refused to take part in the nuclear weapon programme, an example which was not followed by many of his contemporaries. He decided to leave physics and to devote himself to his erstwhile interests in the natural world. He soon became a world authority on trilobites, and on alpine flora. Our sister institution, the Italian Lincei Academy, has recently reissued his magnificent atlas of alpine flowers.

Rasetti returned briefly to physics in the seventies, when he engaged in Rome in the measurement of the refractive index of a gas of free electrons. Some of the techniques he developed on this occasion have become widely used in the diagnostics of plasmas.

With Franco Rasetti disappears the last of the original members of our Pontifical Academy of Sciences, which were nominated on the occasion of its re-foundation in 1936.

Nicola Cabibbo

VICTOR FREDERICK WEISSKOPF (1908-2002)

Victor F. Weisskopf
The Father of Virtual Reality
A Scientist to Whom Europe Owes Much

What makes Victor F. Weisskopf unique in the 20th century is his being a great scientist and an exceptional mentor who was endowed with a nearly unmatchable humaneness. Scientific Europe owes him an enormous debt. CERN (European Subnuclear Research Center) had him as a scientific, moral and effective leader in the crucial years of its younger existence, from 1961 to 1965. During these years, CERN was the first European scientific enterprise to find itself in competition with the colossal USA. His responsibility as Director General of CERN was decisive for creating that which today is known throughout the world as the 'spirit of CERN', which means scientific excellence. In Subnuclear physics Europe is top rank, thanks to the great Weisskopf.

To us young fellows he said:

> Guys, when one day you will have the opportunity to speak about all that I've done in my life, please forget titles and honors. Tell instead about something I did in physics.

This is what I will try to do now, having had the privilege of knowing him when he was at the peak of his scientific strength. He was my teacher and an unwavering supporter of my scientific activity. He loved to recall his first steps. And what steps! I will recount the most beautiful episode. This was how the calculations of 'virtual' reality got started. We physicists call it 'radiative effects'.

It was he, in fact, who was the first to venture into the unexplored territory of the phenomena called 'virtual'. Let us imagine an instrument so full of power that it could observe any phenomenon; even within the intimate heart of matter itself. An instrument from which nothing can hide. Well, almost nothing. This super-powerful instrument would never be able to observe directly the phenomena we call 'virtual'. Prior to the 1930s, it would have been impossible to imagine the existence of this reality. And yet – now that it has become daily bread in our laboratories – it seems to be practically taken for granted.

Start with a single grain of coffee. It is made up of billions and billions of atoms. Each atom has, as an external 'cloud', one (if it is Hydrogen) or many electrons. The electron is endowed with an electric charge. The taste of coffee depends on this charge. The light of a light bulb is emitted from the electrons of atoms that constitute the filament of the light bulb. If the electron did not have an electric charge, it could not produce light, which is made up of 'pieces', 'quanta', which we call 'photons'. It has been noted that photons that are emitted from one electron can be absorbed by other electrons. If this was not so, how could we detect them at all? It is from this question that 'virtual' reality is born.

If it is true that an electron can emit a photon, could the same electron absorb that very same photon? The answer is affirmative, but the phenomenon is not observable. In fact, if we could actually observe that photon, the electron could no longer absorb it directly. This is a very simple example of 'virtual' reality. Even though it is not directly observable, it nevertheless produces calculable and rigorously reproducible effects. This is what the young Weisskopf discovered.

The history of this formidable new reality is incredible. In contrast to the very simple 'virtual' phenomenon I have just described (thanks to 'hindsight'), the young Weisskopf – driven by his interest to understand the 'radiative effects' – calculated a very complex 'virtual' phenomenon, called '*vacuum polarization*', and concluded that the effect was small, but that one day it might be measurable. In 1947, a physicist, Willis Lamb, and one of his collaborators from Columbia University (New York), measured the much simpler virtual effect I described above; they discovered that it was 10 times greater than predicted by the young Weisskopf. And of the opposite sign. It is easy (with 'hindsight') to understand the reason. The more complicated the virtual phenomena at stake, the smaller are their measurable effects. When Lamb measured the virtual effect that bears his name, Weisskopf estimated the value and sign very quickly. It was a calculation much simpler than that which he had done years before. The contributions of Weisskopf to the progress of physics and of scientific culture are so many that a conference would be necessary in order to review all of them.

Let me close by recalling a few of his substantive contributions to making CERN a great European Lab. In the era dominated by Bubble-Chamber-Technology, he encouraged the construction of the highest intensity negative beam; this allowed the discovery of the first example of Nuclear Antimatter, the discovery of the time-like structure of the proton and the first search for the third lepton. It is thanks to Weisskopf that the high-precision neutron missing mass spectrometer was invented and constructed at CERN; this allowed the direct measurement of a basic quantity (the so-called 'mixing' angle) in the structure of the Subnuclear particles called 'vector' and 'pseudoscalar' mesons. This 'mixing' is still of great interest because it requires the most advanced theoretical understanding in Subnuclear Physics, the so-called 'instantons'.

These are just a few examples strictly related to my own research work. Consider how many fellows he has encouraged, inspired and guided, and you will understand why Victor Weisskopf as a physicist and a leader in Europe and in the world will be unique in the history of Science of the 20th century.

Antonino Zichichi

SELF-PRESENTATIONS OF THE NEW MEMBERS

ANTONIO M. BATTRO

I was born in Mar del Plata, Argentina in 1936. My field of research is the neuro-developmental study of cognition and education in children and adults. I am a physician (MD, University of Buenos Aires) and psychologist (Docteur de l'Université de Paris).

I trained in neuroanatomy in Buenos Aires, in experimental psychology with Paul Fraisse in Paris and in genetic epistemology with Jean Piaget in Geneva. I helped to introduce the computer as a relevant tool in education in South America, following Seymour Papert's research at MIT. I applied those powerful information tools as prostheses for disabled persons, a new field of research in rehabilitation and special education. In the last few years I have been focusing my activities on educational cognitive neurosciences, using the computer as a 'tool for the brain'. My effort is to join the two fields of educational computer technology and cognitive neuroscience in order to open a new frontier of research. A first approach towards this synthesis is my recent book *Half a brain is enough* (Cambridge, 2000) where I describe the impact of the digital technologies in the education of a hemispherectomized child. I am now expanding this model to span a larger spectrum of problems related to the effect of neuroplasticity in the 'educated brain'. I am currently the Robert F. Kennedy visiting professor of Latin American Studies at Harvard.

Enrico Berti

My education was essentially in philosophy and for this reason, perhaps, I am not worthy of belonging to this famous Academy, which is mainly composed of renowned scientists. I studied philosophy at the University of Padua, which was a famous centre for the diffusion of Aristotelianism during the Renaissance, but which has conserved some traces of this tradition also in our time. I have been professor of philosophy at the Universities of Perugia, Geneva and Brussels, and I am now professor of philosophy in Padua, where I am leading a Centre for the history of the Aristotelian tradition. As a philosopher I have been elected member of the Accademia Nazionale dei Lincei (Rome), which contends with this Pontifical Academy of Sciences the heritage of the ancient Accademia dei Lincei, to which Galileo Galilei belonged, and as a philosopher I have been elected member of the Institut International de Philosophie (Paris). I am now organizing, as the chairman of the International Programme Committee, the XXI World Congress of Philosophy on behalf of the FISP (Fédération Internationale des Sociétés de Philosophie).

However, if someone generously proposed my name for this Academy, there must be a reason and I suppose that it concerns the main field of my philosophical interests, and this is the philosophy of Aristotle. I have dedicated to this philosopher and to the history of his influence on European culture more than 40 years of my life, with the result of being known essentially as an Aristotelian scholar. The study of Aristotelian philosophy, obviously, gave me the basis for developing some philosophical reflections in most of the fields of philosophical thought: logic, philosophy of language, philosophy of nature, metaphysics, ethics, politics, etc. Moreover, since Aristotle was not only a great philosopher, but also a great scientist, especially in the field of biology, psychology, anthropology and human sciences, the study of his works has necessarily implied for me an interest ancient science as a whole. And because the thought of Aristotle influenced the history of science during the whole of antiquity and the Middle Ages, not only in Christian but also in Muslim Countries, the reconstruction of the Aristotelian tradition obliged me to study the sciences of late antiquity and the Middle Ages in their whole extension.

In modern times, as it is well known, the thought of Aristotle was abandoned and refused by the development of some sciences such as astronomy, mechanics and chemistry, and this refusal gave rise to the birth of modern science. But his teaching has maintained a fundamental role in the development of other sciences, such as biology, medicine and human sciences (psychology, linguistics, rhetoric). In the next few weeks my university will commemorate the fourth centenary of the degree in medicine obtained in Padua by William Harvey, the discoverer of the blood circulation, who was essentially an Aristotelian. And even where Aristotle's influence was refused and fought, as in the case of Galilei, his logic and his method remained as a model for the modern sciences.

In my studies on the presence of Aristotelian philosophy in the 19th and 20th centuries I discovered that it had been striking not only in philosophers such as Hegel, Trendelenburg, Brentano, Moore, Heidegger, Gadamer, Austin, Ryle and others, by also in scientists such as Darwin, Jacob, Delbrück, Mayr, Prigogyne, Thom and others. The French mathematician Réné Thom, who died recently, during the last years of his work experienced a true conversion to Aristotelian physics. For these reasons I have realized that it is impossible to study adequately the philosophy of Aristotle and its connections to the contemporary philosophical debate without knowing the status of the discussion in the main fields of contemporary science, and this has forced me to engage myself in some of them. I am not a philosopher of science, nor a logician who analyses the methods of science, but a philosopher deeply interested in the contents of contemporary sciences, and for this I hope to be not completely unworthy of belonging to this Academy and to be able to contribute in some measure to its proceedings.

THIERRY BOON-FALLEUR

My field is cancer genetics and immunology.

I studied biology and medicine for 3 years at the University of Louvain, but I never completed the medical curriculum because I moved to Rockefeller University, New York, to pursue a doctorate in the field of molecular genetics.

Later I moved to the Pasteur Institute in Paris. There, in 1972 I made a fortuitous observation. It suggested that mouse tumors that were not rejected by the immune system nevertheless carried specific antigens that had the potential to serve as targets for rejection by T lymphocytes, provided proper immunization could be applied. Starting from this observation, we applied the approaches of molecular and cellular genetics to the field of tumor immunology. This led to the demonstration that our initial observation applied to all mouse tumors. Moreover, the genetic mechanisms that lead to the expression of tumor-specific antigens were elucidated. These are mutations of ubiquitously expressed genes and reexpression in cancer cells of genes that are only expressed in germline cells. One conclusion of this work is that the T lymphocytes can exert an immunosurveillance of the integrity of our genome: genetic defects lead to the expression of new antigens that can serve as targets for the destruction of the cell by T lymphocytes.

The observations made on mouse tumors have been extended to human tumors: it is now clear that most, if not all, human tumors carry tumor-specific antigens. As it is equally clear that tumors do not elicit an effective immune rejection response, we are engaged in a program of therapeutic vaccination of cancer patients, mainly melanoma patients, using purified antigens known to be expressed on their tumor. At the present time this treatment induces some degree of tumor rejection in only 20% of the patients. Medically significant rejections are only observed in 10% of the patients. Our present approach is to compare systematically the T lymphocyte responses of the few patients who reject their tumor to the responses of the many who do not, in order to identify critical differences. Hopefully, this will enable us to improve our treatments.

My research is being pursued at the Brussels branch of the Ludwig Institute for Cancer Research, at the Christian de Duve Institute of Cellular Pathology and at the Faculty of Medicine of the University of Louvain in Brussels.

GÜNTER BLOBEL

Omnis cellula e cellula, that each cell derives from a pre-existing cell by division, is the culmination of a profound insight of the late 19th century and a dictum articulated by the German pathologist Rudolf Virchow.

It is estimated that the earth is 5 billion years old that the first cell arose 3.5 billion years ago. Since that time, cells have continuously divided. At first they existed as single cells. Over time they got together and formed ever more complex organisms, culminating in man.

Each of us starts life by the joining of one cell from our father and one cell from our mother. Likewise, our father and mother began their lives from the union of a single cell from each of their parents. If we continue to trace our ancestors back in time we will eventually arrive at the cells that developed 3.5 billion years ago. So as we sit here, each of us represents 3.5 billion years of *continuous cellular life!* All of us are 3.5 billion years old!

Because all forms of life evolved from cells that developed 3.5 billion years ago, we are all related to each other!

This kinship among cells of bacteria, plants, animals and man is reflected in their organization as revealed by the modern tools of molecular biology and cell biology. Many of the organizational features and of the machineries in these cells have been highly conserved.

My own studies have touched on one of these highly conserved mechanisms, namely the intracellular targeting of protein molecules. An average mammalian cell possesses about one billion molecules of proteins. Proteins are polymers consisting of 20 building blocks (amino acids) up to 10,000 building blocks in length. Proteins are steadily degraded and therefore have to be continuously synthesized de novo. Newly synthesized proteins are transported out of the cell, or are shipped to various cellular compartments or are woven into intracellular membranes, each in a specific asymmetric orientation. We found that this is achieved by short sequence elements built into each protein. Each of these address-specific 'zip codes' is recognized by specific recognition factors followed by targeting and routing. These processes are aided by other accessory elements, such as receptors, channels, tracks, motors etc. We found that the zip codes as well the cognate sorting machineries are highly conserved in all cells.

Besides science, I am interested in the arts, particularly music and architecture.

I was born in 1936 in the small Silesian village of Waltersdorf near Sprottau. In February 1945 we fled from the approaching Red Army. On our way to relatives in Saxony, in the centre of Germany, we stopped briefly in Dresden. As a nine-year-old, I was very impressed by the beauty of this city, by its many palaces and churches, particularly by the huge cupola, the 'Stone Bell', of the Frauenkirche. A few days later, from about 60 km away, we witnessed the destruction of this magnificent city. The midnight sky turned red from the raging firestorm that killed tens of thousands of people and destroyed one of the world's most beautiful cities. It was one of the saddest days of my life. I decided then: I will contribute to the reconstruction of that city. More than fifty years later this dream came true, when I was able to donate the proceeds of my 1999 Nobel Prize in Medicine to the reconstruction of the Frauenkirche. It was one of the happiest days of my life.

A smaller portion of the proceeds of the Nobel Prize, I donated to the rebuilding of the Synagogue in Dresden and to the restoration of two churches in the historic center of Fubine, Alessandria in Piemonte. The Synagogue of Dresden was destroyed on Kristallnacht in November 1938. Fubine is the hometown of the parents of my wife, Laura Maioglio, who preserves their ancestral 17th century home.

Presently, I am campaigning for the reconstruction of the Paulinerkirche in Leipzig. This magnificent, over 800-year-old church was, for hundreds of years, also used as the Aula of the University of Leipzig and was witness to many of the most important events in German cultural history. The Paulinerkirche survived the Second World War completely intact. In an act of barbarism, the Paulinerkirche and its surrounding buildings were blown up in 1968 by the East German dictator Ulbricht in order to obliterate religion. The buildings that replaced the Paulinerkirche are now in disrepair and have to be torn down. The University Administration and the Mayor of Leipzig, however, campaign against the reconstruction of the Paulinerkirche. More than 80% of its interior had been saved before the wanton destruction by Ulbricht. I hope that by 2009, on the occasion of the 600th anniversary of the University of Leipzig, the Paulinerkirche will be rebuilt.

Pierre J. Léna

I was born in Paris in 1937, the elder of a family of six children. After secondary school, I decided to study physics and entered the *Ecole normale supérieure* in 1956. I found there an exceptional intellectual atmosphere between humanities and science students, great masters such as Laurent Schwartz or Alfred Kastler, and an extreme sensitivity to injustices and world conflicts, at the time of the Algeria war, the decolonization and the emergence of the Third World. I began to teach at the Sorbonne (Orsay) and decided to go to astrophysics, at a moment when access to space was going to deeply transform this field. The immense infrared spectral range was entirely virgin of exploration and I spent the next two decades on it. My Doctorat d'Etat was prepared partly in Arizona, on the infrared radiation of the Sun, one of the very few objects to be bright enough to be detectable at that time! I was lucky to use a NASA airborne telescope, and, back in France, we created a modest airborne observatory, which made some of the early observations of molecular clouds and dust emission in our Galaxy.

At the end of the 70s, while Professor at the University of Paris VII and inspired by the work of the French astronomer Antoine Labeyrie, I made every effort to obtain astronomical images with high angular resolution and to reach the diffraction limit of large telescopes by gaining one and later almost two orders of magnitude on image sharpness, beating the effects of the Earth's atmosphere. Working with a small team, this led us in 1989 to success with the first astronomical use of adaptive optics, a technique now adopted worldwide by all large telescopes.

While my colleagues or students were exploiting it to study many solar system objects or the star formation process, I became involved in the project of the European *Very Large Telescope*, for which, again following Labeyrie's ideas, we proposed an interferometric mode, using the coherence of light and combining several independent telescopes to gain another order of magnitude in resolution. Although this had never been done at such a scale, the project was adopted in 1987 and is now practically in operation, just in time to plan observations of the extrasolar planets discovered in large number since 1995.

I have always cultivated my interest for education, and in 1991 became president of the French *Institut national de recherche pédagogique*, while in charge of the Graduate School of astrophysics in Ile-de-France. With Georges Charpak and Yves Quéré, we founded in 1995 *La main à la pâte*, a nation-wide movement to renovate science education in primary schools, soon to be expanded to many countries. It led me to discover the urgency and magnitude of science education issues in the world and to spend large efforts on it.

Four children and their spouses and eight grandchildren form a happy circle, while many former students or young colleagues extend this circle: among them I would like to mention especially Daniel Rouan, Christian Perrier, Guy Perrin, Marie Glanc and the regretted Jean-Marie Mariotti.

CARLO MARIA CARDINAL MARTINI

Thank you very much, Mr. President. I was born in Turin, in the North of Italy, seventy-five years ago. I entered the Society of Jesus in 1944.

After my studies in theology, I graduated in fundamental theology at the Pontifical Gregorian University, writing a study on the historical traditions of the Resurrection of Jesus. I then taught fundamental theology for five years. In 1962 I was called by the Pontifical Biblical Institute to teach textual criticism of the Bible, and I graduated at the same Institute with a dissertation on Papyrus Bodmer XIV, which is the oldest papyrus containing the text of the Gospel of Luke (second century) and throws new light on the history of the text of the Gospel of Luke.

I taught textual criticism for seventeen years. During that time I became a member of the small ecumenical and international committee that was responsible for the publication of the critical edition of 'The Greek New Testament', which forms the basis of the translation of the New Testament in about eight hundred languages. In 1979 I was called by Pope John Paul II to become the Archbishop of Milan. This is a very large diocese and I had very little time to continue studying textual criticism. I have recently retired from this position and have now returned to the study of textual criticism.

I am presently engaged in research on a papyrus which is in the Vatican Library (the two Epistles of Peter), of the third century. I plan to work most of the time in Jerusalem, to be near the place where the Bible originated. I am privileged to be a member of this great Academy. Thank you very much.

JÜRGEN MITTELSTRASS

I am a professor at the University of Constance, one of the younger universities in Southern Germany, where I have taught philosophy since 1970. Since 1990, I have been Director of the Centre for Philosophy of Science at the university.

I was educated in Erlangen, Bonn and Hamburg, where I studied philosophy, classical philology and theology, also attending lectures in German literature, mathematics and physics. After taking my Ph.D. in philosophy in Erlangen in 1961 with a dissertation on the history of a Greek research principle in astronomy, I was a post-doctoral student in Oxford. Before I went to Constance, I spent some time as visiting professor in Philadelphia. From 1997 to 1999 I was President of the German Philosophical Association; a few weeks ago I became President of the Academia Europaea (the European Academy of Science).

My main research interests are in epistemology, the history and philosophy of science, the philosophy of mind, as well as, in recent years, in ethics, particularly ethics and the sciences. Within the philosophy of science, I am mainly interested in topics such as theory dynamics, theory structure, and the philosophy of time. My work on the history of science has dealt mostly with the history of physics and astronomy from the Greeks to Newton, in which research Galileo has been a principal focus. I am the editor of an encyclopaedia (*Enzyklopädie Philosophie und Wissenschaftstheorie*) whose four volumes also deal with the history and philosophy of science.

I am greatly honoured to be here, and to have been elected a member of this distinguished Academy; indeed, in all modesty, I am proud to belong to you. A philosopher among scientists – this is no easy thing to be. But I am convinced that we should aim at restoring to science its philosophical core, all while making philosophy more scientific in its methods. And this, as I understand it, is also one of the major aims of the Pontificia Academia Scientiarum.

Ryoji Noyori

Mr. President and Distinguished Members of the Academy,

First of all, please accept my heartfelt gratitude on this splendid occasion for having been honored with the appointment as academician of the world's most prestigious Pontifical Academy of Sciences. I do appreciate the members of the selection committee who recognized my lifelong accomplishments in the area of chemistry. I feel particularly honored to be the sole member who has currently been elected from Japan.

Born in Kobe, Japan, I was educated at Kyoto University to complete my bachelor and then master degrees and immediately became an Instructor at the same university. In 1968 I was invited by Nagoya University to chair a newly created laboratory of organic chemistry. Since then I have stayed there to teach and to conduct research for more than 30 years, while I have been warmly guided and encouraged by many colleagues worldwide. Then, fortunately, I was awarded the Nobel Prize in Chemistry last year.

I am a chemist. One of the major characteristics of our science is that we can design and synthesize any molecules at will, thereby generating a diverse array of molecular functions. We are very proud that our accumulated knowledge can now convert natural resources, including petroleum and biomass, to various chemical substances of a high-added value, thereby contributing to human welfare. Chemistry can generate high values from almost nothing.

My major research interest is in the molecular chirality or handedness. For many molecules, right-handed and left-handed shapes are possible, which are called enantiomers. Two enantiomers are mirror images of one another and have identical free energy. The difference is small indeed. These subtle differences, however, become distinct when these are involved in biological or physiological phenomena. Right-handed and left-handed molecules often smell and taste different from each other. The structural difference between them becomes a serious problem in the administration of pharmaceutical drugs. A compelling example of the relationship between pharmacological activity and molecular handedness was provided by the tragic administration of thalidomide to pregnant women in the 1960s. Right-handed thalidomide has desirable analgesic properties; however, left-handed thalidomide is teratogenic and induces fetal malformation. The actual thalidomide drug, unfortunately, was a 50:50 mixture of right- and left-handed molecules. Such problems should be avoided at all costs.

However, selective chemical synthesis of right-handed or left-handed molecules, called asymmetric synthesis, remained extremely difficult for many years. Early in 1851, some 150 years ago, Louis Pasteur claimed that 'Dissymmetry is the only and distinct boundary between biological and nonbiological chemistry. Then, symmetrical physical or chemical force cannot generate molecular dissymmetry'. Scientifically speaking, this is not true. However, this statement remained valid from a practical or technical point of view until 20 years ago. Therefore, access to pure right- or left-handed compounds has indeed relied largely on biotechnology using microorganisms that contain natural enzymes. However, since biological methods allow for access to only a limited class of substances, an efficient chemical means toward this goal is needed.

We could solve this long-standing problem by inventing efficient man-made molecular catalysts which consist of a metallic element and a chiral organic molecule. In 1966, we discovered the general principle which is now widely practiced in research laboratories and industry. Later we developed a general method to synthesize a wide range of chiral compounds by simply adding a hydrogen molecule to organic substances. Such accomplishments, together with the efforts of other scientists worldwide, have changed the chemist's dream to reality. Application of our original and versatile chemistry has allowed us and other people to achieve a truly efficient synthesis of organic molecules of theoretical and practical importance. Our methods have in fact been utilized for the large-scale production of certain fragrances, antibiotics, and antibacterial agents. Such invention has dramatically changed the processes of chemical synthesis of pharmaceuticals, agrochemicals, flavors, and fragrances among others. The growth of this core technology has given rise to enormous economic potential in the manufacture of precious chemicals. I am very pleased to be involved in contributing to the initiation and progress of this significant scientific realm.

Thank you very much.

JOSEPH CARDINAL RATZINGER

Mr. President, dear colleagues, I was born in 1927 in Marktl, in Upper Bavaria. I did my philosophical and theological studies immediately after the war, from 1946 to 1951. In this period, theological formation in the faculty of Munich was essentially determined by the biblical, liturgical and ecumenical movement of the time between the two World Wars.

Biblical study was very fundamental and essential in our formation, and the historical-critical method has always – even if I am not a specialist like Cardinal Martini – been very important for my own formation and subsequent theological work.

Generally, our formation was historically oriented, and so, although my area of speciality was systematic theology, my doctoral dissertation and my postdoctoral work presented historical arguments. My doctoral dissertation was about the notion of the people of God in Saint Augustine; in this study, I was able to see how Augustine was in dialogue with different forms of Platonism, the Platonism of Plotinus on the one hand and of Porphyry on the other. The philosophy of Porphyry was a re-foundation of Politeism and a philosophical foundation of the ideas of classical Greek religion, combined with elements of oriental religions. At the same time, Augustine was in dialogue with Roman ideology, especially after the occupation of Rome by the Goths in 410, and so it was very fascinating for me to see how in these different dialogues and cultures he defines the essence of the Christian religion. He saw Christian faith, not in continuity with earlier religions, but rather in continuity with philosophy as a victory of reason over superstition. So, to understand the original idea of Augustine and many other Fathers about the position of Christianity in this period of the history of the world was very interesting and, if God gives me time, I hope to develop this idea further.

My postdoctoral work was about St. Bonaventure, a Franciscan theologian of the thirteenth century. I discovered an aspect of Bonaventure's theology not found in the previous literature, namely, his relation with the new idea of history conceived by Joachim of Fiore in the twelfth century. Joachim saw history as progression from the period of the Father (a difficult time for human beings under the law), to a second period of history, that of the Son (with more freedom, more openness, more brotherhood), to a third period of history, the definitive period of history, the time of the Holy of Spirit. According to Joachim, this was to be a time of universal reconciliation, reconciliation between east and west, between Christians and Jews, a time without the law (in the Pauline sense), a time of real brotherhood in the world. The interesting idea which I discovered was that a significant current among the Franciscans was convinced that Saint Francis of Assisi and the Franciscan Order marked the beginning of this third period of history, and it was their ambition to actualise it; Bonaventure was in critical dialogue with this current.

After finishing my postdoctoral work I was offered a position at the University of Bonn to teach fundamental theology, and in this period ecclesiology, history and the philosophy of religion were my main areas of work.

From 1962 to 1965 I had the wonderful opportunity to be present at the Second Vatican Council as an expert; this was a very great time of my life, in which I was able to be part of this meeting, not only between bishops and theologians, but also between continents, different cultures, and different schools of thinking and spirituality in the Church.

After this I accepted a position at the University of Tübingen, with the idea of being closer to the 'school of Tübingen', which did theology in a historical and ecumenical way. In 1968 there was a very violent explosion of Marxist theology, and so when I was offered a position at the new University of Regensburg, I accepted not only because I thought it would be interesting to help develop a new university, but also because my brother was the choirmaster of the Chapel of the Cathedral. I hoped, too, that it would be a peaceful time to develop my theological work. During my time there I wrote a book about eschatology and a book about the principles of theology, such as the problem of theological method, the problem of the relationship between reason and revelation, and between tradition and revelation. The Bible was also always the main point of interest for me.

While I was beginning to develop my own theological vision, in 1977 Pope Paul VI named me Archbishop of Munich, and so, like Cardinal Martini, I had to stop my theological work. In November of 1981, the Holy Father, Pope John Paul II, asked me to become the Prefect of the Congregation for the Doctrine of the Faith. The Prefect of the Congregation is also President of two important Commissions, the International Theological Commission and the Pontifical Biblical Commission. The work of these two bodies, each composed of twenty or thirty professors proposed by the Bishops of the world, is carried out in complete freedom and acts as a link between the Holy See and the offices of the Roman Curia on the one hand, and the theological world on the other. It has been very helpful to me to serve as the President of these two Commissions, because it has permitted me to continue somewhat my contact with theologians and with theology. In these years, the two Commissions have published a good number of very important documents.

In the Biblical Commission two documents in particular were very well received in ecumenical circles and in the theological world in general. The first was a document about the methods of exegesis. In the fifty years since the Second World War we have seen interesting developments in methodology, not only the classic historical-critical method, but also new methods that take into account the unity of the Bible in the diverse developments in this literature, and also new methods. I think this document was really a milestone; it was very well accepted, as I said, by the scholarly community. The second document was published last year and concerns the relationship between the Holy Bible of the Jewish people, the Old Testament, and the New Testament. It treats the question of the sense in which the two parts of the Bible, each with very different histories, can be considered one Bible, and in what sense a Christological interpretation of the Old Testament – not so evident in the text as such – can be justified, as well as our relationship to the Jewish interpretation of the Old Testament. In this sense, the meeting of two books is also the meeting of two histories through their cultures and religious realisations. We hope that this document will also be very helpful in the dialogue between Christians and Jews.

The Theological Commission published documents on the interpretation of dogma, on the past faults of the Church – very important after the confessions made repeatedly by the Holy Father – and other documents. At the moment we are publishing a document on the Diaconate and another on revelation and inculturation.

This last argument, the encounter between different cultures, that is, intercultural and interreligious dialogue, is at the moment the main topic for us in our Congregation. After the disappearance of liberation theology in the years following 1989, there developed new currents in theology; for example, in Latin America there is an indigenous theology. This idea is to re-do theology in the light of the pre-Columbian cultures. We also are dealing with the problem of how Christian faith can be present in the great Indian culture with its rich religious and philosophical traditions.

The meetings of the Congregation for the Doctrine of the Faith with Bishops and with theologians, aimed at finding how an intercultural synthesis in the present moment is possible without losing the identity of our faith is exciting for us, and I think it is an important topic even for non-Christians or non-Catholics.

Thank you for the honour of being present with you.

AWARD OF THE PIUS XI MEDAL

Stanislas Dehaene

Summary of Scientific Activity

When I was a student in mathematics, I was always intrigued by the peculiar mental activity that characterizes mathematical thought, with moments of quick insight followed by periods of tedious, almost mechanical computation. Intuition and computation both seemed essential, but in strikingly different, indeed complementary ways. Following this lead, my scientific research has attempted to shed some light on the mental and cerebral bases of mathematical thought.

Joining Jacques Mehler's Laboratory for Cognitive Science and Psycholinguistics in 1985, I learned that the methods of cognitive science could be applied to study mathematical thought. I focused on what is perhaps its most elementary constituent, the comprehension and manipulation of numbers. My first experiments concerned number comparison. How do we know that 63 is larger than 55? Using chronometric tests, I showed that the time that our brain takes to compare two numbers is a highly regular psychophysical function of the distance between them, as well as of their size. This indicated that numbers were represented internally, not by discrete symbols, but by analogical quantities on an internal continuum that could be likened to a mental 'number line'.

Of course, there were also many indications in my experiments that humans could manipulate numerical symbols mentally if the task required it. In 1991, I discovered that the intuition of quantity and the manipulation of symbols rely on separable brain systems. With Laurent Cohen, at the Hôpital de la Salpêtrière in Paris, I studied a patient who had suffered a large left-hemispheric lesion and experienced devastating impairments in language, calculation, and memory. Remarkably, in all of these domains, he showed a spared ability to approximate the correct quantity. For instance, he could not perform an operation as simple as 2+2 – he sometimes stated that this made 3, or 4, or 5 –, but he knew that 2+2=9 was false because the quantities involved were too distant.

Based on this and many other cases, I proposed a formal model of the mental representations that contribute to number processing, the 'triple code model'. This model helped to predict and to understand the many experimental observations that followed.

When brain imaging techniques became available in the late 1980s, it was clear that they provided a whole set of new tools to test the model. I therefore engaged in a large number of studies that used brain-imaging techniques to probe the functional anatomy of calculation networks with positron emission tomography (PET) and later functional magnetic resonance imaging (fMRI). I also attempted to specify the temporal sequence of number processing stages by recording event-related potentials (ERPs). In particular, by combining fMRI and ERPs, I was able to confirm that approximation and exact calculation tap two distinct cerebral circuits.

My studies pointed to the crucial role of a small region in the horizontal segment of the intraparietal sulcus (HIPS), in the left and right hemispheres. This region can be systematically identified in all subjects. It occupies a fixed location relative to other functional areas in the parietal lobe that are engaged in various sensori-motor tasks. My research suggests that this region is systematically activated whenever a person manipulates numerical quantities mentally. During number comparison, the activity of this region is a direct function of the semantic distance between the numbers to be compared; and during calculation, its activity increases in proportion to the size of the numbers involved. This region is therefore a good candidate for a cerebral map of numerical quantity.

In 1993, with Jean-Pierre Changeux, I proposed a formal theoretical model that specified how numbers could be encoded by a population of neurons. The model proposed the existence of 'numerosity detectors', neurons that were coarsely tuned to a specific quantity of items. In 2002, this prediction was verified when electrophysiologists identified a population of number-sensitive neurons in the monkey parietal lobe, at a location homologous to the human HIPS area. Together with other observations that preverbal infants, in their first year of life, already possess elementary quantity manipulation abilities, those data indicate that 'number sense' is a basic ability which has been laid down in our brains in the course of evolution.

Intuitions are often unconscious. Would it be possible to show that the human sense of number can be triggered automatically and unconsciously? Intrigued by this idea, I designed a paradigm where we could flash subliminal words or digits that were masked by other shapes and therefore could not be consciously seen. Behavioral and brain imaging methods revealed an unsuspected depth of processing of those masked symbols. I discovered that masked stimuli could activate a case-independent fusiform representation of visual words, but also the parietal representation of number, and even the motor cortex when subjects were engaged in a fast chronometric task.

This research lead me to ask what was special about the conscious state. What aspects of human cerebral organization make it possible to slowly but flexibly perform a large variety of mental operations, and give rise to the feeling of conscious access and conscious direction? For many years, I had been working with molecular neurobiologist Jean-Pierre Changeux on the development of neuro-realistic models of cognitive functions. Those models accounted for neuropsychological tests associated with the prefrontal cortex, and their impairments reproduced the deficits exhibited by frontal patients. Recently, we realized that their architecture could be synthesized into a broader proposal, the 'neuronal workspace hypothesis'. Inspired by Bernard Baars' workspace view of consciousness, our model proposes that the neural basis of conscious thought is the sudden and coordinated activation of a highly interconnected network of neurons with long-distance axons. This model serves as a theoretical framework for new imaging studies of conscious and subliminal processing. Most recently, my studies have confirmed that conscious processing is associated with a brain-scale state of coordinated activity at distributed sites in parietal, prefrontal and cingulate cortex.

In the future, I plan to continue to search for the cerebral bases of high-level mental activity in humans. Brain-imaging techniques are providing us with remarkable insights into the organization of the brain and how it supports abstract thought. Mathematical thought remains my central theme, but I also apply the methods of cognitive neuroscience to other fields. With Jacques Mehler and other colleagues, I study the organization of language comprehension and, in particular, how bilinguals manage to fit two languages in the same brain. With Laurent Cohen, I study how written words are decoded and how this changes when the brain learns to read in a given culture. Finally with my wife Ghislaine Dehaene-Lambertz, I attempt to specify how the brain systems that we can visualize in human adults are laid down in the course of child development.

Juan M. Maldacena

Research Interests

My research has always been directed towards understanding different aspects of quantum gravity using string theory. In string theory there are certain black holes that can easily be described in terms of D-branes. D-branes are some excitations that string theory has. D-branes are objects that have a very precise and explicit mathematical description. Furthermore, they are rather heavy so that they curve the spacetime rather easily. Due to these properties they can be used to describe black holes, which arise when we have very heavy objects in a small region of space. With this description it is possible to understand the microscopic origin of black hole entropy, and to obtain a microscopic picture of Hawking radiation. Some of these formulas seemed to work too well and outside their naïve region of validity.

Motivated by this, in 1997 I conjectured that a certain region of spacetime near the horizon of these black holes could be given an equivalent description in terms of an ordinary quantum field theory, very similar to the quantum field theories that describe particle physics. This gave a novel relationship between quantum field theories and gravity which illuminated aspects of both of these theories. In other words, this relationship could be used both ways in order to learn about properties of quantum field theories or to learn about properties of gravity. Interestingly this gave a relationship between quark confinement and black holes. In the field theory description the strings are composite objects made with particles while in the gravity description they are the fundamental objects. I have spent the past few years studying different aspects of this relationship in order to learn more about gravity and field theories. One interesting consequence of the conjecture is that the process of black hole formation and evaporation does obey the standard rules of quantum field theory.

In the future I plan to continue these studies with the objective of understanding more precisely how to describe in a precise way situations where the spacetime is time dependent in an important fashion, such as what happens in the beginning of the Big Bang or in the interior of black holes.

Quantum Gravity

Our present description of nature is based on two kinds of fundamental theories.

One is the theory of gravity, which describes the dynamics of space-time. This is the General Relativity theory that Einstein formulated. It describes very successfully the motion of planets around the sun, the dynamics of very heavy and fast moving objects in the universe, and most notably the expansion of the universe as a whole. The second theory that we have is the theory of particle physics. This theory formulates a certain number of elementary particles and their interactions. Among these particles are the electrons and quarks that make up ordinary matter as well as the force carriers like the photon, which carries the electromagnetic force. This theory obeys the rules of quantum mechanics. Moreover, quantum mechanics is crucial in order to explain correctly most properties of matter.

These two theories, gravity and quantum particle physics, are extremely successful theories, they can explain a huge number of observations and they are not inconsistent with any experiment that has been done so far. (It might be necessary to include new particles in order to explain dark matter, but that can be done without changing the framework). Nevertheless this is an inconsistent picture of reality. It is mathematically, or logically, inconsistent. The inconsistency arises because we treat gravity as a classical theory, we would need to treat gravity in a full quantum mechanical form. There is no disagreement with current experiments because it is expected that quantum gravity effects, if present, would be very small and undetectable with the resolution of current experiments. On the other hand, there are certain physical processes that cannot be understood without quantum gravity. The most interesting and important one is the beginning of the Big Bang, the explanation of the initial stages of the Big Bang. Another question we cannot describe using the standard physical laws is what happens in the interior of black holes. When matter falls into black holes it is crushed into a region of very large density (formally infinite if computed with the current theories). To understand what is happening there we need a quantum theory of gravity. The basic reason that quantum gravity can be ignored for experiments we can do in the laboratory is the following. Gravity is important if an object is heavy while quantum mechanics is important if it is small. Ordinary objects are either small and light, so that we can neglect gravity, or are heavy and large, so that we can neglect quantum mechanics. On the other hand, in the beginning of the Big Bang the whole universe, which is heavy, is concentrated in a very small region. For this reason quantum gravity is important.

When one tries to quantize Einstein's theory of gravity one encounters difficulties since the straightforward methods, that worked very well for particle physics, now produce nonsensical infinite answers. So a quantum theory of gravity requires some new idea. The most serious contender, as a theory of quantum gravity, is the so-called 'String Theory'. This is a theory under construction. Many aspects of this theory are known but its final formulation is not yet known. Instead of describing the theory, let me just give a flavor of some of the new ingredients that String Theory uses. The first is the idea that fundamental objects can be one-dimensional instead of point-like. In particle theories the particles are points, they have zero dimensions. In string theory the fundamental objects have one dimension, i.e. they look like a tiny string, hence the name 'String' Theory. When strings oscillate in different ways they produce different elementary particles. So an electron would be a string oscillating in one way while a photon is a string oscillating in a different way. The second ingredient is the presence of some extra dimensions. So instead of having a spacetime with 1+3 dimensions (one time and three spatial dimensions) the universe can have 1+9 dimensions. Six of these dimensions have to be very small since we have not yet observed them. The third ingredient is supersymmetry. This is a symmetry that postulates that each known particle has a partner with different spin but otherwise similar properties. It is a symmetry that relates bosons and fermions. Bosons are particles that carry integer spin and fermions carry half integer spin. Fermions make matter while bosons carry forces.

The main virtue of string theory is that it can put together gravity and quantum mechanics into a consistent set of equations. It gives a very tight mathematical structure which is intimately connected with many ideas in particle physics and gravity. String theory gives rise to particles and interactions that are very similar to the ones in the standard model such as chiral gauge interactions, family structure and grand unified gauge groups. The precise nature of the particles one obtains depends on the precise nature of the six-dimensional space spanned by the six small dimensions. We have not yet found the space that gives precisely the standard model of particle physics. Finally another very nice aspect of string theory is that it leads to a precise understanding of various quantum properties of black holes, such as their entropy. The entropy of black holes gives the number of microscopic configurations that a black hole can be in. It is intimately associated with the fact that black holes have a temperature, which leads to the so-called Hawking radiation.

Finally let me point out some of the main challenges and unsolved problems that we are faced with. The first is to understand the beginning of the Big Bang. The second is to find the six-dimensional space that gives precisely the standard model of particle physics. And finally and most important is to find some experimental evidence that this is really the theory that describes nature.

PROGRAMME

Plenary Session *The Cultural Values of Science*
8-11 November 2002

FRIDAY, 8 NOVEMBER 2002

9:00 *Welcome Speech*:
Prof. N. Cabibbo, President of the Academy

9:15 *Commemorations of Deceased Academicians*:
André Blanc-Lapierre by Prof. P. Germain; Louis Leprince-Ringuet by Prof. P. Germain; Jacques-Louis Lions by Prof. P. Germain; Minoru Oda by Prof. N. Cabibbo; Max F. Perutz by Prof. W. Arber; Franco Rasetti by Prof. N. Cabibbo; Victor F. Weisskopf by Prof. A. Zichichi

10:15 *Self-presentation of the New Academicians*:
Prof. A.M. Battro, Prof. E. Berti, Prof. G. Blobel, Prof. T. Boon-Falleur, Prof. P.J. Léna, Card. Prof. C.M. Martini, Prof. J. Mittelstrass, Prof. R. Noyori, Card. Prof. J. Ratzinger

11:00 Break

11:30 *The Subject of the Plenary Session*:
H.E. Prof. M. Sánchez Sorondo, Chancellor of the Academy

12:10 Chairperson: W. Arber
Science and Culture
Prof. M. Iaccarino
Discussion

13:20 Lunch

15:00 Chairperson: P. Germain
Que la science s'inscrit dans la culture comme "pratique théorique"
Prof. P. Ricœur
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

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

19:15 Dinner

SATURDAY, 9 NOVEMBER 2002

9:00 Chairperson: V.I. Keilis-Borok
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: G.V. Coyne
The Moral Substance of Science
Prof. J. Mittelstrass
Discussion

16:00 *Reconnecting Science with the Power of Silence*
Prof. T.R. Odhiambo
Discussion

16:40 Chairperson: J.E. Murray
Towards a Culture of Scientific Excellence in the South
Prof. M. Hassan
Discussion

17:00 Break

17:30 *Science as a Culture: a Critical Appreciation*
Prof. C.N.R. Rao
Discussion

18:30 *On the Predictability of Crime Waves in Megacities*
Prof. V.I. Keilis-Borok
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

12:00 Closed Session

13:00 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: H. Tuppy
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

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

MONDAY, 11 NOVEMBER 2002

17:00 Break

17:30 Chairperson: Cabibbo
Surgery of the Soul
Prof. J.E. Murray

17:45 *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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PREFACE

The Pontifical Academy of Sciences devoted its plenary session of November 2002 to a debate on The Cultural Values of Science. Most of the talks delivered represent personal views of Academy members, and only a few non-members had been invited to complement the programme. For this reason, there is no claim for completeness of the transdisciplinary topical contributions. However, these proceedings clearly show that and how the progress of scientific knowledge and its applications also enrich the cultural heritage of our civilization.

One of the motivations to discuss this important topic was to contribute actively to the follow-up of the fruitful debate on science and society held in June 1999 at the World Conference on Science in Budapest, jointly organized by UNESCO and the International Council for Science (ICSU). The Pontifical Academy of Sciences is grateful to UNESCO for having welcomed its contribution on the cultural values of science in a wider debate on the relations between science and society and more specifically as regards a strengthening of the social contract between science and society. Our Academy also thanks UNESCO for its readiness to help diffuse the present publication to a wider interested readership. Any feedback from readers will be welcome and can help to intensify the dialogue between the natural sciences on the one hand and other fields of academic activities as well as the general public on the other hand. The readers are invited to take this publication and in particular the included Statement by the Pontifical Academy of Sciences on The Cultural Values of the Natural Sciences as a stimulus for further debates on a topic concerning all human beings.

Werner Arber

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.