PONTIFICIAE ACADEMIAE SCIENTIARVM SCRIPTA VARIA

73

CINQUANTENAIRE DE LA FONDATION DE L'ACADÉMIE PONTIFICALE DES SCIENCES

Compte-rendu et Actes
de la Session Plénière et des Célébrations

27-30 Octobre 1986

PONTIFICIA
ACADEMIA
SCIENTIARVM

EX AEDIBVS ACADEMICIS IN CIVITATE VATICANA

MCMLXXXVIII

PONTIFICIA ACADEMIA SCIENTARVM

CINQUANTENAIRE DE LA FONDATION

Page précédente:
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Les opinions exprimées en toute liberté pendant la présentation des discours et les discussions ultérieures des participants de la session plénière, bien que publiées par l'Académie, representent les points de vue des participants et pas necessairement ceux de l'Académie.

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PREFACE

Du 28 au 30 octobre 1986, l'Académie Pontificale des Sciences s'est réunie pour commémorer le 50ème Anniversaire de sa fondation par Pie XI de vénérée mémoire. L'Académie Pontificale des Sciences doit son origine à l'Académie des «Lincei», qui a été fondée en 1603 par Federico Cesi et qui a compté parmi ses membres, à partir de 1611, Galileo Galilei.

Comme Académie privée, malgré l'effort de ses présidents successifs, entre autres l'Abbé Félicien Scarpellini, l'institution a eu plusieurs vicissitudes. En 1847, elle a été transformée par Pie IX en Académie Pontificale avec la dénomination de «Accademia Pontificia dei Nuovi Lincei». De cette façon elle a cessé d'être une académie privée pour devenir une institution de l'Etat Pontifical.

La dénomination «Lincei» est née peut-être de la croyance que le lynx voit plus loin que les autres animaux. Federico Cesi et ses compagnons, en admettant que les philosophes de la nature, c'est-à-dire les hommes de science, étaient capables de voir plus loin que les autres personnes, adoptèrent pour la nouvelle Académie cet appellatif.

L'Académie Pontificale des «Nuovi Lincei» qui avait comme objectif la promotion de la science, exerçait aussi la fonction d'organe de consultation de l'Etat Pontifical pour la science et la technologie. Elle était ainsi le précurseur des Conseils de la Recherche qui se sont formés par la suite.

Depuis l'établissement en 1870 de Rome capitale d'Italie, la nouvelle Académie Royale, fondée en 1871, absorba une grande partie des membres de l'Académie Pontificale. Pie IX, toutefois, la garda vivante. Comme l'a dit le Père Agostino Gemelli, à l'occasion du troisième centenaire de la mort de Federico Cesi: «...À la fin du Gouvernement Pontifical, en septembre 1870, un groupe d'académiciens resta fidèle aux Statuts émanés par Pie IX en 1847. Par cet acte de courage, digne de louanges, ils gardèrent en vie l'Académie Pontificale des «Nuovi Lincei», assurant ainsi la continuité entre cette dernière et notre Académie».

En 1936, Pie XI transforma l'ancienne Académie en «Académie Pontificale des Sciences» par le Motu Proprio *«In multis solaciis» du 28 octobre 1936. L'Académie Pontificale des Sciences était composée de 70 membres représentants des divers pays du monde et de différentes disciplines scientifiques, avec la tâche de promouvoir la science et de coopérer à la mission de l'Etat Pontifical en qualité de «Senatus Scientificus». Ses membres devaient être choisis pour leurs éminentes qualités scientifiques, sans aucune discrimination de race ou de religion, tenant compte seulement de leurs qualités morales. Ces règles, établies par Pie XI, ont été suivies jusqu'à présent, excepté le nombre des membres qui, récemment, a été élevé à 80. Outre les Académiciens Pontificaux nommés à vie, il faut considérer aussi trois Académiciens à titre «perdurante munere», à savoir, le Directeur de l'Observatoire Astronomique de Castel Gandolfo, le Préfet de la Bibliothèque Vaticane et le Préfet des Archives Secrètes. L'Académie compte aussi à présent deux Académiciens honoraires, titre qui est donné à des personnes qui ont acquis des mérites particuliers pour l'aide donnée à l'Académie et à ses entreprises scientifiques.*

Le choix des nouveaux membres est fait par élection de la part des Académiciens.

Tous les deux ans l'Académie organise des séances plénières auxquelles sont invités tous les Académiciens.

À l'occasion des séances plénières l'Académie confère la Médaille d'Or Pie XI à un savant âgé de moins de 45 ans. Quatre fois les récipiendaires de la médaille ont reçu par la suite le Prix Nobel.

Les travaux de l'Académie se poursuivent encore par des Semaines d'étude et des Groupes de travail. Les Semaines d'étude doivent faire le point sur un problème scientifique ou technologique dans toute son ampleur. Les Groupes de travail doivent se pencher sur un problème scientifique bien délimité.

Les sujets d'étude sont choisis après avoir examiné les suggestions présentées par des Académiciens ou par des membres de la communauté scientifique internationale. Le choix final est fait par le Conseil. L'Académie doit aussi répondre aux questions présentées par le Vatican.

Les travaux de l'Académie sont effectués avec la conviction que la science et la technologie doivent être au service des hommes et doivent respecter les valeurs éthiques et morales qui orientent l'humanité dans sa destinée. L'activité de l'Académie se déroule dans un certain nombre de directions qui se sont formées petit à petit, au

fur et à mesure de son propre développement. L'Académie, pendant ces 50 ans, n'a pas oublié l'importance de la connaissance scientifique et s'est efforcée surtout de traiter des sujets nécessitant un approfondissement spécifique.

En outre l'Académie s'intéresse fortement des problèmes de caractère global qui peuvent, par leur projection future, menacer le progrès de l'humanité.

L'Académie Pontificale des Sciences a traité les questions les plus vitales pour le développement du Tiers Monde. Dans ce but elle essaie de présenter des solutions aux problèmes scientifiques et techniques dans le cadre des conditions sociales et morales de ces pays. En plus l'Académie essaie d'établir entre les pays riches et les pays pauvres des relations scientifiques et techniques qui puissent donner aux peuples sous-développés la liberté de choix, qui est essentielle à leur propre progrès.

L'Académie a également étudié des évènements historiques dans le cadre de la culture de leur temps. C'est le cas, par exemple, de l'étude faite sur le Calendrier Grégorien, en collaboration avec l'Observatoire Astronomique du Vatican, à l'occasion du 4ème Centenaire de sa promulgation. Dans l'optique de l'histoire de la science, l'Académie a publié en 1962 une importante étude sur l'oeuvre de Galilei et, plus récemment, un volume contenant tous les documents relatifs au procès de Galilei qui existent dans la Bibliothèque Vaticane.

L'Académie ne pouvait pas se dérober au défi de la guerre nucléaire. À ce propos l'Académie a envoyé au Saint Père en novembre 1979, une lettre contenant un certain nombre de détails sur les effets de la guerre nucléaire et, au commencement de l'année 1980, elle a organisé un Groupe de travail sur ce sujet. Ces recherches ont été utilisées par le Saint Père dans un certain nombre de ses allocutions. En 1981 une nouvelle réunion a mis au point la question des conséquences d'une explosion atomique et a élaboré un document qui, à la suite de la décision du Saint Père, a été présenté par des Académiciens à M. Leonid Breznev, à M. François Mitterand, à M.me Margaret Thatcher et à M. Ronald Reagan. En plus il a été remis au Président de l'Assemblée Générale de l'O.N.U. et à son Secrétaire Général.

En 1982, après deux séances préparatoires, l'Académie a réuni dans son siège 61 scientifiques de haute qualité, dont 40 étaient Présidents ou représentants des Académies de divers pays du monde.

Le document relatif a été reproduit dans beaucoup de pays de l'ouest et de l'est.

En 1984 l'Académie a étudié le phénomène de l'hiver nucléaire qui se verifie à la suite d'un bombardement atomique. Le document relatif, «Nuclear Winter», a eu un grand retentissement.

L'Académie, qui est en même temps au service de l'Eglise et de l'humanité, en réunissant, dans un climat de liberté et de confiance, les savants de tous les pays, a contribué au progrès de l'esprit de paix dans le monde.

D'autre part, aidant le progrès des pays sous-développés par ses propres recherches scientifiques et technologiques, considérant leurs ressources naturelles, l'Académie a contribué de cette façon à la paix du monde, car, comme l'a dit le Pape Paul VI, le développement est le nouveau nom de la paix.

Au cours de ses réunions l'Académie a pu accueillir dans son siège au Vatican de 1972 à 1986 plus de 1350 scientifiques, venus de tous les pays du monde.

Le volume que je présente expose les évènements qui ont eu lieu à l'occasion du 50ème anniversaire du renouveau de l'Accademia dei Nuovi Lincei en Académie Pontificale des Sciences.

Je désire remercier d'abord le Saint Père et le Saint Siège pour l'appui toujours donné à l'Académie et particulièrement à la commémoration de son 50ème anniversaire. Je remercie aussi avec émotion tous ceux qui ont aidé l'Académie à réaliser l'extraordinaire commémoration de son 50ème anniversaire. Ma gratitude s'étend à toutes les Académies du monde qui se sont faites représenter et qui ont renforcé, avec leur amitié, notre espoir de collaborer à toutes les initiatives scientifiques et techniques nécessaires au monde pour pouvoir entrer en toute confiance dans le XXI siècle. J'aimerais présenter mes remerciements spéciaux au Directeur de l'UNESCO et au représentant de l'ICSU. Enfin je cite ceux qui ont été plus près de moi au moment de l'organisation de ces séances: le Prof. Marini-Bettòlo, le Père di Rovasenda, l'Ing. Dardozzi et le prof. Pietrangeli ont été particulièrement valables. Ma gratitude va aussi au personnel de la Chancellerie de l'Académie Pontificale des Sciences et à tous ceux qui ont rendu possible la réalisation de la commémoration du 50ème anniversaire de l'Académie et la publication de ce compte-rendu.

Nos sincères remerciements à la société «Cartiere Burgo S.p.A.» de Corsico (Milan) d'avoir rendu possible la publication de ce volume.

La lecture des Actes du 50ème anniversaire de l'Académie Pontificale des Sciences nous donne la certitude que nous pouvons envisager avec espoir de faire face au prochain cinquantenaire et que les services rendus à l'Église et à la société humaine, à travers la communauté scientifique, continueront à être valables.

CARLOS CHAGAS

COMPOSITION DE L'ACADÉMIE PONTIFICALE DES SCIENCES AU 1er JANVIER 1987

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George	Coyne	Cité du Vatican
Joseph	Metzler	Cité du Vatican

Jean Paul II

PREMIÈRE JOURNÉE

27 octobre 1986

SÉANCE INAUGURALE

La cérémonie inaugurale de la Session Plénière de l'Académie Pontificale des Sciences s'est déroulée au siège de l'Institution, à la Casina Pie IV, dans les jardins du Vatican. Sous la présidence du prof. Carlos Chagas, étaient réunis les Académiciens Pontificaux:

Anatole ABRAGAM
Christian ANFINSEN
Werner ARBER
Sune BERGSTRÖM
André BLANC-LAPIERRE
Hermann BRÜCK
Nicola CABIBBO
Carlos CHAGAS
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Maxine SINGER
Janos SZENTÁGOTHAI
Walter THIRRING
Charles TOWNES
Hans TUPPY
Alfred UBBELOHDE

Académiciens honoraires:

Silvio RANZI

Académiciens «perdurante munere»

Leonard BOYLE
George COYNE
Joseph METZLER

Le Directeur de la Chancellerie de l'Académie Pontificale des Sciences, le Père Enrico di Rovasenda et le Directeur-adjoint, Rév. Ing. Renato Dardozzi assistaient également.

ADRESSE DE SALUT DU PRÉSIDENT

A l'ouverture de la séance, le Président a prononcé son discours d'accueil.

Ladies and Gentlemen,
Academicians,

On the 28th day of October 1936 Pius XI, by means of the Bull "In multis solaciis", restored the former Accademia dei Nuovi Lincei transforming it into the Pontifical Academy of Sciences. Pius XI established the norms for the Academy, which were: to promote the progress of Science and at the same time provide a "senatus scientificus" for the Holy See.

Pius XI decreed that there were to be 70 academicians — the number of cardinals at the time — who were to be chosen for the excellence of their scientific work, barring all racial or religious discrimination. The number of nations represented in the list of academicians chosen by Pius XI shows his intention of emphasising the international characteristic of the Academy, a characteristic implanted in the Accademia dei Nuovi Lincei, founded in 1847 by Pius IX.

The continuity between the Pontifical Academy of Sciences and the Accademia dei Nuovi Lincei points to the fact that the Pontifical Academy originated from the one founded by the Roman Prince, Federico Cesi, in 1603, which he named Accademia dei Lincei. Cesi chose this name because he considered that scientists have a more acute vision of the natural world than the layman and the fact that the lynx was thought to be the animal with the most acute vision.

The Pontifical Academy of Sciences, with the constant presence of scientists of all nations who meet at its seat for workshops and study weeks, dealing with problems which cover an extensive range

of scientific subjects, is the ideal tool to integrate the scientific world as a whole.

Furthermore, the Academy reports on all scientific questions put to it by the Holy See, providing it with elements which correspond to our present day scientific knowledge.

Ladies and Gentlemen, it is with joy that I welcome you to the seat of our Academy.

I would like to thank all those who, having come from close or faraway places, representing the Academies of Science of the world, join the academicians of the Pontifical Academy of Sciences in the celebration today, of the fiftieth anniversary of its restoration by Pope Pius XI.

COMMÉMORATION DES ACADÉMICIENS DÉCÉDÉS

Présentant la commémoration des Académiciens décédés depuis la dernière Session plénière de 1983, le Président a annoncé la nouvelle de la disparition récente de l'Académicien Edward Adalbert Doisy, dont la commémoration aura lieu à l'occasion de la prochaine Session Plénière.

Sanichiro Mizushima a été commémoré par Kenichi Fukui
Alberto Hurtado a été commémoré par Hector Croxatto
Giuseppe Colombo a été commémoré par Giampietro Puppi
Martin Ryle a été commémoré par Hermann Brück
Paul Dirac a été commémoré par Carlo Rubbia
Alberto De Almeida a été commémoré par Carlos Chagas
Giovanni Battista Bonino a été commémoré par par Giovanni Battista Marini-Bettòlo
Giuseppe Moruzzi a été commémoré par Rita Levi-Montalcini
Albert Szent-Györgyi a été commémoré par Hans Tuppy.

Sanichiro Mizushima (1899-1983)

It is indeed a privilege to have this opportunity to say a few words in honour of the late Professor Mizushima at this Plenary Session of the Academy. My last encounter with Professor Mizushima was in Tokyo on April 12, 1983, at a party hosted by the Chemical Society of Japan to welcome the members of the Executive Committee of the International Union of Pure and Applied Chemistry, who had come to Japan in connection with the IUPAC international committee meeting. A Bureau member himself, Professor Mizushima was well-known for his active interest and participation in IUPAC. At this particular party, he looked fine, chatting amicably with his fellow chemists and giving a short speech

full of wit and humour — despite the fact that his health was already fast deteriorating.

I was not to see the good Professor alive again.

It was with deep sorrow that I heard of Professor Mizushima's death on August 3rd, 1983, at the age of 84. At the time I was President of the Chemical Society of Japan, a post that Professor Mizushima had held more than two decades earlier, and to the advancement of that Society Professor Mizushima had for long dedicated himself. Professor Mizushima's last published writing was an article entitled "A Gift to Young Scientists from a Senior" which appeared in the Members' Journal of the Chemical Society of Japan two months after his death. I am told he wrote these last words on his sickbed even though he needed an oxygen mask to breathe. This article, together with more than ten other prominent essays published in the same journal, had an immense influence on all Japanese chemists.

Born in downtown Tokyo on March 21st, 1899, Professor Mizushima graduated from the University of Tokyo's Department of Chemistry in 1923. Even after graduation, Professor Mizushima remained associated with the University of Tokyo, throughout his remarkable scientific career, including the period from 1938 to 1959 when he was Full Professor of Chemistry. After retiring from the University, he became Director of the Yawata Iron and Steel Company Tokyo Research Institute.

Although he had the wide-ranging interests typical of a genius, physical chemistry was always his first academical love. Since a complete description of his many achievements would fill a volume, I will restrict myself to a few highlights. Professor Mizushima's unusual scientific abilities became evident early in his career when he accurately measured the anomalous dispersion of the dielectric constant in several alcohols by using electromagnetic waves in the 3-50 metre part of the spectrum, the first experimental proof of Debye's theory of permanent dipole moment of molecules. Amazingly, the main part of this work was contained in five important papers published within three years after his graduation from the University of Tokyo. Shortly after this proof was published, he was awarded a Japanese Government stipend to work with Professor Peter Debye in Leipzig. Between 1929 and 1931, Professor Mizushima studied in Europe, and it was during this period that he got interested in the use of quantum mechanics to explain chemical

phenomena. In fact, Professor Mizushima was himself one of the pioneers who adapted quantum mechanics to the interpretation of the molecular structure, significantly influencing the later development of theoretical chemistry.

Upon returning to Tokyo, Professor Mizushima focussed his attention on the structure of molecules, particularly their internal rotation. Studying dipole moments and the Raman spectra of 1,2-dihalogenoethanes, he discovered a new rotational isomeric form which he named "gauche", in 1934. This discovery was to have a profound impact on structural chemistry. After World War II, Professor Mizushima expanded his research into molecular structure with a variety of elaborate experiments making use of vibrational spectroscopy. His penetrating insight led him to initiate studies of the structures of biomolecules, proteins in particular. His having had interest in biomolecules during these years encouraged many students, who later contributed much to the development of related fields in Japan.

In 1959, Professor Mizushima brought the curtain down on a 36-year career in the University of Tokyo faculty, the final reception at the University Club being attended by a crowd of his admirers and distinguished guests, including his Imperial Highness Prince Hitachi, gathering to honour this outstanding scientist.

As might be expected of one who has had such a profound impact on the advancement of science worldwide, Professor Mizushima's brilliant achievements brought him a shower of prestigious awards. In Japan he was awarded the Imperial Academy Prize, Japan's highest accolade for scientific achievement, in 1938, while still in his thirties. He has also been designated a Person of Cultural Merit and awarded the Order of Culture and First Class Order of the Sacred Treasure, among other decorations. A member of the Japan Academy since 1963, he also belonged to a number of foreign Academies, besides this Pontifical Academy of Sciences, including the National Academy of Sciences, USA, the American Academy of Arts and Sciences, and Indian Academy of Sciences, and was an Honorary Councillor of the Supreme Science Council of Spain and an Honorary Member of the Spanish Royal Society of Physics and Chemistry.

In the closing years of his life, Professor Mizushima was fascinated with the interaction between traditional Japanese culture and Japan's rapid technological development following the Meiji Restoration of 1868. Clearly a departure from molecular chemistry,

this is indicative of his range of interests and scholarship. In the introduction to his definitive paper on this subject, published in the Proceedings of the American Philosophical Society, he explained that he had been prompted to write the treatise by a discussion with President Chagas, during the morning session of the Pontifical Academy of Sciences on October 22nd of 1976, and that the title "Cultural and Social Background of the Rapid Modernization of Japan" had been suggested by President Chagas.

In September 1984, an international seminar was held in Shimoda and in Tokyo, Japan, to commemorate the fiftieth anniversary of the publication of Professor Mizushima's first paper on rotational isomerism in molecules. Unfortunately, Professor Mizushima passed away just one year earlier and his absence was sorely felt by the many participants who knew him. Professor Mizushima was truly irreplaceable. Although he has passed away, his greatness endures, and I am proud to have known him.

(Kenichi FUKUI)

Alberto HURTADO (1901-1983)

I was awarded a great honor and privilege, when President Dr. Chagas asked me to frame a brief, and I would like it to be a solemn moment of remembrance, to pay tribute to a great scientist and an admired colleague: Dr. Alberto Hurtado, who was a member of this Academy since 1961; however, with a deep feeling of sadness I have to say that after months of confining sickness he peacefully passed away in November 1983.

His death was a great toll to Science. Most physiologists all over the world do not hesitate to call him one of the leading pioneers in the studies on the physiological adaptations of human beings to high altitude. He excelled in his research work, carried out at times under very hard and primitive conditions, particularly at the very beginning of his career. Likewise, he will be remembered as a brilliant leader and organizer, first as a Dean of the Faculty of Medicine, in San Marcos University (a post he held for four years between 1956-60) and later on, as a founder and Rector of the University Cayetano Heredia (1966). In both universities he struggled unceasingly in a demanding manner to achieve levels of excellence in all academic activities. Many generations of students envisaged him as a symbol of the moral virtues which dignify a true master.

With great vitality and zest, he had an unusual ability to stir the enthusiasm for research in young students, always willing to help and inspire beginners, adhering nonetheless to strict discipline, austerity and strong attachment to moral responsibilities.

Another aspect, probably least known, was his silent and humanitarian crusade, dedicated to the welfare of the needful in his country, a cause which he sustained through the years. No sooner was he appointed Director of Public Health and later on, Minister of Health, he set forth the laws that at a national level benefited the working class, in particular the native Indians working at high altitude. Although research work, more than anything else, was Hurtado's life and devotion, he was a medical doctor profoundly convinced of the potential contribution that Science and medical research in his country could make to improving living conditions. We have to bear in mind that some decades ago in his country (Perú), as in many other South American nations, scientific research work was a task for only a few enlightened and passionate pioneers. There were no full time professors and basic research was regarded with mistrust and considered a luxury only afforded by institutions in developed countries.

During his life he had to strive against misunderstanding and the upheavals of political unrest. But two happy events earlier in his scientific career left an unerasable print in his mind. One was the decision to study Medicine at Harvard Medical School, in Boston, USA. In 1920 he had been admitted to the University of San Marcos at Lima, but that was a stormy political year and the University was closed. In Boston, he was qualified as a brilliant student and meticulous experimenter and had the chance to collaborate with a great clinical researcher, Francis Peabody, and as soon he obtained his MD degree he became a member of the staff and collaborated in several papers on basic aspects of lung function and on pathological respiratory distresses. In Boston, he not only witnessed how scientific work was performed at its best but was also deeply involved in studies of the effects on respiratory functions at a low O_2 pressure. This is the natural physical condition under which a large proportion of the population in the Peruvian Andes lives. He refused an attractive proposal to stay in Boston. The preservation of his own identity was not at stake, there was the most pressing inner urge to abide by his feelings and his generous sense of responsibility compelling him to serve his countrymen. The other happy event

occurred on his return to Lima. He was fortunate enough to meet one of the most outstanding personalities in Peru, Dr. Carlos Monge, very well known for his studies on the so-called mountain sickness or Monge's disease. Both made expeditions into the Andes and Hurtado carried out studies upon soldiers of the Peruvian army, Indians and especially on miners living and working under strenuous conditions at high altitudes in La Oroya and in Morococha. He described, for the first time a serious risk to which are exposed newcomers to the very high mountains, especially children, who can be affected by an acute pulmonary edema which today is known as the Hurtado disease. He also became keenly aware of the stressful conditions of the workers in the mines located at 4,500 meters or above who in large numbers were victims of pneumoconiosis.

When in 1928, he was appointed Associate Professor of Physiopathology in the Faculty of Medicine of the National University of San Marcos, Lima, he brought distinction and high spirit to stimulate basic and clinical research. But money was greatly needed to supplement the scanty budget and the meager scientists' salaries, and in 1931 he accepted a fellowship from the Rockefeller Foundation which enabled him to continue research on respiratory and circulatory functions in different pathological conditions, at the University of Rochester (N.Y.). He declined a permanent position at that University and returned to Lima in 1935. He preferred to follow the harder and hazardous road of scientific toil in his own country. He strongly felt that the ultimate aim of his endeavour should be to contribute to the scientific development of Peruvian universities. With a large group of collaborators he started the most productive period of his life, trying to investigate the underlying mechanism which produced adaptation to continuous exposure to a high altitude environment in the native Indians. He organized and became the director of the Institute of Andean Biology, which was built at an altitude of 4,540 meters at Morocha.

Time is running out and I am afraid I cannot dwell upon the description of the most relevant discoveries made by him and his group. The number of published papers is large and his main contributions are cited in the classical books of Human Physiology. To date, the Institute continues to be the most important, and in many respects is unique in the Continent.

To come to an end, in speaking of his struggles and successes, I cannot but mention one of the most dramatic and bitterest moments

of his life. Political turmoil was threatening the essence of academic enterprise. He became the main protagonist of a crucial controversy over academic liberty in San Marcos University, in 1961. The epilogue was very painful for him, but a turning-point in the history of the Peruvian universities. He refused to accept the political throng and he preferred to resign his post and to remain loyal to his moral principles. This act is one of the greatest tokens of his indomitable uprightness. In the darkest hours he had the fortitude and invaluable support of the love of his wife and family. He became one of the leaders of an ideological movement which never will be forgotten in the historical record of Latin American Universities.

Four hundred prestigious members of that University followed him. He endured a very difficult time, but overcoming enormous problems, he succeded, and a new Faculty of Medicine opened its doors in 1962 in Lima and a new University was created: the University of Cayetano Heredia, today one of the leading institutions in Peru. Hurtado was unanimously elected its first Rector.

Alberto Hurtado not only lives on, as any scientist does, in the work and disciples he left behind. There was in his personality a never-failing spring of moral action which was at least as strong as the search for truth. He has rendered inestimable services to mankind. It is comforting to realize that his memory will remain positively as a source of inextinguishable hope for people striving for a better world.

(Hector CROXATTO)

Giuseppe COLOMBO (1920-1984)

Most of you do remember Giuseppe Colombo. He joined the Academy in '78 and he left us and this world two years ago at the age of 63. He had the privilege to participate in two of our general meetings, and in one of them we listened to his lecture on mathematical science. As a matter of fact he began his scientific activity in mathematics, but he is probably best known for his contribution to celestial mechanics and to space science and technology. I remember the interpretation of the period of rotation of the planet Mercury. Mercury performs one and a half rotations, per revolution.

The talent of Colombo combined, in a unique way of thinking

about nature, the mentality of a mathematician, that of a physicist, that of an engineer. Sometimes they were using their proper context, as in the investigation of the stability properties of general dynamic systems, or in the study of the characteristics and rules of the motion of celestial bodies, or finally in the conception of human artefacts to be sent into space.

At other times, they were joined together in a systemic approach for defining, for example, a complete logistic organization in space for its utilization by man, with permanent stations on planets and satellites, free-flying large and ultra lightweight structures for service to the earth and, in addition, appropriate shuttle for interorbital traffic.

But his central interest was always the natural phenomena: first to understand their real physical meaning, then to give a correct theoretical interpretation and finally to envisage extension and practical applications. One example, he has always been interested in the physics of a standard distribution of mass in the solar system, like the Saturn rings. Freely orbiting particles have in principle no structures, and if structures are present they must be either a consequence of a peculiar process of information which has survived, or they must be maintained by a body, like satellites discovered, known or undiscovered. But what happens if the particles are not free but bound in some way, while the centre of mass is still freely orbiting? The gravity gradient shows up giving a new type of stability. If matter is extended enough in terms of a unique coherent motion, you can apply this concept to stabilize a large continuous structure in space.

This specific idea, very dear to Colombo in his last years of life, is now developed in a joint programme by NASA and Italy. Colombo has been not only a scientist but also a teacher for a wide audience in Europe and America. His preferred tool was not the lecture but the discussion. A discussion with him was an intellectual game with no rules, no constraints, no limit of subject, where intuition and fantasy played a fundamental role but with an unresting scientific control of concept.

What I'm trying to say is that with Colombo we lost not only a real scientist but also a source of inspiration and of intellectual excitement. He was a man of extraordinary human qualities, generous with ideas, friendly in human relations, strong in pursuing the truth. He was a believer in God and I'm sure that this interior

attitude gave him the strength necessary to accept the end of his life, an end of which he was perfectly conscious a long time in advance.

(Giampietro PUPPI)

Sir Martin RYLE (1918-1984)

Sir Martin Ryle, who died on 14th October 1984 at the age of 66, was one of the most outstanding figures in British science of the present century. He was born into a distinguished academic family, his father being, first, Regius Professor of Physics in Cambridge and then Professor of Social Medicine in Oxford. Gilbert Ryle, the eminent Professor of Metaphysical Philosophy, was Martin's cousin.

Martin Ryle himself was a student at Christ Church, Oxford, from where he graduated with First Class Honours in Physics in 1939 just before the beginning of the last war. At the outbreak of war Ryle joined a brilliant team of electronic scientists who were concerned with research in the field of radar and in particular with the development of airborne radar systems.

When war was over Ryle joined the Cavendish Laboratory in Cambridge, where he started to investigate the emission of radio waves, which James Hey had discovered during the war as coming from the sun and as affecting radar networks. Not many scientists believed at the time that the sun was really the source of radio emission, but if it was, where exactly did the radio waves come from? In the 1940s radio aerials operating in the metre waveband had beam widths of 10 degrees or more. They could well detect radio emission from the Sun as a whole, which is half a degree wide, but they were quite unable to pinpoint possible sources such as sunspots, which Galileo had easily spotted with his tiny optical telescope more than 300 years earlier.

The problem, then, was to improve as much as possible the small resolving power of radio telescopes. In this Ryle started his work by introducing a radio analogue to the optical interferometer, with which Michelson 30 years earlier had been able to determine the diameters of stars. Instead of using a single antenna Ryle used two which could be moved apart and which at the same time could be connected by cable. With this device he was able to pinpoint radio sources such as sunspots with considerable accuracy.

With ever more refined equipment and using the same principle of radio interferometry, Ryle was soon in a position to pinpoint radio sources with accuracies which made it possible to compare their positions with those of objects visible in optical telescopes. In this way he discovered that the majority of localised radio stars in the sky could be identified with distant galaxies many millions of light years away. In his Nobel Lecture in 1974 Ryle said: "I think that the event which more than anything else led me to the search for ways of making more powerful radio telescopes, was the recognition in 1952 that the distant radio source in the constellation of Cygnus was a distant galaxy – 1000 million light years away".

By 1955 Ryle and his colleagues had discovered nearly 2000 such radio sources, whose numbers increased as their intensities decreased, and this in such a way that there were more galaxies per unit volume the further one looked out into space, or in other words the further one looked back in time. This observation was in obvious disagreement with Fred Hoyle's steady state theory of the Universe which was then much under discussion. Few modern scientific theories have led to such a major controversy and personal bitterness between scientists as the dispute between Hoyle and Ryle. Ryle insisted that his observations of radio sources pointed not to a steady state but to an evolving Universe which had started with a "Big Bang" from a superdense condition some 10,000 million years ago. This picture was very much confirmed when Penzias and Wilson discovered the microwave background radiation in 1965.

For the rest of his life Ryle was concerned with the mapping of radio sources with positional accuracies of seconds or even fractions of a second of arc. He achieved this by his most ingenious method of "aperture synthesis", in which the power of a large telescope, such as Sir Bernard Lovell's 250 foot (76 metre) dish at Jodrell Bank, is achieved and more than achieved by the use of a number of smaller radio telescopes which can be moved successively to different separations and whose output processed by suitable computers can simulate exactly the performance of a huge single radio telescope, too large to be actually constructed.

Ryle's genius showed in everything he did but perhaps nowhere better than in his concept of aperture synthesis. He was a marvellous designer of instruments and he was equally great in the use of his equipment for the solution of theoretical problems like those in astrophysical cosmology.

His exceptional achievements were rewarded in 1966 by a knighthood from the Queen, by his appointment to the first Chair of Radio Astronomy in the University of Cambridge three years later, and in 1974 by the Nobel Prize, which he received jointly with his friend and colleague Antony Hewish, who with the Cambridge equipment had discovered the existence of pulsars. In 1972 Ryle also became the first Astronomer Royal to come from Radio Astronomy. Other honours followed, coming, however, at a time when poor health did not any longer allow him to leave Cambridge. He was unable even to attend the Nobel ceremony and he never managed to come to any of our meetings in this Academy, to which he was elected in 1975. However, he took a great interest in our proceedings and particularly in the discussions of our Study Week on Energy in 1984. He became increasingly worried about the possible misuse of nuclear energy and the danger of nuclear war. In one of his last publications, "Towards the Nuclear Holocaust", he took a very pessimistic view of the future and in a letter to Professor Chagas, President of our Academy, the year before his death he said: "I am left at the end of my scientific life with the feeling that it would have been better to have become a farmer in 1946". This was indeed a sad sentiment coming from one who was not only one of the most ingenious scientists of our time and a great inspiration to a generation of students but also one of the most charming of people whom to know was a privilege and an unforgettable experience.

(Hermann BRÜCK)

Paul Adrien Maurice DIRAC (1902-1984)

Paul Adrien Maurice Dirac has been one of the most illustrious scientific personalities of our times. His formulations of the fundamental law of quantum mechanics and his discovery of the relativistic equation of the electron, place him at the same rank as Einstein and Bohr in the history of modern Science for the novelty and originality of new ideas.

He was born in Bristol on the 8th of August 1902. His father Charles had left Monthey, a French-speaking town of the Canton du Valais in Switzerland, to come to Bristol as a French tutor. His early upbringing appears to have been rather severe, for his father was known to be a strict disciplinarian at school and more so at

home. Children were required to speak only grammatically exact French at the dinner table and Paul has always attributed his taciturnity to this circumstance.

Dirac's first paper on quantum mechanics parallels much of what was being done at the same time by Born, Heisenberg, Jordan and others, but expressed in his own characteristic style. This was followed by a series of papers developing, generalizing and applying the new theory. He was at first puzzled by the appearance of non-commuting quantities, i.e., that by the multiplication rules Heisenberg had been led to, the product of two quantities depended on their order, i.e., *A times B* did not equal *B times A*. This result had also worried Heisenberg. But then Dirac realized that this was the essence of the new approach. It was for him a big step to see that the commutators were the analogue in quantum theory of the Poisson brackets of classical mechanics. This thought occurred to him during a walk in the country. He had developed the habit of relaxing during weekends by going on long walks, and not thinking about his problems, but on this particular occasion he kept thinking about the problem of non-commuting variables, until the similarity with Poisson brackets occurred to him in a flash. He did not remember the theory of Poisson brackets in detail, and he waited impatiently until Monday morning when he could check the details in the library.

He commented later that it was easier for him than Heisenberg to find it since scientists who propose a new idea tend to have an emotional attitude to it, and fear it may yet prove wrong. "Lorentz did not have the courage to express relativity, and Heisenberg had the fear of non-commutativity ... the originator of an idea is not the best person to develop it".

He went to Copenhagen in September 1926. Here he completed his paper on transformation theory which shows the Schroedinger wave equation, Heisenberg's matrix equations to be special cases of more general formulation. He comments that this work gave him more pleasure in carrying it out than any other paper he wrote on quantum mechanics before or after. In this paper he also introduces a notation which has become standard for most work in quantum mechanics.

He enjoyed the formal friendly atmosphere in Copenhagen and many long conversations with Niels Bohr whom he appreciated greatly for his depth. He said later that he did not know whether

Bohr had any influence on his work because Bohr tended to argue qualitatively while he himself liked to think in terms of equations.

He moved to Göttingen in February 1927. At that time he had become very well-known and appreciated by the scientific community. Recognition did not change his habits greatly. He continued to work intensely, mostly in his college room and largely following his own thoughts. He interacted particularly with fellow student Robert Oppenheimer and he had many discussions with Max Born, James Franck, Igor Tamm, with whom a lasting friendship developed.

He kept looking for a relativistic theory of the electron and in the winter of 1927-28 he found the right equation now known as Dirac equation, probably his greatest contribution to modern physics. This equation not only gave a relativistic description of the electron, but showed that it had a spin of half a unit, as was known empirically, and associated with this spin a magnetic moment of the correct magnitude.

A comment by Mott is typical of the impact of this paper on physicists: "This seemed, and still seems to me the most beautiful and exciting piece of pure theoretical physics that I have seen in my lifetime — comparable with Maxwell's deduction that the displacement current, and therefore electromagnetism, must exist".

The energy levels predicted by Dirac's equation were the same as those given by Sommerfeld's formula, which agreed well with observation. The equation had, however, a serious flaw in that it allowed unphysical solutions in which the electron moved with negative energy. Dirac gave much thought to attempts at avoiding this trouble, and in 1930 hit on the idea that all negative-energy states might in nature be filled, thus preventing, by Pauli's exclusion principle, any further electron going into any of these states. A vacant place, or "hole", would then appear as a particle of positive charge, and of the same mass as the electron. Such a particle had never been seen, and Dirac decided that if it existed it could not have escaped detection. The only known positively charged particle was the proton, and for a time Dirac believed that the "holes" were protons. In that case their very much larger mass would have to be attributed to the Coulomb interaction between charged particles, which is difficult.

However, he had to abandon this hypothesis, and by 1931 he came to seriously consider the possibility that there was a new, as

yet undiscovered particle, which he called "anti-electron". This idea was indeed confirmed when the positron was discovered in 1932. In an autobiographical interview he candidly said that he had forgotten that he had made this remark, and it is not generally realized that he was the first to speak of such a particle.

Meanwhile, besides a substantial output of research, he completed his book *The principles of quantum mechanics*, of which the first edition was published in 1930. This, and the three later editions, which were substantially revised, have helped generations of physicists to learn the spirit of the new physics. It reflects Dirac's very characteristic approach: abstract but simple, always selecting the important points and arguing with unbeatable logic.

Although in the 1930's the quantum mechanics of atoms and systems of atoms was complete and well understood, in no small part due to the work of Dirac, the quantum theory of the electromagnetic field was still giving trouble. To many questions the theory gave infinite answers. Dirac was unhappy about these difficulties and made numerous attempts to eliminate them, but without success.

At the same time he continued working on new applications and new methods. In addition he produced two quite revolutionary ideas not directly connected with the search for an improved quantum electrodynamics.

One of these was the magnetic monopole. He showed that the equations of physics could consistently accommodate a magnetic pole, not previously regarded as possible, provided the product of its strength and the charge of the electron was in integral multiple of $hc/2$. An interesting implication of this result is not only that the pole strength of any magnetic pole would have to be a multiple of $hc/2e$, where e is the electron charge, but that if there exists a pole of strength $nhc/2e$, the charge of any particle would have to be multiples of e/n. This would account for the quantization of charge.

The other idea was what he later called the "large numbers hypothesis". This hypothesis, first put forward in 1937, starts from the belief that the laws of nature should not contain fundamental dimensionless constants of enormous magnitude, and that, where such numbers appear, they are not constant but related to the present age of the universe, which, measured in atomic units, is also a very large number.

Both these ideas attracted much attention and were discussed in

many papers besides Dirac's own further work. On their reality there is as yet no final verdict; no certain experimental evidence for magnetic poles or for the variation in the planetary orbits predicted by Dirac has been found, though there are some positive indications.

However, since 1947, a large number of new particles have been discovered experimentally and their properties confirm the idea and the consequences of the Dirac equation. Fundamental particles which are now believed to be ultimate constituents of matter, namely the ordinary electrons, muons and tau and their neutrino partners, as well as six quarks, have their properties connected to the principles contained in the Dirac equation. In particular the properties of spin and the existence of the antiparticle were all observed experimentally.

The genious of Dirac has permitted a better understanding of the symmetry principle which dominates nature. Amongst those who had the fortune of knowing him personally, he will be however long remembered for his proverbial modesty and taciturnity. As a very general style of life he did not seek honours and replied "regretfully no" when any University sought to award him with honorary degrees. When in 1933, he shared the Nobel Prize for Physics with Schroedinger, at first he was inclined to refuse the prize because he did not like publicity, but then he accepted when Sir Earnest Rutherford told him: "a refusal will get you *much more* publicity".

He retired in the United States, where so many of his friends lived. From 1969, he spoke regularly at the Coral Gables conferences. Right to the end Dirac was opposed to the doctrine of renormalization of field theory and this was the topic of his last talk in January 1984. Although visibly failing, he spoke clearly and firmly, albeit softly. His lecture is to be published in a book, originally intended as commemoration of his 80th birthday, now entitled "The Dirac Memorial Volume".

Paul Adrien Maurice passed away peacefully on October 20, 1984.

(Carlo RUBBIA)

Antonio DE ALMEIDA (1900-1984)

Antonio de Almeida was an eminent anthropologist and ethnologist, born in 1900 in Vizeu, Portugal.

Graduated from the Faculty of Medicine in Lisbon, he became very early an anatomist, studying under Professor Mendes Correia, who was to precede him as a member of the Pontifical Academy of Sciences. From anatomy Almeida drifted to anthropology.

As Professor of Anthropology and Ethnology, Antonio de Almeida refused to remain secluded in the rigid walls of his study and classroom, and extended his zeal and vision to the field where he spent part of his life.

Overcoming the difficult conditions of living in the hinterlands of Africa, he mixed with the natives, living their lives and winning their confidence, which allowed him to undertake experiments and grasp the dominant traits of their culture.

From 1934 to 1975 he travelled extensively throughout the Portuguese colonies in Africa and Asia, Angola, Timor, Goa and Macau among others. Mozambique and the islands of Cabo Verde were also visited in his scientific travels.

In Angola, he studied the yellow and red bushmen, the Hottentots and Kwadis, together with 55 tribes of the Bantus. The biometric data accumulated by him surpasses 50,000 in number, and blood sampling corresponds to over 10,000 blood group typings and more than 7,000 Rh factor determinations.

In Timor, de Almeida, following the work done in Angola, and using the same methods, obtained biometric data on thousands of natives of various ethno-linguistic groups. He also studied the blood groups and the Rh factor of about 9,000 individuals.

The conclusions of his work put him in the first line of those who occupy themselves with human geographic biology.

During his voyages, Almeida, a tremendous worker, also obtained cultural data, enabling him to establish the specificity of the different tribal cultures. His work destroyed many taboos established by less diligent researchers. He thus showed, for instance, that many corporal deformations considered to be of genetic origin were in fact due to cultural tradition.

His work was also extended to the discovery of more than 600 archeological sites, and most of his scientific data and thousands of photographs were documented by black and white movie films.

All this is presented in more than 200 scientific papers, plus many articles in daily newspapers and scientific books. Almeida was a pioneer in his country, but in the field of physical anthropology he

brought to it the contribution of other disciplines, showing that biometric measures should be complemented by biological data.

(Carlos CHAGAS)

Giovanni Battista BONINO (1899-1985)

The Academy in its continuous renewal today honours our past Colleagues. I was invited by President Chagas to commemorate Professor G.B. Bonino, professor of Chemistry in Bologna and Genova, who was for many years for his science and wisdom one of the pillars of the Academy. He was born in 1899 and left us at the end of 1985.

I had the privilege to be his disciple and friend for many years, which allows me to give of him a quite personal picture.

When in the early thirties I was approaching for the first time the study of chemistry, and in particular of organic chemistry, the name and the work of Professor Bonino, became for me a revelation and a guideline for his new approach to the representation of organic formulae as well as of organic reactions. The reprint of his theory on the structure of benzene, presented at the International Congress of Chemistry of Madrid, was for me — because of its criticism of the standard formulae of Kekule — extremely stimulating for the proposed way to interpret the substitution rules in the benzene ring.

At that time, young chemists looked for a more rational approach to the reaction mechanisms in organic chemistry.

Bonino elaborated a theory on a modern physico-chemical basis, which represented — with the idea of electron delocalisation — a substantial advance in the approach to chemical problems. Although the complete theory of the reaction mechanisms was developed later in Great Britain by Robinson, Ingold and Hinshelwood, we must be grateful to Bonino for his pioneering work.

In order to find an experimental confirmation of his theory, Bonino dedicated himself, stimulating also his coworkers, to the study of molecular spectroscopy — mainly the use of infra-red spectroscopy, which was just at its beginning in those years, for interpreting the true chemical structures.

Also Raman spectroscopy was for him a means to understanding the molecular structure of many products.

His work represented in the late thirties a real change in the approach to the dynamic studies of organic molecules, establishing new models now generally accepted.

For his authority in the field of physical-chemistry he was also involved in the study of solid states and alloys.

His scientific approach was that the theoretical aspect was the starting point for experimental evidence and even for practical applications.

I will not give here a scientific curriculum of Bonino's work, but I should like to mention that he has opened important fields of research in chemistry and has formed, as all true scientists, an important school.

Bonino had other interests than scientific ones. Talking with him, one could realize his profound humanistic and philosophical formation. His knowledge did not seem to have any boundaries. Evidence of this aspect is seen in lectures given on the occasion of such great events as Avogadro's centenary, the landing of man on the moon, in which he was able to permeate facts, figures, formulas and experimental data with philosophical knowledge and historical criticism. I was often amazed, in talking with him, by his wisdom, not only his science, and I compared him in my mind with the men of the XV century who through their thought and action made our Renaissance spread out from the towns of Italy to Europe and to the world.

The problems of the two cultures faced today by scientists and humanists did not exist for him. He may be considered an example of the successful compenetration of the cultural and scientific horizons of mankind.

He was a believer — I apologize for going into this most delicate aspect of his personality — and as a believer he accepted with resignation the most severe events of his life.

He had a very clear idea regarding the present world. More than once he told me that the disarray of our modern society was due to the lack of spirituality, and the fact that "people are too much preoccupied with material goods and human promotion and have forgotten about eternal life". He was aware of the present uncertainties of modern society, due, in his opinion, mainly to the difficulties of our present way of thinking, in adsorbing the new results of science and technology. He believed that these effects influenced even the religious spirit and said that we would need in the present

times a powerful mind — like Saint Thomas Aquinas — "to coordinate in a new body the spiritual and the new science".

Bonino was appointed to the Academy in 1942: he always served very actively, also as a member of the Council for twenty years.

Although in the last few years he could not attend the meetings, owing to his health conditions, he was always interested in the Academy's activity and generous with suggestions in order to promote new initiatives in science.

The Academy has lost one of its most distinguished members who contributed so much to its development. We have lost a friend. His name and memory are part of the history of Science.

(Giovanni Battista MARINI-BETTÒLO)

Giuseppe MORUZZI (1910-1986)

I first met Giuseppe Moruzzi at an international conference in Copenhagen on the fateful day of September 1st, 1939, when the German army invaded Danzica, an event which signed the beginning of the Second World War. In spite of his young age — Moruzzi was 29 years old — he had already gained an international reputation for his outstanding contributions in the field of neurophysiology. At that time, he was working at the field of neurophysiology. At that time, he was working at the Neurophysiological Institute of Cambridge, headed by lord Edgar Adrian. Together they had recorded the discharge of single motor units of the pyramidal tract. These classical studies were to exert a most profound influence on the budding field of brain electrophysiology. I was, instead, an utterly unknown neuroembrylogist who had been forced by racial laws to leave Italy and continue her research in a neurological center in Brussels. From our first encounter, I was impressed by Giuseppe as a scientist and as a most gentle human being, deeply concerned with political and social problems. We spent many hours together considering the future, which looked very gloomy for us. The following day, he returned to Cambridge and I went back to Brussels.

It was in a very different state of mind and atmosphere that Giuseppe and I met again, ten years later, in Chicago. I was at that time working at Washington University in St. Louis, Missouri, in

the Department of Zoology chaired by Viktor Hamburger, and our work was progressing well. On the occasion of a neurological meeting in Chicago in the Spring of 1949, I visited Giuseppe who was at that time Guest Professor at Northwestern University. I had the great privilege of being present when he and Horace Magoun performed one of their celebrated experiments leading to the discovery of the ascending reticular system. Both scientists immediately realized the far-reaching significance of their findings which were to revolutionize the fields of neuroanatomy, neurophysiology, neuropharmacology, neurochemistry, experimental psychology and behavioral sciences. If, on the occasion of our first encounter, I had been deeply impressed by Giuseppe's broad scientific knowledge, his reserve and kindness, at this time I was no less impressed by his modesty, which, however, did not result from a lack of awareness of the fundamental importance of his discovery.

Many times in subsequent years I had the pleasure of spending several hours with Giuseppe, either in Pisa or in Rome where I had established a neurobiological research unit in the early sixties. In the conversations which took place in the relaxed environment of the laboratory, I could appreciate in full his human qualities which are very seldom found in scientists of his, or even much less, stature. Typical of him, was an unlimited generosity in the evaluation of colleagues, coworkers and pupils, total indifference to recognitions and honors and last but not least, a profound humanistic and philosophical culture which inspired his Spinozian way of facing — sub specie aeternitatis — injustices and all other human weaknesses. Another trait which became apparent in the last years of his life and that I greatly admired, was his stoical acceptance of a neurological disorder which caused him tremendous suffering but did not prevent him from working until the very end of his life.

Giuseppe Moruzzi's scientific contributions are too numerous and well known to need to be reported in detail; here I shall only list the most important.

As a young student of two great and beloved masters, Professors Pensa and Camis, Moruzzi started his career in neurophysiology exploring the role of the cerebellum in the control of posture. This research resulted in the discovery of the influence of the anterior lobe of the cerebellum on postural tone and phasic movements. At the same time, he explored the cerebellar influence on vegetative functions and discovered that the cerebellar vermis inhibits the cardiovascular

changes induced by stimulation of the baroreceptors. As the recipient of a Rockefeller Fundation Scholarship, he spent the year 1937-38 in the Neurophysiologic Institute of the University of Brussels, directed by the already famous scientist, Frederic Bremer. The following year he joined the Neurophysiology Institute of Cambridge, headed by Edgar Adrian, awarded six years earlier the Nobel Prize for his discoveries of the characteristics of the impulse discharges in sensory receptors and motor nerve fibers. The experience acquired in both Institutes was of tremendous benefit to the young Moruzzi and brought his fervid mind to its full blossoming. From Bremer he learned not only to master the electrophysiological techniques but also, and perhaps even more important, he became aware of the key role played by afferent sensory systems in maintaining the tonic activity of the cerebral cortex. This activity is lost upon mesencephalic transection, a surgical intervention which results in the isolation of higher brain centers from ascending afferent fiber tracts, but is maintained if the transection is performed at a lower brain stem level. As Moruzzi stated many years later, he learned "not only to carry out electrophysiological experiments... but also how to develop visual imagination with an extremely clear way of thinking". From the time that he spent in Cambridge, he learned not only the technique of recording from individual nerve fibers and single cell units, but also and above all "to gain confidence" which, as stated by Adrian in his essay on *Creativity in Science*, "is one of the most important ingredients in the scientific attack".

If Moruzzi's contributions to the classical studies performed with Lord Adrian on the single cortical cell discharge in the pyramidal fiber tract in the period 1938-39 were of such importance as to win him an international reputation, his fundamental discovery of the ascending reticular system, many years later, opened an entirely new field in the Neurosciences and made of him one of the most influential, leading scientists of our time. In the last, equally productive period of his life which ended on March 11, 1986, Moruzzi made fondamental contributions to the study of the physiology of sleep, giving unequivocable evidence that brain stem mechanisms are actively involved in the process of falling asleep and on the maintenance of sleep.

Besides his scientific work, Giuseppe Moruzzi devoted a large part of his time to instruct and follow the work of an ever-increasing list of pupils and cowokers coming from all over the world to the

prestigious Institute of Physiology in Pisa, headed by him. It would be impossible to remember the names of all scientists who had the privilege of working under his direction and who continued their careers in Italy as well as in other countries. It may suffice to say that all of the most distinguished neurophysiologists now working in Italy, and of the most distinguished neurophysiologists now working in Italy, and many of those who work abroad, can praide themselves of the honor of having been students of a great master: Giuseppe Moruzzi.

(Rita LEVI-MONTALCINI)

Albert SZENT-GYÖRGYI (1893-1986)

On Saturday October 25th, 1986, the day before yesterday, the Pontifical Academy of Sciences lost one of its most imaginative, most creative, and most non-conformist members, Albert Szent-Györgyi. He died shortly after having reached his 93rd birthday, after having lived a long and colourful life, rich in scientific adventure, in success and in controversy.

Szent-Györgyi's life was one of unrest, due both to scientific and to political challenge. He was born in Budapest, in Hungary, on the 16th October 1893. He got his Doctor's degree in Medicine at the University of Budapest in 1917. As a medical student, he first engaged in research in histology, but slowly turned to physiology, to pharmacology, to physical chemistry and finally to biochemistry. During World War I he had to join the army, and in 1917, when working in a bacteriological laboratory of the army, he revolted against atrocious instances of human experimentation and was sent to a swampy and malaria-stricken region in Italy. After the end of the war he started work at the University of Poszony, then Hungarian but soon after assigned to Czechoslovakia by the Treaty of Versailles. Szent-Györgyi passed from Czechoslovakia to Hungary, and shortly afterwards, deprived of all his property in those days of social and revolutionary upheaval, furtively returned to Czechoslovakia. He joined the electrophysiologist Von Tschermak in Prague, then moved to Berlin, then to Hamburg, before settling for two years at Leyden, Holland, as an Associate Professor at the pharmacological laboratory of the University.

From 1923 to 1926 he worked at the physiological laboratory of the University of Groningen, and from 1927 to 1932 as a

Rockefeller fellow at the University of Cambridge, England. Returning to Hungary, Szent-Györgyi became Professor of Medical Chemistry at the University of Szeged.

During World War II, in Hungary, he soon got into trouble with Nazism, but after the end of the war, in 1947, when he assisted a friend of his who had been arrested, he got into political trouble again and he had to leave the country and moved to the United States, where he stayed and worked until his death, directing a laboratory in the Marine Biological Station in Woods Hole.

Now regarding his work: in the 20s, Szent-Györgyi engaged in research on biological oxidations and he immediately became involved in an acute controversy at that time between Wieland and Warburg on the mechanism of biological oxidations. He discovered the important role of C4 acids such as succinic acid, and the respective dehydrogenases such as succinic dehydrogenase, and he paved the way to the elucidation by Hans Krebs of the citric acid cycle.

When investigating oxidations in plant tissues, he detected a then unknown reducing agent which later turned out to be vitamin C, ascorbic acid.

He then proposed the hazardous theory, on very little experimental evidence, that the same reducing agent might be present in adrenal glands. In fact, Szent-Györgyi subsequently succeeded in isolating and crystallizing the reducing agent, from oranges, from lemons, from cabbage and from adrenals.

During one year's stay at Rochester in the United States, he succeeded in isolating 25 grams of this mysterious substance from the adrenal glands. Later, in Hungary, having no adrenals at his disposal, on the occasion of a supper rich in paprika, he had the idea to test paprika for its vitamin C content, and indeed paprika turned out to be a veritable mine of vitamin C.

When Szent-Györgyi administered impure vitamin C to patients suffering from Purpura of Schönlein-Henoch, which involves capillary fragility and subcutaneous bleeding similar to bleeding in scorbutic patients, he was remarkably successful, but he failed using pure ascorbic acid. That is how Szent-Györgyi discovered the group of compounds called vitamin P which were impurities in the original vitamin C preparations and could be prepared from paprika.

Szent-Györgyi was then fascinated by a mysterious yellow, fluorescent, reversibly reductible compound which he called "cytof-

lavin" and which later became known as riboflavin, one of the most important vitamins. Later again, he was fascinated by the co-enzyme of lactic dehydrogenase, his findings paving the way to the discovery by Warburg of the pyridine nucleotides.

Later, turning to more complex biological phenomena, Szent-Györgyi investigated muscle contraction. He discovered, together with his pupil Straub, actin and the contraction of actomyosine by ATP.

The available molecular explanations of energy transformation in muscle contraction and in other biological systems, however, did not satisfy Szent-Györgyi. He advocated the extension of biology into the submolecular and supramolecular dimension. He particularly concentrated on the study of electron transfer reactions in living tissues, involving semi-conducting protein molecules. He considered bioelectronics to be the key to cellular processes and cellular regulations, and he finally proposed an electronic theory of cancer.

Szent-Györgyi was a biochemist and physiologist of world-wide reputation. He was awarded the Nobel Prize in Medicine in 1937, for the elucidation and discovery of the catalytic function of C4 dicarboxylic acids for his discovery of vitamin C. He received honorary Doctor's degrees from many universities and enjoyed the membership of the most renowned academic and scientific societies.

Szent-Györgyi never contented himself in making an interesting observation. Experimental findings induced him to put forward most ingenious and sometimes rather bizarre theories which were leading him, and more often other scientists, to great and most important discoveries. His later and most speculative theories, however, met with much skepticism. Nevertheless, Albert Szent-Györgyi has been one of the pioneers of modern biochemistry, always original, fascinating and challenging, one of the most imaginative and penetrating scientific minds and, moreover, a marvellous character, an exuberant personality.

He was a member of our Pontifical Academy since 1970. We shouldn't and we shall not forget him.

(Hans TUPPY)

PRÉSENTATION DES NOUVEAUX ACADÉMICIENS

Le Président a ensuite présenté les quinze nouveaux Académiciens Pontificaux nommés par le Saint Père Jean Paul II le quatorze décembre 1985, le neuf janvier et le neuf juin 1986, et leur a remis les Brefs Apostoliques de nomination, ainsi que les emblèmes traditionnels de l'Académie.

Après cette brève cérémonie, les nouveaux Académiciens ont exposé une synthèse de leurs activités scientifiques respectives.

Sune Bergström

Mr. President, Members, Ladies and Gentlemen, at a moment like this, when you look back on your life, you realize how much you owe to your mentors and teachers. I started scientific work at the Karolinska Institute, the Medical School of Stockholm in 1934. That school has a strong scientific tradition for being a medical school. Berzelius was one of the founders, and the Retzius brothers followed. They introduced a scientific spirit that has remained. In the early part of this century, a wealthy merchant gave so much money to the Karolinska Institute, that we had more research funds than any other school in Europe during the Twenties and Thirties.

The medical studies were very loosely organized. You could interrupt the studies at any time to do scientific work. Most of the Professors in preclinical sciences are not only MDs but they have often done their thesis in some basic science and usually before they finished their medical studies.

I was introduced to science by Professor Jorpes working on heparin and participated in the purification and structure elucidation of this polysaccharide. I could watch how they were brought for the first time into the clinic and how the results became the basis for the development of extensive surgery on the cardiovascular system.

Jorpes was very determined that his students should go abroad and I spent the summer of 1938 in London, working on bile acids.

During the war, after doing service in the Navy, I spent a year and a half in America with Professor Wintersteiner, working on steroid autoxidation. Coming back, I continued that work but on unsaturated fatty acids and characterized the autoxidation products. Working in Hugo Theorell's laboratory, we also crystallized the enzyme that oxidizes linoleic acid. I also spent some time in Professor Reichstein's department in Basel 1946-47 working on steroids.

Ulf von Euler, the Professor of Physiology, in 1947 asked me to purify a crude extract from sheep vesicular glands that he had prepared before the war. This extract had a strong smooth muscle stimulating and blood pressure lowering effect. Preliminary work showed that the extract contained several lipid soluble unsaturated acids with strong biological activities.

The work was interrupted for some years when I was appointed professor in Lund in 1947 and had to build up a new department.

In the late 50s the work was taken up again and our group isolated and determined the structure of the "prostaglandin" family of compounds with a group of very able collaborators. The prostaglandin family has continued to grow through the years — prostaglandins E, F, D with many different types of activities. They are formed in every cell in the body, from certain unsaturated fatty acids when these cells are stimulated. They have various effects in various organs. This synthesis is blocked by aspirin.

Some of these compounds as well as several analogues have found clinical utility in various fields.

The prostaglandins E and F are playing fundamental roles in all stages of human fertility and have also found use in therapy. They are used to initiate and enlighten normal delivery. One analogue is the most potent drug to stop dangerous bleeding after delivery. Another prostaglandin is now used to reduce blood pressure in preeclampsia at the end of pregnancy, a disease that is relatively common in developing countries. Several prostaglandins are now registered for medical termination of pregnancy.

The E type prostaglandins have a peculiar property to protect cells of the gastric mucosa and some analogues are now marketed for treatment of gastric ulcers.

The same fatty acids that are the precursors of the prostaglandins are also used for the biosynthesis of the thromboxanes and the

leucotrienes, that have now been elucidated by my colleague Samuelsson. They have a fundamental role in many immunological conditions and diseases.

It is very peculiar how these fatty acids were disregarded for so many years due to the lack of proper chemical methods. It was only in the 40s and 50s, when especially chromatography in combination with mass spectrometry was available, that the whole area could be developed.

During my last 15 years, I have in addition been increasingly involved in the World Health Organization's new "special research programmes" aimed at diseases and problems in the developing world.

Nicola Cabibbo

Mr. President, I'm a theoretical physicist. I studied in Rome, where I now teach as Professor of Theoretical Physics. After graduating in 1957, I worked for a few years in Frascati, with my teacher Bruno Toushek and with Raul Gatto, on the possible application of electron-positron storage ring machines, and at the same time on the nature of weak forces which also became my main interest since then. In fact, probably the best work I have done is work on the weak forces, which are responsible, for example, for the beta radioactivity of atomic nuclei, manifest in different kinds of processes, especially processes which differ with respect to the so-called strangeness quantum number. This is a quantum number which distinguishes the normal components of the atomic nucleus, the protons, the neutrons, from the more exotic particles like the hyperons.

Now, it was experimentally known that the weak forces act with much greater intensity, more than a factor of ten, in those processes which preserve this quantum number. For example in beta decay, transformation of a neutron into a proton with emission of an electron and neutrino. In this case the intensity of weak forces is much higher than in processes where this quantum number is modified, as for example, in transitions where a hyperon is transformed into a proton or neutron.

This was a real puzzle because it seemed to invalidate the idea, which goes back to Puppi, that the weak forces should have a universal intensity. The solution for this puzzle, which I found in

'63, is that weak forces view elementary particles in a way which is completely different from the way in which other kinds of forces view elementary particles. In other words, while most of the forces, in fact all the other forces of nature like the strong and the electromagnetic forces, view the proton, the neutron, the hyperon, as the basic units of nature, the weak forces view mixtures of these particles as a basic unit and this mixture is determined by a new constant of nature which is called the "weak interaction angle". The existence of this mixture explained the puzzles and in fact gave a large number of predictions for many different kinds of processes of weak disintegration, predictions that over the years have been verified. Only last year one of the remaining problems, having to do with the detailed mechanism of sigma minus hyperon disintegration, was cleared up by an experimental group at Fermilab.

Apart from these direct predictions done at the time, the idea of mixing was found to have many ramifications. For example, it was found to predict the existence of new kinds of quarks. In particular the charmed quarks were predicted in this way, and it also gave the basis for the unification of weak and electromagnetic interactions, as embodied in the theories of Glashow, Salam, and Weinberger, and this was brilliantly confirmed, as you know, by the discovery of the intermediate bosons, W and Z.

My present activity is again related to weak interactions. I'm now interested in understanding some aspects of the weak interactions of quark which are obscured by the strong effects of the quark-binding force. Although we have since 1972 a satisfactory theory of interquark forces — called Quantum Chromo Dynamics — this theory is mathematically very difficult and resists analytical treatment. In the last few years a new technique emerged, which is based on the idea of a numerical simulation of the theory on electronic computers. This technique has a long history, dating back to the post-war by Fermi, Pasta and Ulam, of the Rosenbluths and of Metropolis. Only recently, however, with the advent of fast computers, it has been possible to apply this technique to the solution of field theoretical problems, both classical (e.g., hydrodynamics) and quantum (those of interest in elementary particle behaviour). My group is at present engaged in the design and construction of a dedicated supercomputer, APE, which we will use to obtain a significant improvement of our understanding of quark behaviour.

Albert ESCHENMOSER

In the forties, when I entered the Swiss Federal Institute of Technology in Zürich to study Naturwissenschaften, it was the time when organic natural products chemistry in Europe was moving towards its post-war climax. The field was still in possession of that almost absolute monopoly which it had kept for an entire century, the monopoly of being the only branch of science that could provide structural information on biomolecules. It had been the time, when the chemical studies on the structure of vitamins and hormones constituted the frontier of science at the interface between Chemistry and Biology. In Zürich at the ETH, the great Leopold Ruzicka was teaching, a volcanic, monumental figure in the field of natural products chemistry, renowned for his work on terpenoids and male hormones. He was a member of this Academy and I happen to remember from later years his high esteem for this institution, his pride in belonging to it and his enthusiasm for the scientific gatherings organized by the Academy.

Having grown up as a scientist in the school of Leopold Ruzicka, my own research interest naturally came to be in organic natural products chemistry and — quite probably induced by the inspiring influence of a Robert Burns Woodward — in natural product synthesis. Almost everything which, over the years, my collaborators and I could contribute to natural products chemistry was achieved with the tools of chemical synthesis. I might touch upon three directions along which our work proceeded: first, studies on chemical reactivity and stereochemistry of organic reactions; second, chemical synthesis of structurally complex natural products of biological significance, and finally, studies on the structural origin of fundamental biomolecules.

Chemical reactivity is studied on all floors of chemistry, be it in quantum chemistry, in experimental physical chemistry and physical-organic chemistry, or on the level of preparative organic chemistry where the reactivity of molecules is studied for the sake of understanding and inventing organic reactions for the purpose of chemical synthesis. This is the level on which we, as many others, have been operating; the stereochemistry of cyclization reactions of terpenoid polyenes, the oxidation of alicyclic alcohols, and fragmentation reactions were topics among others. A presentation of results would lead us too much into chemical details; worth

mentioning, however, is perhaps the following more general aspect: the post-war period during which I entered research was a particularly favorable time to do so in the field of natural products chemistry. It was the time when the traditional concept of rationalization of chemical reactivity by constitutional analogy was replaced by the concept of mechanistic reasoning, a change that dramatically widened the chemist's horizon and his potential for interpreting as well as inventing new reactions. Happening to enter a field of research in young years at a time when paradigms are changing is good luck.

In the field of natural product synthesis, our main effort went into the conquest of the structure of vitamin B_{12} by synthesis. Elucidation of the complex structure of this cofactor molecule had been one of the early highlights of structure determination by x-ray analysis (Dorothy Hodgkin 1955). The presence of this vitamin in the human body in daily microgram doses is absolutely vital; remarkably enough, only microoganisms seem to be capable of its biosynthesis. The chemical synthesis of vitamin B_{12} was eventually accomplished via two approaches and was the result of a transatlantic collaboration with the late Robert Burns Woodward at Harvard.

The basic aim in a chemical synthesis of a complex biomolecule is to contribute to the understanding of its structure. Thus, the chemical synthesis of vitamin B_{12} led us to chemical studies on the problem of the vitamin's biosynthesis, and our subsequent work became more and more dominated by questions concerning the structural origin of this outwardly complex biomolecule and of the family of porphinoid cofactors as a whole. The outcome of many of the recent experiments encourage us in the belief that the problem of the structural origin of biomolecules fundamental to life is one of the important challenges to chemistry and, in particular, to organic synthesis.

Kenichi Fukui

President Chagas, highly esteemed colleagues, Ladies and Gentlemen, first of all I should like to express my sincere gratitude for being invited to this memorable event, that is the 50th Anniversary of the Pontifical Academy of Sciences, as one of its members. It is my great honour and pleasure to have a chance at this

Plenary Session to talk about a brief summary of my work on the theory of chemical reaction, as one of the new members of the Academy.

My study on chemical reactivity started essentially in 1951, when I wanted to explain the reactivity of non-substituted, condensed aromatic hydrocarbons. These compounds were not suitable material for the then available electronic theory to discuss their behaviour, because these compounds possessed a uniform intramolecular distribution of electronic charge, essentially in terms of which the electronic theory discussed their reactivity. While the electronic theory mainly looked at the density distribution of total assembly of electrons, my theory differentiated only particular electrons or orbitals which were most closely related to the electron delocalization process between reacting molecular species.

The first paper was published in 1952 and soon after that the applicability of my theory was extended to wide varieties of compounds and reactions. In 1964, it was found that the symmetry of these particular orbitals which were then commonly called "frontier orbitals", had some essential relations to the easiness of occurrence of a certain kind of reactions. In this way, the orbital symmetry was connected to the "selection rule" of some chemical reactions. Independent from this result, the orbital symmetry theory was developed more comprehensively by Professor Roald Hoffmann, one of my best friends, who had worked with Professor Robert Woodward.

On the other hand, it was another aim of mine to reform my theory so as to make it more quantitative. In 1970, I defined the "central line" of the chemical reaction pathway as a solution curve of a kind of simultaneous differential equations. It opened a method to enable the calculation of the rate of chemical reaction. In 1981, this method was combined with the "coupled frontier orbital technique", applied between the two reacting molecules, so as to visualize by a computer graphics technique the mode of bond formation and bond breaking along the model reaction path.

I was fortunate since the small idea of the frontier orbital has been developed and used in many directions and by many scientists so far, to whom my deep appreciations are due.

Paul GERMAIN

A l'exception de mes quatre premières publications (2 articles, 2 notes), tous mes travaux portent sur la mécanique théorique classique.

Durant une première période d'une vingtaine d'années (1945-1967), je me suis intéressé à la mécanique des fluides dans la perspective de ses applications à l'aéronautique. Je signalerai trois directions de recherches principales.

1. Un premier axe de recherche concerne *l'aérodynamique linéaire supersonique.*

Un avion supersonique en régime de croisière n'impose à l'écoulement relatif de l'air que des déviations angulaires relativement faibles. Le potentiel des vitesses de l'écoulement relatif de perturbation causé par la présence de l'avion peut alors en première approximation être considéré comme solution d'une équation linéaire qui, si l'on identifie la direction du vent à celle d'un temps, s'identifie à l'équation classique des ondes planes. Mais les problèmes aux limites à résoudre pour déterminer l'écoulement sont différents de ceux rencontrés en acoustique. J'ai développé une théorie créée par Busemann en 1943, dite théorie des écoulements coniques, et par composition intégrale d'écoulements coniques, résolu de nombreux problèmes relatifs aux ailes et aux fuselages. Ces travaux firent l'objet de ma thèse en 1948, qui fut traduite en anglais par le NACA (National Advisory Committee for Aeronautics). Peu après, j'ai créé la théorie des écoulements homogènes, généralisation de la théorie précédente. Tous ces travaux furent effectués à l'Office National d'Etudes et de Recherche Aéronautiques et furent l'objet de nombreuses applications au sein du groupe d'aérodynamique théorique que je dirigeais. Nous savions au début des années cinquante, calculer de nombreuses configurations d'ailes, de fuselages, d'empennages. Nous étions capables de traiter des problèmes d'optimisation.

2. A partir de 1949, je me suis intéressé à *l'étude des écoulements transsoniques*, thème qui a inspiré nombre de mes travaux jusqu'au début des années 60. Un écoulement transsonique est régi par une équation fondamentalement non linéaire de type mixte, c'est-à-dire de type elliptique là où l'écoulement est subsonique, de type hyperbolique là où il est supersonique. Mais exprimé à l'aide

des vitesses — c'est-à-dire dans l'espace de l'hodographe — le potentiel des vitesses est solution d'une équation de type mixte linéaire. Néanmoins, ce type d'équation linéaire n'avait fait l'objet, avant 1940, que d'un mémoire, remarquable il est vrai, dû à Francesco Tricomi (1923), dans lequel se trouvait défini le problème de Tricomi et démontré l'existence de la solution pour l'équation la plus simple — l'équation de Tricomi. J'ai repris l'étude de l'équation de Tricomi, étudié une famille remarquable de solutions, appelées les solutions de Darboux, démontré un théorème du maximum pour le problème de Tricomi. Pour une classe plus générale d'équations, comprenant celle intéressant les écoulements plans, j'ai formé la solution élémentaire, étudié son comportement lorsque le point singulier passe d'une région elliptique à une région hyperbolique, révélé le lien, jusqu'alors caché, entre fonction de Riemann et solution élémentaire de Green. Ces études m'ont permis de décrire le comportement qualitatif de nombreux écoulements transsoniques — en particulier d'introduire le concept de frontière transsonique — et pour certains d'entre eux d'en donner des représentations analytiques globales approchées. Une étude exhaustive des solutions de Darboux m'a permis de préciser le comportement asymptotique autour de points remarquables, par exemple, à l'infini pour un écoulement permanent autour d'un profil à vitesse sonique à l'infini ou encore au point de rencontre d'une onde de choc et d'une ligne sonique.

3. L'onde de choc conçue comme surface de discontinuité est une représentation schématique d'une zone de très faible épaisseur dans laquelle les effets de la viscosité — si faible soit cette dernière — deviennent importants en raison des forts gradients de vitesse présents dans une zone de compression et s'opposent au raidissement indéfini des profils de vitesse et de pression dû aux effets non linéaires de convection. Les lois gouvernant les discontinuités sont connues depuis Hugoniot, la descripton approchée de la structure du choc depuis les années 1920-1930. On s'est rendu compte aux environs de 1960 que ces résultats constituaient les premiers termes de développements asymptotiques et qu'il serait intéressant, notamment dans l'étude des écoulements hypersoniques, de connaître les seconds termes. Un mémoire d'auteurs soviétiques sur le sujet s'est révélé erroné comme l'indiquait un article d'auteurs américains qui proposaient une autre analyse et une autre formule.

Mettant en oeuvre la technique des développements asymptoti-

ques raccordés, j'ai montré que ce dernier résultat n'était pas lui-même correct et j'ai donné non seulement les formules explicites complètes pour les seconds termes — en écoulement permanent ou non — mais la méthode systématique pour obtenir les développements à tout ordre. La méthode s'applique à toute «onde de choc» apparaissant au sein d'un phénomène régi par un système hyperbolique non linéaire.

Fasciné par ce phénomène intrigant qu'est une «solution avec choc» pour un tel système — le concept mathématique malgré de nombreux travaux n'est pas encore complètement clair, ni à fortiori maitrisé — j'ai étudié les ondes de choc en M.H.D. Dans ce cas, 4 mécanismes dissipatifs sont présents, 6 types de chocs sont a priori possibles, compte tenu de l'inégalité fondamentale de la thermodynamique. Mais je suis l'un des premiers à avoir noté l'insuffisance de cette condition. Deux types de choc et deux seulement sont physiquement possibles. J'ai étudié leur structure et j'ai montré comment ces chocs étaient le résultat d'un processus asymptotique, résultat indépendant de la loi gouvernant les 4 mécanismes de dissipation. Ce fût, je crois, la première étude de cette nature pour un phénomène physique prenant en compte autant de mécanismes dissipatifs. Ces résultats ont été repris, généralisés, complétés par de nombreux chercheurs (soviétiques, américains, polonais). J'ai également étudié par la même méthode la structure de l'onde de choc dans un plasma schématisé par un milieu continu à deux fluides — ions et électrons. On met en évidence dans la structure du choc, à l'aval, des oscillations analogues à celles observées expérimentalement, oscillations absentes avec la dissipation schématisée de la M.H.D.

La seconde période de mon activité d'homme de science est certes marquée par un net ralentissement de ma production en termes de nombre de publications — dû à des charges autres que celles inhérentes à la recherche — mais aussi par un approfondissement de mes réflexions sur les concepts de base de la mécanique et de la physique des milieux continus — la physique macroscopique. Pour m'en tenir à l'essentiel, je signalerai ici seulement deux voies dans lesquelles j'estime ma contribution significative et féconde, à en juger par le nombre de chercheurs qui en ont fait leur profit.

1. La représentation mathématique des efforts exercés par un système sur un autre, s'effectue depuis Newton au moyen de vecteurs et de champs de vecteurs — c'est-à-dire par des forces. J'ai

mis à profit la notion de puissance virtuelle, bien connue, depuis d'Alembert et Lagrange, pour proposer une représentation fonctionnelle des efforts comme point de départ des formulations des théories de la mécanique, et de la mécanique des milieux continus très particulièrement. Cette représentation se révèle très utile pour traduire directement les lois universelles sous forme variationelle et pour étudier les milieux complexes comme les milieux micromorphiques — qui comprennent le cas très particulier des cristaux liquides — ou comme les milieux fluides et solides doués de propriétés électromagnétiques.

2. A partir des travaux de Jean-Jacques Moreau, j'ai contribué à l'élaboration et au développement d'une thermodynamique des milieux continus, dite de l'état local associé, généralisant, pour les phénomènes non linéaires, la thermodynamique des processus irréversibles de Donder-Onsager. Les lois de comportement des matériaux s'écrivent à partir de deux potentiels convexes à l'aide de gradients ou, plus généralement, de sous-gradients. Ainsi peut être formulée, par exemple, une théorie des milieux élastoplastiques et viscoplastiques, mathématiquement et physiquement satisfaisante. Cette théorie thermodynamique a largement contribué à faire accéder à un stade vraiment scientifique l'étude des structures en matériaux anélastiques et celle des écoulements de fluides complexes.

Me sera-t-il permis d'ajouter en terminant qu'au cours d'une existence consacrée à l'enseignement et la recherche, j'ai toujours porté une attention très particulière à la signification culturelle et aux implications philosophiques, sociales et politiques du développement scientifique et technique. Depuis vingt-cinq ans, j'ai été personnellement confronté par multiples questions posées par les relations entre la Science et les Pouvoirs. Face à notre avenir, la responsabilité des communautés scientifiques me paraît décisive. Aussi ai-je toujours essayé de favoriser la constitution de communautés scientifiques, leurs réflexions, leur expression. C'est le sens que je donne au service de mon Académie des Sciences comme secrétaire perpétuel. C'est aussi ce qui rend si précieux pour moi l'honneur d'être appelé à participer aux travaux de l'Académie Pontificale des Sciences, honneur qui me comble de reconnaissance envers ceux à qui je le dois et dont j'espère ne pas décevoir la bienveillance.

Stephen William HAWKING

This is my third visit to the Academy. I came in 1975 to receive the Pius XI medal and in 1981 to a study week on cosmology. My research has been in the fields of cosmology, general relativity and particle physics. I have wanted to find out the structure of the universe we live in and the nature of the laws that it obeys.

My research began in 1962, when I came to Cambridge to do a Ph. D. in General Relativity and Cosmology, under the supervision of Dr. D.W. Sarmer. It was about this time that I was first diagnosed as having ALS, or motor neuron disease, a progressive disorder of the nervous system.

The first phase of my research, from 1962 to 1970, was concerned mostly with the question of whether the classical theory of general relativity predicted that there should have been a big bang singularity, a point of infinite density that would have been a beginning of the universe.

Together with Roger Penrose, I developed the global theory of space-time structure and used it to prove that there would have been a big bang singularity in any reasonable model of the universe, if general relativity was correct.

From 1970 to 1974, I worked mainly on the black holes in space that are predicted to form when a massive body, such as a star, collapses under its own gravity. I showed that the area of the event horizon, the outer boundary of the black hole, always increased, very much like the way the entropy of an isolated system always increases. The combined work of Israel, Carter and Robinson and myself, proved the no-hair theorem for black holes, which showed that a black hole must settle down to a stationary state which depends only on the mass of the body and its rate of rotation.

The no-hair theorem implied that a large amount of information about the collapsing body was irretrievably lost when a black hole formed. One could identify this lost information with the entropy of the black hole, which by the area theorem might be expected to be related to the area of the event horizon.

This raised a problem: if black holes have an entropy, they should also have a temperature and should emit thermal radiation, like other hot bodies, but by their very definition, black holes were supposed to be black and did not emit anything, at least in classical theory.

The paradox was resolved when, in 1974, I showed that quantum effects would cause small black holes to emit thermal radiation like other hot bodies, with a temperature that was higher, the smaller the black hole. The black hole would lose mass and would eventually disappear in a tremendous explosion. Unfortunately, there do not seem to be any low mass black holes around that we could observe to test this prediction of the unification of general relativity with quantum theory.

From 1975, I have worked on the Euclidian approach to quantum gravity. This explains the reason for the thermal properties of black holes. It also predicts that in an exponentially expanding universe there should be quantum fluctuations with a thermal spectrum.

It has been suggested that the universe may have had a period of exponential or inflationary expansion in its very early stages. This might explain many of the otherwise unaccounted for features of the universe today, such as the fact that it looks the same in every direction and it is expanding at just the critical rate to avoid collapse.

In such an inflationary expansion, the quantum fluctuations would grow and could lead to the formation of galaxies, stars and eventually of human beings. Thus the structure of the universe could have arisen from quantum fluctuations.

But how did the universe begin? Was there really a big bang singularity as classical general relativity predicts? At the Conference on Cosmology at the Vatican in 1981, I suggested that maybe quantum effects removed the singularity and that the universe was completely self-contained and was finite but without boundary in space or time, like the surface of the earth but with two more dimensions.

Since then I have been working on the consequences of this proposal. At least in simple models, it seems to predict that the universe appears from nothing, without a singularity, expands in an inflationary manner and becomes a universe like the one we observe.

In the time that I have been doing research, we have greatly increased our understanding of the universe and of the laws that govern it. It remains to be seen if there is some ultimate theory and if so, whether we shall find it.

Beatrice Mintz

When I was a graduate student with Professor Emil Witschi, a developmental biologist and endocrinologist at the University of Iowa, I acquired from him certain attitudes that proved to be as important for me as any of the more formal knowledge he conveyed. First was his enormous enthusiasm for science. I ultimately discovered that not all scientists were as devoted to their work and loved it as much as he did, but by then I was incurably infected. We were working at the time on various aspects of amphibian development. I told him that when I would have a laboratory of my own I would want to analyze how mammals develop and to concentrate specifically on mice — the most readily available laboratory species that was closest to man. Very little experimentation on mammalian embryos had been done at that time and Witschi gave me one very important piece of advice. He cautioned, "Don't believe everything you read. If you look directly at the material, it will often turn out to be quite different from what people have said".

Some time went by before I had the possibility to undertake the experiments I wished to carry out, and to appreciate the wisdom of my old professor's comments. In the interim, after completing the Ph. D. degree, I had taken a position on the faculty of the University of Chicago, where I taught biology to the very bright and highly motivated and self-selected undergraduates, many of whom have, gratifyingly, gone on successfully in science. However, the time available for my own research at Chicago was very limited. The opportunity to move to the Institute for Cancer Research in Philadelphia enabled me at last to undertake the program I had in mind.

The prevailing dogma then firmly entrenched in the literature was that mammalian development was highly deterministic, that is, that it was already spatially fixed in a causal relation to embryogenesis from the very outset. If true, one could do little to intervene experimentally in a way that would be revealing. But I questioned the validity of this view, not only because it rested on histochemical observations that appeared partly artifactual on technical grounds, but also because the gradients of specific materials reported in the egg, even if correct, need not be causal to the emergence of differentiation.

The experiment that I undertook on mammalian embryos was

one that I had in fact first envisioned when I was a graduate student years before. At that time, we were reading the classical work on amphibians in which the egg cytoplasm was artificially redistributed or the cells of the early embryo rearranged, as clues to the role of the egg architecture in embryogenesis. I was struck then by the potential power of an alternative approach: one in which genes, rather than the previously used vital dyes, would be the markers to trace the contributions of cells to the developing organism and to elucidate their interactions. The objective was to construct mosaic embryos from two genetically different strains of mice by bringing together embryo cells from the two sources during the early cleavage period. I felt greatly encouraged by Ray Owen's 1945 landmark on spontaneously occurring genetic mosaicism of blood cells in non-identical twin cattle as a result of exchange of blood-forming cells through vascular fusions in shared placental regions. I ultimately worked out simple methods for experimentally producing mosaic (allophenic) embryos. Despite the expectation of traditionalists that these embryos would fail to develop normally or would produce monsters, they gave rise to normal healthy mice, thereby attesting to the flexibility of early mammalian development. I anticipated that the study of allophenic mice would disclose totally unforeseeable phenomena and raise questions that our pre-existing knowledge would not have allowed us to pose. I was not disappointed. I will mention here only two of these surprises.

First, we found that there was an amazing numerology of development. That is, at very early stages long before the specialized cells with which we are familiar could be identified, a fixed number of precursor cells, specific for a given specialization, became committed to that line of differentiation. For example, all of the thousands of pigment cells in the coat of a mouse apparently arise from 34 precursor cells, set aside at least two weeks before recognizable melanocytes are present. Their initial arrangement can be deduced, as can the migration of their mitotic progeny, each of which "remembers" that a pigment-cell-specific unique constellation of genes is to function, even if the gene products are not yet manifest. Similarly, other specialized cell types arise clonally from a small, genetically fixed number of precursor cells in a certain place with a certain characteristic pattern of movement of their mitotic descendants. All the hairs in the coat arise from some 200 committed cells, the neural retina cells from 20 precursor, and so forth.

The next thing that became apparent was far more astonishing, namely that *within* any cell type, there is considerable phenotypic microheterogeneity at the level of cell clones. Quite unlike the conventional picture, the evidence implied that there must be many variant kinds of cells, exemplified by different color variants among the 34 pigment cell clones of the coat pigmentary system. The critical point is that the genes responsible for the phenotype (e.g., color) may even be completely homozygous within an individual and thus structurally identical in all of the cells. Despite this, there can be different "usages" of the gene, or its parts; they are each transcriptionally established in a clonal initiator cell and perpetuated in the progeny cells of that particular clone.

This idea emerged after I had deciphered the clonal histories of some of the kinds of specialized cells in allophenic mice with mutually exclusive genetic markers in the two subpopulations of cells within a tissue. Then, from the allophenic model, I observed similar variants among clones of that tissue in ordinary (single-genotype) homozygous mice. This led me to the view that the structure of genes must be very different from what was thought at that time (in the mid-to-late 1960's, before the discovery, by others, of introns). I thought that perhaps virtually all mammalian genes, far from being the relatively simple structures generally supposed, might consist of a series of subunits that could be transcribed separately, and recombined functionally in different ways, depending partly on the character of the initiating region. I called this "variable reading". As a result, multiple phenotypic possibilities could be realized among cell clones, even without an increase in the number of genes. There would obviously result a much more fine-tuned control of development, of physiological buffering, and of cellular shifts during aging, due to Darwinian selection operating at the cellular level. Moreover, the subunits of a gene could be individually mutated; and translocation could occur, with some subunits changed or missing.

These ideas met with great skepticism at the time and therefore had no real influence on the later discoveries of gene structure made with the new tools of molecular biology, although the discoveries validated many of the points I had predicted (including serial exons and pseudogenes). I suspected, and still do, that we have barely begun to detect all the mechanisms whereby genes may achieve cellular heterogeneity. What evolution has apparently managed to

do is to introduce the means of utilizing existing DNA components in different ways. What is true in this regard in the immune system, enabling heterogeneity to occur, is only one example; many other devices probably exist in other tissues.

In the early-to-mid-1970's, I became increasingly interested in cell differentiation as the normal alternative to proliferation in the mitotic progeny of any stem cell. I viewed the occurrence of malignancy as essentially a developmental anomaly: if the normal balance between proliferation and differentiation were to be shifted toward proliferation, a tumor could result. Malignancy could therefore be regarded as arising in a stem cell exercising primarily the proliferative mode, at any point in the complex developmental hierarchy of stem cells. I proposed that the genes whose function was critically involved in the proliferation-differentiation choice would most likely be "banal" rather than exotic genes — in other words, any of the many genes ordinarily required for proliferation and cell growth. The gene(s) in question might merely be changed in function; or they might actually be mutated, with a resulting change in function.

An opportunity to test this notion presented itself in the form of a mouse teratocarcinoma. These tumors (also found in people) seem to arise from a developmentally very early stem cell as judged from the chaotic array of many kinds of tissues often found in them. I thought that the genetic potential for full normal function might therefore still be intact and might become more appropriately regulated if stem cells of the tumor were placed in the company of their presumed normal counterparts — the developmentally totipotent cells of early normal embryos. This experiment was a kind of modification of our previous constructions of allophenic mice, except that here the stem cells of a tumor were substituted for one of the two genetically distinct input strains of normal embryo cells.

We did indeed obtain long-lived tumor-free animals in which the previously malignant cells now developed completely normally and had the capacity to contribute functional cells to all tissues, including germ cells. This became the first unequivocal example of complete reversal of a malignancy to fully normal development. It contributed a paradigm for possible new cancer treatments based on promoting stem-cell differentiation rather than causing cell destruction. In addition, one of our objectives has been to use the teratocarcinoma stem cells as vectors for changing an animal's

genome through prior genetic manipulation of the stem cells in culture, before they are introduced into embryos.

In closing, a brief word will be added concerning an alternative route to genetic manipulation in mammals. Also in the mid-1970's, before recombinant DNA was available, we decided to investigate the possibility that foreign genetic material might be introduced into early mouse embryos and become integrated into the host genome and replicate with it. This could supply a new tool for the study of gene effects, tumors, and viral influences. We were in fact able to attain integration of purified SV40 viral DNA in this manner.

The jump from amphibians to mammals in research has thus provided me with many fascinating opportunities to enter a field in its infancy and to contribute toward making it experimentally accessible.

Marcos Moshinsky

It is a great honor for me to enter today the distinguished Pontificial Academy of Sciences, possibly the oldest scientific institution of its kind if we consider its relation with the Accademia dei Lincei. To me another motive for satisfaction is to be the second person from Mexico to be admitted to this body, where the first was my teacher and friend Dr. Manuel Sandoval Vallarta.

I understand that it is customary for the new Academicians to give at their first appearance a brief survey of their scientific work and training, which I will proceed to do.

All my education took place in Mexico City, where my undergraduate period at the Universidad Nacional Autónoma de México coincided with the last part of the Second World War. This could have been a rather barren experience due to the low level of teaching and research in Science in my country at the time, as well as to the disruptions caused by the war. Instead it was for me a most fruitful period as on the one hand Professor Vallarta returned to Mexico, and on the other three of the best mathematicians of the time George D. Birkhoff, Norbert Wiener and Solomon Lefschetz were spending several months of each year in Mexico. I was exposed to their teachings while still an undergraduate and it was Lefschetz that encouraged me to continue my studies in Princeton under the direction of Professor Eugene P. Wigner. Thus I spent the years

1946 to 1949 in Princeton which, between the University and the Institute of Advanced Study, directed then by Robert Oppenheimer, was at the time probably the leading center of Theoretical Physics in the world.

On my return to Mexico in 1949 my first line of research concerned a schematic theory of nuclear reactions which allowed a time description of the interaction process, including transient phenomena which I called diffraction in time. The interest in these developments increased in the last few years due to the importance today of many time-dependent phenomena in quantum mechanics.

The above subject, together with work on boundary value problems and some aspects of general relativity kept me busy until the middle fifties, when my interest shifted to problems in nuclear structure, particularly with the help of the then relatively new techniques of Racah algebra. At the time these techniques reduced the matrix elements to radial ones but calculated the latter through the old approach of Slater integrals. As the oscillator potential was the one more appropriate to the nuclear problem I introduced the concept of transformation brackets for two particle harmonic oscillator states, which greatly simplified these calculations and which later was used extensively both in Shell Theory and Hartree Fock calculations of the nucleus. These concepts appeared in a book in collaboration with T.A. Brody entitled "Tables of Transformation Brackets for Nuclear Shell Model Calculations".

The work just mentioned led me to the study of the underlying group theory of many body harmonic oscillator states and their application to nuclear structure in the 2s-1d shell. From that time work in group theoretical methods in mathematical physics has been one of my main interests. This has included discussion of basis for irreducible representations of unitary, orthogonal and symplectic groups; multiplicity problems associated with non-canonical chains of groups; explicit expressions for the Wigner coefficients of some of these groups; matrix representation of the generators of Lie algebras with respect to irreducible representations of the corresponding group, etc. Part of this work was summarized in my books on "Group Theory and the Many Body Problem" and "The Harmonic Oscillator in Modern Physics: From Atoms to Quarks".

Besides the problems mentioned above, in the decade of the sixties I was interested in the structure of few nucleon systems, in the validity of Hartree-Fock and Born-Oppenheimer approxima-

tions through the discussion of exactly solvable problems, and in various aspects of nuclear reaction theory.

One of my main interests since the early seventies concerns the representation in quantum mechanics of canonical transformations. This old problem has acquired new significance, on the one hand because of the many applications of linear canonical transformations, and on the other due to the new problems raised by non bijective canonical transformations such as those that lead to action and angle variables. Questions are raised about the structure of phase space and the way it translates to the quantum picture, which affect our views of the relations between classical and quantum mechanics.

Another of my interests, that started also in the seventies, concerns a group theoretical approach to collective motions in the nuclei. Initially I was concerned with the group theory underlying the Bohr-Mottelson model, but later this interest extended to the Interacting Boson Approximation, and to microscopic nuclear models, among which we were concerned particularly with the symplectic model, i.e., the one based on the symplectic Lie algebra in 6 dimensions sp(6,R). A systematic discussion of our approach was given in a series of papers with the general title of Collectivity and Geometry.

As a final point I would like to indicate our recent interest in problems on the structure of matter in strong certain tubes and see how the equation behaves on the boundary, then you can say if there are bounded solutions and what the structure of the set of bounded solutions is. The applications of this method were the subject of my first research papers.

Then in '61, I was invited by Professor Solomon Lefschetz to R.I.A.S. This was a research institute in Baltimore, United States, which for some years had a very active group, chaired by Professor Lefschetz in differential equations and in what was at that time a new branch of mathematics, the mathematical theory of optimal control. The fact that I spent a year there resulted in my becoming interested in this new mathematical theory and I contributed to the linear problems, to the theory of integration of set-valued functions, and to the existence of optimal solutions when the cost function has more than one component or, in other words, is multivariable. This is connected with the so-called Pareto problem in optimization.

In the last several years, I was involved in the international life

of mathematics by serving for the last eight years on the Executive Committee of the International Mathematical Union. I was responsible for the 1982 International Congress of Mathematicians in Warsaw. The main activity of the Union is holding those congresses every four years and one in 1982 was to be in Warsaw. It so happened that at that time in Poland there were those events which are well-known to you and which made this congress much more difficult to organize, on the one hand, but, on the other hand, the work became also more exciting.

John Charles POLANYI

Mr. President, members and guests, I thank you most sincerely for inviting me to join you. I'm very much in awe of this organization and impressed by it, not least by its incredible stamina. I think by this time even your appetite for new intellectual stimulus must be giving way to appetites that normal human beings share, and so I'll be very brief and say that my interests are in the motions of atoms and molecules in the course of very simple, or the very simplest, chemical reactions.

I came by those interests under the tutelage of my father, Michael Polanyi, and his student Meredith G. Evans, at Manchester University and was inspired to do something about it by discoveries which included prominently those of Professor Porter, who is one of your members, and who in the early 1950's found, together with Drs. Norrish and Thrush, that sometimes chemical reactions can spit out products which have an enormous amount of vibrational excitation in the newly-born molecule. The question was, was this a general thing? If so, it could be very informative.

At that point I turned to the classic volumes on vibrational spectroscopy by Gerhart Herzberg, who is also here, and I got about as far as Chapter 2 where it explains how hydrogen chloride emits infra-red radiation when it is vibrationally excited. It seemed a natural thing to find a chemical reaction that would form vibrationally excited hydrogen chloride, and I explained this to my first graduate student on arriving as a lecturer at the University of Toronto in 1956. This graduate student was a newly-ordained Basilian priest, Father Ken Cashion. Father Cashion was impressed by my knowledge that hydrogen atoms react with the chlorine to

form hydrogen chloride, and he duly set up a piece of equipment in which this took place. He peered in with our one and only departmental infra-red spectrometer and there, out of this cold vessel, was coming radiation which indicated that the molecules inside were at thousands of degrees Kelvin. This vibrational excitation was, we surmised correctly, the residue of a very much larger amount of vibrational excitation that they had when they were newly born. Then, with a number of other students, always at the University of Toronto where I've had my whole career of thirty years, we set about trying to make this into a quantitative tool to find out what is the distribution of newly born molecules — just born in a chemical reaction — over vibrational and rotational states of excitation, and hence translational.

What's missing from the story is why we should bother. Perhaps I hinted at that. It's because, particularly over this period with the advent of high-speed computers, one can infer from the motion in these newly born molecules what sort of forces impelled them into existence. One can arrive at a cinematographic sort of rendition of the secret event of chemical reaction.

I pass on quickly to what we are doing at the moment. We have spent all these decades looking at the molecules rather as one might view a ballet where you can only look in the wings as the dancers come off the stage, and actually also as the dancers prepare to go on stage. It would be awfully nice to get into the theatre and take a look at the ballet, and that's what we're trying to do currently. What we have so far achieved is to give a name to the field, but the field doesn't really exist too much. It would be, if it did exist, a "transition state spectroscopy". This constitutes the probing of the collocation of atoms which endures for subpico second intervals and that is part way between reactants and products.

The other thing that we're engaged in is trying to simplify the reactive event in an odd way, by taking it from the messy arena of gases where things can approach from all directions, to the much simpler two-dimensional world of the surface. That is very recent work in the last months. You know how uncertain results of the last months are, but it does seem very much as if we are able to see chemical reactions at a surface, induced by a pulse of light, in which the molecules are being held in preferred orientations and preferred patterns at the surface. So our problem is very much simplified since the molecules don't quite decide where they will sit; we help decide.

Were there more time, I would love to go on and tie this last adventure in with what Professor Eschenmoser was saying about the origins of the molecules that underlie life. It could be that several billion years ago there needed to be more than just a primaeval soup with a spark going through it. There needed to be a cookbook which gave instructions. Maybe that cookbook was written on the surface of a crystal, or the many crystals that existed billions of years ago and exist today, which provided a template for ordering the molecules prior to their reaction.

We look forward with joy to living a little longer and exploring these possibilities.

Vladimir Prelog

Because of the advanced time, I must make my exposé brief. I am an organic chemist who has spent most of his life working in the area of natural compounds and related topics. I started my scientific work about sixty years ago in the autumn of 1926. Now I am the second generation of natural product chemists from Zurich who became a member of this Academy. The first was my predecessor on the chair in Zurich, Leopold Ruzicka, and the third generation, my successor Albert Eschenmoser, reported about his work this morning.

Why natural products? I believe that all natural products carry a message or function and it is an important task for chemists and biologists to find out what these messages mean and what these functions are. To achieve this, we must know their structure, and therefore I spent most of my life learning about structures of organic compounds, particularly natural products.

I am a born Croatian, from the northern part of Yugoslavia, but I learned my chemistry in Prague, Czechoslovakia. My first academic position was at the University of Zagreb in my native country. I left Zagreb and Yugoslavia in 1941 and emigrated to Zurich, Switzerland, where I found a working place at the Federal Institute of Technology (ETH). Zurich was at that time the Mecca of chemistry of natural organic compounds. Not only my predecessor at the ETH, Leopold Ruzicka (Nobel Prize in Chemistry 1939), but also Paul Karrer (Nobel Prize in Chemistry 1937) at the University of Zurich were protagonists in this field. Ruzicka had

already several predecessors who made important contributions to natural product chemistry; among them Hermann Staudinger (Nobel Prize in Chemistry 1953) and Richard Kuhn (Nobel Prize in Chemistry 1938).

To continue with this great tradition and with my own predilections I worked on alkaloids and succeeded in determining by chemical methods, partly or completely, structures of classical, well known alkaloids such as quinine, strychnine, or less known Solanum-, Vetrarum- and Erythrina-alkaloids.

After 1950 the style of organic chemistry and the methods of structure determination of organic compounds changed dramatically. Physical methods replaced the chemical ones. This change can be compared to the introduction of firearms into the art of war. Before this change, much empirical knowledge of the chemical behaviour of compounds and a little of the touch of a poet were necessary. By introduction of all kinds of molecular spectroscopy and X-ray structural analysis the chemical methods became partly obsolete and the structure elucidation became gradually almost routine. Thus several prominent organic chemists abandoned the field altogether. We continued to work on natural products and profited by new methods, which allowed us to determine the structures more quickly and less ambiguously, but we changed the source of our raw material. After the discovery of penicillin, during the Second World War, microorganisms became a favourite source of natural organic compounds. Instead of working on compounds from plants and animals as before, we investigated intensively the fascinating variety of compounds from microorganisms. Some of them such as rifamycins (investigated in cooperation with the Italian firm Lepetit) or desferrioxamines play today a notable role in human medicine.

I think that organic chemistry will continue to work in this direction. By improvement of methods, novel natural compounds with bizarre structures and new properties will be discovered.

When I started to work sixty years ago, about 400,000 compounds were known. Today about 8,000,000 are registered and 400,000 are added every year. It is a privilege to be as old as I am, and not to have to cope with the problem of this overwhelming multitude, a problem the next generation of chemists will have to come to terms with.

Carlo RUBBIA

I am very honoured to be part of such a distinguished group of people and to be called to contribute to the important tasks of the Academy.

Most of my scientific work has been carried out in a rather unusual international environment which is the European Organization for Nuclear Research in Geneva. This is a truly unique organization, supported jointly by fourteen European member States and where scientists from all over the world can carry out cooperative endeavours without discriminations coming from nationalities, race or political system.

My field is Elementary Particle Physics, namely the study of Nature at the level of its smallest constituents. The definition of "smallest components" has changed of course with time and as a consequence of the improvements of the instruments in use. Today, we can discern distances and explore objects which have characteristic sizes of the order of 10^{-17} centimeters. In order to achieve such a sensitivity we must have in the centre of mass of the particles which — so to say — are exploring each other, energies of the order of the Tera-electron Volt, or 10^{12} electron Volts, which is equivalent to the kinetic energy that an elementary particle of unit charge would acquire under the global effect of applying in succession one million times one million volts of accelerating voltage.

This kind of experiment can be carried out only using colliding beams of particles, consisting of two counter-rotating race tracks in which two opposite beams of particles are circulating for many hours, even days, and which are made to cross in a few chosen points around the circumference where collisions can be observed. The exploration of the behaviour of the particles at small distances relies on the purely random event of a close "encounter". The probability of such event is extremely small. For instance, with two beams of N particles each and a beam size or cross sectional area a, the frequency of occurrence of (accidental) minimum distance of approaches $\leqslant r$ is given by the formula $R = fN^2a/(\pi r^2)$, where f is the revolution frequency of the particles in the ring. The enormously small value of the ratio $a/(\pi r^2) \approx 10^{-34}$ corresponding to "realistic" experiments, requires very intense particle beams, very many non-destructive crossings and tiny beam sizes.

Particularly interesting is the possibility of using a pair of

particle-antiparticle beams which counter rotate sharing a common race track. Since particles and antiparticles have equal masses and opposite charges, they can circulate in opposite directions inside a single magnetic guide structure.

Two different types of these devices have been realized, that operate with (1) protons and antiprotons or (2) electrons and positrons. I have chosen to work with proton-antiproton collisions. Although they are perfectly stable, neither antiprotons nor positrons exist in appreciable quantities in nature, since in contact with their anti-particle they annihilate immediately. Therefore they have to be created or — as Paul Dirac used to say — they have to be "pulled out of the vacuum". In other words they have to be made out of energy. The first task is then the one of producing a sufficient amount of antimatter — so to say, the main "tool" — directly out of energy. After production, these beams must be made as dense as possible, accelerated to the highest possible energy and stored in a magnetic guide ring where they are made to cross the beam of their anti-particles, i.e., ordinary matter.

These experiments have provided a very large amount of scientific information on the actual nature of the smallest constituents of matter. Presently we believe that they are so-called quarks and leptons. There are a number of varieties of quarks and of leptons. For instance the ordinary electron is a lepton; the proton instead is composite and made initially out of three quarks. Elementary particles, quarks and leptons, are generally electrically charged, with the exception of the so-called neutrinos, which are electrically neutral. In addition, quarks carry another attribute, besides charge, which is called colour and which comes in three different varieties.

The exploration of Nature at the smallest inter-particle distances has also permitted to understand better the mechanisms behind the elementary forces which act between them. As you certainly know, in Nature there are a number of different kinds of fundamental forces. Two of these types of forces exhibit long distance effects, gravitation and electromagnetism. Therefore they can be observed at large distances, they have the so-called classical limit which allowed us to derive many of their features without the need of near collisions.

On the contrary, the two other basic forces in Nature — namely the so-called Weak Interactions and Strong Interactions —

can be observed only at very small distances. For instance, we know today that Weak Interactions start acting only at distances of less than 10^{-16} centimetres. Strong Interactiones become significant only below 10^{-13} centimetres. One can easily see that, as a consequence, even to detect the presence of these last two forces one has to approach elementary particles at very small distances. At small distances, forces no longer excercise simple mechanical effects, they can be also responsible for particle transformations and reactions.

Particularly important is the area of the Weak Interactions, which are responsible, for instance, for the well known radioactive effects. Back in 1934 Fermi gave a phenomenological description neglecting the effects of its intimate structure which has for a long time escaped detection. We know now that Weak Interactions are mediated by other particles called Intermediate Vector Bosons, just like the photon is mediator of the electromagnetism. However these new particle quanta are much more massive and two of the three are charged. We also know — and this is extremely important — that these new particles, the mediators of the weak forces, and the photon, share a lot of properties in common. Indeed we believe in a description which succeeds in unifying the two different types of forces by generalization of the electromagnetism which may comprehend them both.

Strong interactions are also of very great interest. Strong interactions are responsible for the strong forces which bind together nuclei. For many years, people believed that to harness the mechanism behind the nuclear forces would have been an impossible task, that we would never be able to understand for instance how a proton is materializing out of quarks and how a nucleus is holding so many nucleons together. Mainly thanks to the colliding beam experiments, we now believe that we have finally started to perceive this mystery as well. We know, for instance, that quarks are carrying, in addition to charge, another quantum number called colour, in a sense the equivalent to the electric charge when it comes to strong forces. At very small distances, the interactions between quarks can be predicted theoretically with significant accuracy. Also these forces — like electromagnetic interactions — are mediated by a number of massless vector particles, called gluons. We have started to produce directly these gluons with our machines.

Today a fundamental experiment consists in probing the

effective force acting between quarks by bringing them into collision, in essence to map the strength of the interaction as a function of the distance. A significant result is for instance the fact that at the very small distances (10^{-14} to 10^{-15} centimetres) the strong forces between two quarks due to the color show something like the well known, classic $1/R^2$ law characteristic of gravity and of electromagnetism.

Of course the primary goal of these research programmes is basic knowledge. Recently however a growing number of applications of modern accelerators have begun to appear. One can briefly mention for instance the utilization of syncrotron light and more in particular the one of the so-called Free Electron Laser, where the stringent demand in beam quality for colliding beams has permitted the development of new devices based on a relatively old idea. The Free Electron Laser can greatly extend the performance of ordinary Laser, in terms of frequencies, power and efficiency. Likewise the development of superconducting magnets, used to guide particle beams and to deflect them in the detection devices is now widely used in Medicine for NMR applications. Finally new particle detectors have ever-growing applications in Industry and Medicine.

Kai Siegbahn

Much of our knowledge of the internal structure and properties of matter is based on spectroscopic investigations. This concerns not only matter on Earth but also matter in our Solar system, the Galaxies and the Universe as a whole. By means of spectroscopy in various forms we can get into a rather direct contact with the atoms. Their properties determine in principle the behaviour of matter and thereby at the same time all processes which are of importance for our life. The connections between our life and the finest details of the atoms are in fact so strong that it is indeed claimed that it is possible to calculate fairly precise values of entities which characterize elementary particles like the charge of the electron from the mere fact that we exist as human beings. If our Lord had decided another slightly changed value of, for example, the electric charge to mass ratio of the electron, that we with great accuracy have been able to measure in the laboratory, we and the other biological life could not have existed. In addition to this, the temperature and all other

circumstances are so wisely chosen that the atoms have at their disposal a sufficiently wide spectrum to expose their finest details in order to generate the actual complex biological life situation. In this connection the determining factors are combined with the generally valid natural law that Physics has discovered in the form of Quantum Mechanics.

For spectroscopy it is in particular the binding between the electrons and the atomic nucleus which is important, but also the interaction between the electrons themselves and with the neighbouring atoms. When electrons are making small quantum jumps between different possible modes, radiation is being emitted. This circumstance has for long been the base for the ordinary photon spectroscopy. There is another possible approach to this which is much more recent and in many ways complementary to the just mentioned photon spectroscopy, namely electron spectroscopy.

In this spectroscopy one tries to expel the atomic electrons from their atomic and molecular bonds in a precise and well defined way by X-radiation or UV radiation and then to measure the kinetic energies of these expelled electrons. In this way one can deduce their original atomic bindings. In such an electron spectroscopy one has to be very careful to make sure that the energies of the liberated electrons really are the true ones and not disturbed by processes which could affect the electrons on their way out from the piece of matter under study. The electrons could then easily lose the memory of the speed they had when they left their inner atomic sites. The original information of the conditions inside the atoms would then get lost and the electron spectrum worthless. Furthermore, a number of other factors have to be under absolute control in order to reach such a high resolution in the spectra that they reflect correctly the sharpness of the atomic levels and their precise energies.

I started my work like many physicists of my generation in the field of nuclear physics. I was interested in the radiation which was emitted from the nuclei when they decayed by emission of radioactive radiation. The early part of my production therefore concerned nuclear spectroscopy in the form of α-, β- and γ-ray spectroscopy of radioactive nuclei. From this spectroscopy one could draw conclusions about the shell structure and symmetry properties of nuclei which provided the experimental material for the advancement of models of the constitution and behaviour of atomic nuclei.

This activity was summarized in a book with the title "α-, β- and γ-ray Spectroscopy". With this background and with the experience I had obtained, I started to develop electron spectroscopy for atoms, molecules and condensed matter. We found that this spectroscopy indeed turned out to be a surface spectroscopy when applied to solid materials. The spectroscopic information was related to the properties of the last few outer atomic layers of the surface. We also found that our electron spectra at sufficiently high resolution were very sensitive to the chemical properties of the surface. We called the spectroscopy we thus developed ESCA (Electron Spectroscopy for Chemical Analysis). It furthermore turned out that the electron spectra gave information on elemental composition solid state band structure, valence states, etc. This work gradually developed in different directions in physics and chemistry with applications in industrial technology, in particular related to surface technology. Together with my coworkers we described our development of Electron Spectroscopy in two books in 1967 and 1969. This spectroscopy can be applied to all states of aggregation of matter and yields information on atomic and molecular orbitals in chemical compounds in gases, solids and, more recently, also in liquids and solutions. From a technological point of view its high surface sensitivity, much less than a single atomic layer, is being utilized in fields like corrosion, surface reactions, catalysis, polymers and solid state electronics. New available radiation sources, in particular the synchrotron radiation, have turned out to give further impacts in recent developments of the field. The future looks promising for further extensions. For example, by new radiation sources one can penetrate deeper into the sample to reach interfaces between different atomic layers which are encountered in present day electronics and in this way determine the electric potential distribution in semiconductors. Other fields just now under development are the study of higher molecular and surface states and of free molecular radicals excited by laser radiation.

Maxine Singer

I don't know how it is in other parts of the world, but in the United States many students in biology currently seem to think that the DNA molecule and all of the biological principles that flow

from it, have been known forever and were learned without any degree of effort or work. I am sorry that they do not realize the excitement and the cleverness and intelligence that my colleagues have brought to this endeavour. I suppose it's a description of the nature of that work that some of the students seem to think that it's all so simple and was learned so easily.

In the late 1940s and early 50s when I was an undergraduate, I thought that I wanted to be a chemist. But it was during that time that the first of these principles was established when Avery and then Hershey and Chase learned that genes and genomes, the whole informational systems that encode the competencies of living things, actually reside in DNA. While I was only very vaguely aware of this notion at the time, I did for some reason take the first step toward becoming a biologist by doing my graduate studies in biochemistry under Joseph Fruton at Yale.

While I was a graduate student and busy with enzymology and phosphoproteins, the second really gigantic step of modern biology was taken. Watson and Crick proposed a double helical, base-paired structure for DNA. After that there was no way to avoid the challenges, the intellectual and experimental challenges, that that macromolecule and its close relative RNA presented to all of us.

So upon completing the Ph. D. degree, I entered the world of nucleic acids by becoming a postdoctoral fellow with Leon Heppel at the National Institute of Health in Bethesda, Maryland, where I have worked ever since. That year was 1956 and the world of nucleic acid chemists was then a very small world with only a few laboratories scattered about the globe. For me it was the beginning of thirty years of unflagging scientific excitement and also the start of association with a group of people that have become my most cherished colleagues and friends, with some of whom I'm very happy to share this day.

These days, when in a year's time thousands of people attend tens of meetings on nucleic acids every year, it is amusing to remember that in the late fifties, the nucleic acid group was given, and given grudgingly, only one morning by those such as Chris Anfinsen, who ran the week-long Gordon Conference on proteins. They gave us Friday morning to talk about nucleic acids. The central contribution of the mid-Fifties to the progress of nucleic acid biochemistry was, I think, the recognition that chemistry was

really not going to be of very great help in the future and that we would have to depend on enzymes to give us the specificity and versatility that were needed to deal with these very complex but on the other hand very simple and redundant molecules.

My own work in those years had to do with the mechanism of the biosynthesis of RNA molecules by the enzyme polynucleotide phosphorylase. By 1960 I had learned to make a variety of polymers and for that reason when the third major principle of modern biology was established, I was able to be a participant and not just a distant admirer. So along with various other NIH scientists, I put aside my own experiments, to assist our colleague, Marshall Nirenberg, in his efforts to establish the nature of the genetic code. My own contribution was to prepare RNA molecules of different structures and we thought at that time that that was really high-tech work. From the current vantage point it seems almost trivial, even embarrassing to mention having done this.

My interest in the mechanism of polymerization and depolymerization reactions continued through the 1960's and along with my first postdoctoral fellows, I was able to demonstrate that the enzymatic synthesis of long polymers and indeed their degradation as well, could occur by what we call the processive mechanism. That is to say, for synthesis, that after joining the first two residues in a polymer, many enzymes simply continue to add units onto that same initial chain rather than releasing it and beginning a new chain again. Very early in the reaction, then, one sees very long polymers, rather than having all the polymers grow simultaneousy in an orderly fashion in the course of the reaction. It's now known that many enzymes that work on nucleic acids, both synthetic and degradative enzymes, work by processive mechanisms.

The mechanistic work on polynucleotide phosphorylase and on bacterial ribonucleases was rewarding through those years. Moreover, my frustration grew as one approach after another failed to define the functional role of those enzymes in the bacteria from which they were isolated. I felt very much that it was time to shift gears. I initiated that change with a sabbatical year at the Weizmann Institute of Science, where I worked in the laboratory of Ernest Winocour and spent the time learning about mammalian cells and about viruses whose genomes are DNA.

When I returned to the NIH, I spent a few years trying out various ideas and systems. The time coincided with the era of the

emergence of what we call recombinant DNA techniques, or genetic engineering. As the extraordinary capacity of those techniques to deal with previously intractable problems became clear, it seemed foolish, if not impossible, to resist their seduction, especially because those techniques appeared to be applicable to what I thought was a particularly interesting puzzle, a puzzle that was important enough to have been given (not by me) the name "C-value paradox".

It's a paradox that's actually simple to describe. The average size of most genes is about twelve hundred base pairs of DNA which encode 400 amino acids. In a simple bacterium like *E. coli*, which we estimate to have about 4,000 genes, you would then predict that there would be something of the order of five million base pairs, which in fact is the size of the *E. coli* genome. Most people think it would take about one hundred thousand genes to encode a complex multicellular organism and so by that simple calculation, it should take about 1×10^8 base pairs to make a complex multicellular organism. But in fact, mammals and plants, and many other complex organisms, have ten or a hundred times as much DNA in their genomes and therein is the paradox. What is all the extra DNA for?

In the last years we have learnt that a good deal of it resides in introns, that is non-informational regions of DNA that interrupt the informational parts of genes. About 20 years ago there were the first hints that a large portion of that extra DNA, also probably not informational in the classical genetic sense, exists in sequences of DNA that are repeated many times. It's as if I were simply to stand here and repeat the same sentence over and over again. You would quickly conclude that it was not informational. But such sequences exist in genomes, not only in tandem repeats, but also scattered throughout the genome.

We have been studying two different kinds of such sequences. Most recently the experiments that deal with a scattered or interspersed repeated sequence family have proved to be the most interesting and the most fruitful line for us. These particular sequences are called lines. They can be as long as 6,000 base pairs and occur as many as 50,000 or 100,000 times, spread in the genomes of all mammals. Work on their structures has recently suggested that one or a few members of this family may in fact be functional genes and even suggests what those functional genes

might be. Further, the data suggest certain models for why there might be so many copies of this sequence. In particular, the data suggest that the few functional genes that may be included in this line family might encode a reverse transcriptase, an enzyme that can copy an RNA molecule and make DNA from it. Reverse transcriptases are generally believed to be associated only with certain kinds of viruses. The import of this notion, which is not yet proven, is of many different kinds. One of the most interesting is that it provides a fruitful way to think about where a lot of DNA has come from in evolution: by reinsertion of DNA sequences that were copied from RNA molecules and inserted back into genomes. This new work is leading us in many new and interesting directions and I look forward in the future to being able to tell you about the results of those experiments.

Walter Thirring

I feel greatly honoured to speak about my work here at this Academy which has for its purpose the promotion of peace and I'm very sorry to say that modest efforts which I made in this direction were all failures as far as I could see and I somewhat cherish the hope that through this Academy maybe my activities in this direction may become more effective.

Now in my scientific work I was very fortunate because after my Ph. D. in Vienna in '49, I enjoyed some close or more sporadic scientific contact with the great old gentlemen in my field, namely with Schrödinger, Heisenberg, with Pauli and Einstein. They inspired me to go into a field where something new can be discovered, which was elementary particle physics at that time, and indeed it turned out that this field was much richer than was thought originally. When I started there were only two mesons, the pion and the muon, and now there are hundreds of particles.

However, this development also entailed that the technical effort which goes into it and also the time scale of the experiments became larger and larger and now one has to work for many years until the results of experiments become known, and therefore the position of theoretical physicists is somewhat difficult. What do you do in the meantime when you are waiting for years? So some of them just pushed ahead without hesitation and they are now

thinking about what happens at distances of 10^{-33} centimetres, whereas we learned from Rubbia that experimentally we are now at 10^{-17} centimetres.

Now, I personally don't have too much hope that within my lifetime we will know what happens at 10^{-33} centimetres, so in the meantime I turned to some other fields called mathematical physics, and the philosophy is the following: some people think that in physics once the laws are known, physics is over, but I think that's a misunderstanding. I think this is just the starting point of physics. The previous attitude is like learning English and you think you know English once you know the grammar and some words and you never go on to read Shakespeare. I think the main problem is then just to find what are the consequences of the equations and what are the right notions, what is the right way of looking at the situation. Since time is running short for me, I think I will just illustrate this by one example. I hope perhaps at another time I may get another chance to expound my work. It is a problem on which I worked for a long time with Elliott Lieb, that is, the question of stability of matter. Matter means the matter around us which is composed of electrons and nuclei which attract each other with the electrostatic force. So this is something which one thinks one knows very well. Everything should be in the Schrödinger equation. But what are the right questions to ask?

Now stability means in technical terms that energy is an extensive quantity, or more naively, there's a maximal chemically binding energy particle, or in everyday life, that the energy which is contained in two litres of gasoline is just twice the energy of one litre of gasoline. These things seem to us quite obvious; however, it is not easy at all to find this out from the fundamental laws, namely just looking at the Schrödinger equation. In fact it turns out that generally it is wrong. There are some very specific properties of matter which come in for this to be true. In particular, what one has to have is the particles of one sign of charge, like the electrons they have all to obey Fermi statistics. If this were different, then matter would not be stable in this sense. In fact it would collapse to a highly condensed phase of very high energy. So if the Lord had decided, in the words of Siegbahn, to make the electron heavier than the pion and so the lightest charged particle would be a boson, there would not only be no life on earth but in fact there would be no earth at all in the form we know it today.

Now, why is this called stability of matter? In fact it is a stability against implosion, it is not quite the stability we think about, namely stability against explosion or stability in the thermodynamic sense that specific heats are positive and that the compressibilities are positive. It is an interesting fact that these properties are related among each other by a mathematical theorem in the sense that two of these properties imply the third; and indeed the stability in the sense I described just now also implies that thermodynamics works in the way we are used to it.

PRÉSENTATION DES ACADÉMIES ET INSTITUTIONS CULTURELLES

Au début de l'après-midi, ont été accueillis dans l'Aula Magna les Représentants des Académies des Sciences et des Institutions Culturelles venus de toutes les parties du monde à l'occasion du Cinquantenaire de l'Académie.

Parmi les autres invités étaient présents MM.: M. Baker (International Council of Scientific Unions - France), V. Canuto (NASA - National Aeronautics and Space Administration - États Unis), P. Lazar (INSERM - Institut National de la Santé et de la Recherche Médicale - France), J.M. Lehn (Université Louis Pasteur - France), F. Mayor (Universidad Autónoma de Madrid - Espagne), C. Mérieux (Fondation Mérieux - France), A. Sackler (Foundation for Arts and Sciences - États Unis), G. Nemethy (Cornell University - États Unis), H. Uznanski (National Science Foundation - États Unis), R.J. White (Cleveland Metropolitan General Hospital - États Unis).

Le début des célébrations a été retardé pour permettre aux personnes présentes de suivre, grâce a un écran géant, les images provenant, en liaison télévisée directe, de la ville d'Assise où Sa Sainteté Jean Paul II présidait une exceptionnelle réunion des Représentants des religions mondiales, invités par le Saint Père dans la ville natale de Saint François pour une Prière universelle de paix.

Désireux de témoigner leur propre adhésion à la réunion d'Assise, les Académiciens Pontificaux présents ont décidé sur-le-champ d'envoyer un télégramme au Souverain Pontife:

«The Members of the Pontifical Academy of Sciences, gathered in the Casina Pio IV on the occasion of the Fiftieth Anniversary of the Restoration of Your Academy, join in meditation this grand initiative for peace taking place in Assisi and reaffirm their pledge that Science and Research be placed at the exclusive service of peace and the progress of Humanity».

De leur côté, les Délégués des autres Académies des Sciences ont approuvé l'envoi de ce message:

"The Presidents and Delegates of the various Academies of Sciences gathered in the Vatican on the occasion of the 50th Anniversary of the restoration of the Pontifical Academy of Sciences wish to express to Your Holiness their most sincere appreciation for the historic initiative which You have promoted in Assisi. They share Your aspiration to a real and lasting peace, and they wish to affirm their belief in the peaceful use of Science as one of the means to achieve it".

Ensuite le Président invite les représentants des Académies à présenter les salutations selon l'ordre de date de fondation de l'Institution.

ACCADEMIA NAZIONALE DEI LINCEI
Italie
Fondée en 1603
Représentée par F. Gabrieli

DEUTSCHE AKADEMIE DER NATURFORSCHER LEOPOLDINA
République Démocratique Allemande
Fondée en 1662
Représentée par H. Bethge

THE ROYAL SOCIETY
Royaume-Uni
Fondée en 1662
Représentée par G. Porter

ACADÉMIE DES SCIENCES
France
Fondée en 1666
Représentée par A. Blanc-Lapierre

AKADEMIE DER WISSENSCHAFTEN DER DDR
République Démocratique Allemande
Fondée en 1700
Représentée par W. Scheler

REAL ACADEMIA DE CIENCIAS EXACTAS,
FÍSICAS Y NATURALES
Espagne
Fondée en 1713
Représentée par A. Martin-Municio

ACADEMIA NAUK SSSR
Union des Républiques Socialistes Soviétiques
Fondée en 1724
Représentée par V.A. Kirilin

KUNGL. VETENSKAPSAKADEMIEN
Suède
Fondée en 1739
Représentée par C.G. Bernhard

BAYERISCHE AKADEMIE DER WISSENSCHAFTEN
République Fédérale Allemande
Fondée en 1759
Représentée par A. Schluter

ACADÉMIE ROYALE DES SCIENCES, DES LETTRES
ET DES BEAUX-ARTS DE BELGIQUE
Belgique
Fondée en 1769
Représentée par H. Chantrenne

KONINKLIJKE ACADEMIE VOOR WETENSCHAPPEN,
LETTEREN EN SCHONE KUNSTEN VAN BELGIE
Belgique
Fondée en 1769
Représentée par G. Smets

ACADEMIA DAS CIÊNCIAS DE LISBOA
Portugal
Fondée en 1779
Représentée par M.J. Nunes

ACCADEMIA NAZIONALE DELLE SCIENZE
DETTA DEI XL
Italie
Fondée en 1782
Représentée par A. Ballio

ROYAL IRISH ACADEMY
République d'Irlande
Fondée en 1785
Représentée par J.O. Scanlan

KONINKLIJKE NEDERLANDSE AKADEMIE VAN WETENSCHAPPEN
Hollande
Fondée en 1808
Représentée par D. de Wied

MAGYAR TUDOMANYOS AKADEMIA
Hongrie
Fondée en 1825
Représentée par I.T. Berend

AUSTRALIAN ACADEMY OF SCIENCE
Australie
Fondée en 1854
Représentée par A.J. Birch

DET NORSKE VIDENSKAPS-AKADEMI
Norvège
Fondée en 1857
Représentée par O. Johansen

NATIONAL ACADEMY OF SCIENCES
États-Unis
Fondée en 1863
Représentée par A. Rosenblith

BULGARIAN ACADEMY OF SCIENCES
Bulgarie
Fondée en 1869
Représentée par A. Balewski

POLSKIEJ AKADEMII NAUK
Pologne
Fondée en 1872
Représentée par J.K. Kostrzewski

ACADEMIA NACIONAL DE CIENCIAS EXACTAS FÍSICAS Y NATURALES
Argentine
Fondée en 1873
Représentée par G.B. Marini-Bettolo

NIPPON GAKUSHIIN
Japon
Fondée en 1879
Représentée par K. Fukui

ACADEMIA BRASILEIRA DE CIÊNCIAS
Brésil
Fondée en 1884
Représentée par C. Pavan

JUGOSLAVENSKA AKADEMIJA ZNANOSTI EI UMJETNOSTI
Yougoslavie
Fondée en 1886
Représentée par J. Sirotkovic

HEIDELBERG AKADEMIE DER WISSENSCHAFTEN
République Fédérale Allemande
Fondée en 1909
Représentée par H. Mosler

ACADEMIA NACIONAL DE CIENCIAS
Mexique
Fondée en 1916
Représentée par M. Moshinsky

ACADEMIA DE CIENCIAS FÍSICAS, MATEMÁTICAS Y NATURALES
Vénézuela
Fondée en 1917
Représentée par L. Wannoni-Lander

AKADIMIA ATHINON
Grèce
Fondée en 1926
Représentée par C. Bonis

THE ISRAEL ACADEMY OF SCIENCES AND HUMANITIES
Israel
Fondée en 1959
Représentée par J. Jortner

CENTRE SCIENTIFIQUE DE MONACO
Principauté de Monaco
Fondé en 1960
Représenté par C.C. Solamito

ACADEMIA CHILENA DE CIENCIAS
Chili
Fondée en 1964
Représentée par L. Vargas-Fernández

INSTITUT NATIONAL DE RECHERCHE SCIENTIFIQUE ET TECHNIQUE
Tunisie
Fondé en 1969
Représenté par N. Ariguib

ACADEMY OF SCIENTIFIC RESEARCH AND TECHNOLOGY
Egypte
Fondée en 1971
Représentée par M. Badran

NATIONAL ACADEMY OF SCIENCES OF SRI LANKA
Sri-Lanka
Fondée en 1976
Représentée par J. Samarasekera

ACADEMIA DE CIENCIAS DE AMÉRICA LATINA
Vénézuéla
Fondée en 1984
Représentée par R. Villegas

Etaient également représentées les Institutions Culturelles suivantes:

INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS (ICSU)
Représenté par L. Ernster

OFFICE OF SCIENCE AND TECHNOLOGY POLICY - EXECUTIVE OFFICE OF THE PRESIDENT OF THE UNITED STATES OF AMERICA
Représenté par Mme D. Wince

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCES (A.A.A.S.)
Représentée par Mme S.E. Widnall

UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION (U.N.E.S.C.O.)
Représentée par A.M. M'Bow

Nombreux les objets, les parchemins, les médailles commémoratives présentés à l'Académie, parmi lesquels une remarquable sculpture en bronze donnée par le Prof. Jean-François Lemaire et représentant le Souverain Pontife Pie XI, fondateur de l'Académie Pontificale des Sciences.

Alors, le Président a remis à chacun des invités la Médaille frappée à l'occasion du Cinquantenaire, dessinée et gravée par le sculpteur Guido Veroi; la médaille porte sur le revers une vue de la Casina Pie IV, l'inscription «Pontificia Academia Scientiarum», les dates 1936-1986 et les noms des Souverains Pontifes Pie XI et Jean Paul II.

Sur le revers de la médaille est gravée la maxime des Premiers Lincei, «Sapientia Cupidi» et un groupe allégorique dans lequel apparaît la Science ainsi qu'une série de symboles représentant les succès réalisés dans les différents domaines au cours des cinquante dernières années: l'exploration de l'espace, l'équation de Schrödinger, la comète de Halley, l'antenne parabolique de Marconi, la double spirale du D.N.A., l'orbite et la formule des astéroïdes.

Vingt-trois Académies étrangères ont remis des messages écrits.

DEUTSCHE AKADEMIE DER NATURFORSCHER LEOPOLDINA (RÉPUBLIQUE DÉMOCRATIQUE ALLEMANDE)

Die
Deutsche Akademie der Naturforscher Leopoldina
übermittelt der
Pontificia Academia Scientiarum
anläßlich der Feier
ihres 50jährigen Bestehens
herzliche Glückwünsche

Es ist mir ein willkommener Anlaß, der viel weiter zurückliegenden Vorgeschichte beider Akademien zu gedenken, reichen doch ideelle Gemeinsamkeiten bis in die Zeit des Aufbruchs der neuzeitlichen Wissenschaften, als dessen Folge sich die Welt heute mit naturwissenschaftlicher Großforschung konfrontiert sieht, die den Weg der Menschheit entscheidend geprägt hat und ihr Schicksal mitbestimmen wird. Es kennzeichnet das Ansehen der modernen Naturwissenschaft, daß die Päpstliche Akademie der Wissenschaften in jener Akademie ihren Vorläufer sieht, in welcher der achtzehnjährige Herzog Federigo Cesi im Jahre 1603 hervorragende Naturwissenschaftler seiner Zeit, darunter Galileo Galilei, Franciscus Stelluti und Giovanni Battista della Porta, versammelte, um dem scholastischen Denken die Freiheit des Geistes, die Liebe zur Wahrheit und die Anerkennung des Unbekannten entgegenzusetzen und als die wahren Quellen menschlichen Wissens die durch Vernunft und Beobachtung erforschte Wirklichkeit der Natur anzuerkennen. Diese «Accademia dei Lincei» ist zu Recht als erste naturwissenschaftliche Akademie der modernen Welt anzusehen.

Unter dem Namen der scharfsichtigen Luchse benutzten Cesi und seine Gefährten zum Beispiel als erste das neuentdeckte Mi-

kroskop mit echter wissenschaftlicher Fragesrellung, um tiefer in die Geheimnisse der Natur einzudringen, zu einer Zeit, als noch das allgemeine Vorurteil herrschte, die Bedeutung eines Gegenstandes für die philosophische Welterkenntnis sei proportional zu seiner Größe. So mag symbolisch für das neue Wissenschaftsverständnis der «Luchsgenossen» stehen, daß gerade heute wieder ein Nobelpreis für das weitere Eindringen in die submikroskopischen Strukturen durch die Erfindung des Elektronenmikroskopes vergeben wurde.

Eben diese erste «Accademia dei Lincei» war aber auch eine der wichtigsten Anregungen für den Scheinfurter Stadtphysikus Johann Lorenz Bausch, in seiner Heimatstadt im Jahre 1652 eine freie Gelehrtenvereinigung, die heutige Leopoldina, ins Leben zu rufen, die sich «die weitere Aufklärung auf dem Gebiet der Heilkunde und den daraus hervorgehenden Nutzen für die Mitmenschen» zum Ziel setzte. Er hatte auf seiner Peregrinatio academica in Italien viele berühmte Gelehrte und wahrscheinlich auch in Rom Mitglieder der «Accademia dei Lincei» kennengelernt, und wir finden diese Akademie neben anderen ausdrücklich als Vorbild für die «Academia Naturae Curiosorum» in Bauschs Rundbrief von 1651 genannt, worin er die Ärzte seiner Zeit zur Mitarbeit aufrief.

Als die Leopoldina mit ihrer 1670 geründeten Zeitschrift und der durch kaiserliches Privilegium von 1687 garantierten völligen Zensurfreiheit zu einem öffentlichen Forum selbständigen Denkens und freier Meinungsäußerung über alle konfessionellen, politischen und weltanschaulichen Grenzen hinweg geworden war, gehörte der großartige Impuls der «Accademia dei Lincei» schon der Vergangenheit an. Sie hatte sich 1630 nach dem Tode Federigo Cesis aufgelöst. Um so wichtiger ist es, daß ihre Tradition im 19. Jahrhundert wiederbelebt wurde als «Pontificia Accademia dei Nuovi Lincei» unter Papst Pius IX. und als «Regia Accademia dei Lincei». Nach ihrer Wiedererrichtung vor 50 Jahren hat sich die «Pontificia Academia Scientiarum» den wissenschaftlichen Meinungsaustausch über die brennenden Probleme der Gegenwart zum Ziel gesetzt, wobei allein die wissenschaftliche Qualifikation ohne Ansehen von Nationalität oder Religion den Maßstab für die Teilnahme bilden soll. Wir sehen darin wiederum eine ideelle Gemeinsamkeit, die die Wissenschaftler der gabzen Welt verbinden sollte, und erkennen als ehrendes Zeichen dieses Bestrebens, daß viele hervorragende Gelehrte als Mitglieder unserer beiden Akade-

mien die freie wissenschaftliche Diskussion der Gegenwart aktiv mitgestalten.

Möge solch fruchtbares Wirken im Dienste der Wissenschaft Ihrer Akademie auch weiterhin beschieden sein!

THE ROYAL SOCIETY
(ROYAUME-UNI)

The Royal Society of London
to the
Pontifical Academy of Sciences

The Royal Society of London for improving natural knowledge is honoured to send its congratulations and felicitations to the Pontifical Academy of Sciences on the occasion of the Golden Jubilee of its reformulation and is glad to take this opportunity of expressing warm admiration for the many notable contributions to knowledge made by members of the Academy during the fifty years of its existence.

The Royal Society recalls with pleasure the cordial relations it has enjoyed in the past with members of the Pontifical Academy and looks forward to their continuation in the future.

ACADÉMIE DES SCIENCES (FRANCE)

L'Académie des Sciences
de
l'Institut de France
à la
Pontificia Academia Scientiarum
à l'occasion de la Commémoration
du
Cinquantième Anniversaire
de
son institution
par
Sa Sainteté le Pape Pie XI

A l'occasion de la Commémoration du Cinquantième Anniversaire de l'institution, par Sa Sainteté le Pape Pie XI, de la charte et des statuts actuels de l'Académie Pontificale en 1936, date à partir de laquelle le nom de cette dernière devint: Pontificia Academia Scientiarum et, ayant aussi présent à l'esprit que l'année 1986 a été marquée par le quatrième Centenaire de la naissance de Federico Cesi qui, en 1603, fonda avec ses compagnons l'Accademia dei Lincei, qui est à l'origine de l'Académie Pontificale, l'Académie des Sciences de l'Institut de France tient à exprimer tous ses voeux à son aînée et tous les souhaits qu'elle forme pour le développement de son activité. C'est, pour moi, un grand honneur et une grande joie d'être, ici, son porte-parole.

Comme le soulignait Sa Sainteté le Pape Jean Paul II dans son discours du 2 juin 1980, à l'Unesco, lors de son premier voyage en France, tous les problèmes qui se rapportent à l'avenir pacifique de l'homme sur la terre sont intimement liés comme pour ainsi dire dans un vaste système de vases communiquants. A côté des mises au point scientifiques qui se font dans ses Semaines d'Etudes, l'Acadé-

mie Pontificale attache une grande importance à toutes les questions liées à l'insertion de la Science dans la culture et plus généralement dans la vie de l'Humanité. Notre Académie des Sciences est heureuse d'avoir été associée, en particulier à propos de tout ce qui touche au problème de la paix, à l'action de l'Académie Pontificale.

Avec tous les remerciements de l'Académie des Sciences de l'Institut de France, je suis heureux de vous exprimer, Cher Monsieur le Président, mon Président puisque j'ai le grand honneur d'être Membre de l'Académie Pontificale, toute l'admiration respectueuse que, personnellement, je porte à votre action.

AKADEMIE DER WISSENSCHAFTEN DER DDR (RÉPUBLIQUE DÉMOCRATIQUE ALLEMANDE)

Die Akademie der Wissenschaften der Deutschen Demokratischen Republik beehrt sich, der Pontificia Academia Scientiarum anläßlich ihres festlichen Jubiläums die besten Wünsche zu übermitteln. Diese Wünsche richten sich auf das von humanistischer Verantwortung, aufrichtigem Friedenswillen und wissenschaftlicher Gründlichkeit getragene Wirken Ihrer traditionsreichen Institution.

Das Jubiläum der Pontifikalen Akademie der Wissenschaften fällt in eine für die Geschicke der Menschheit kritische Wendezeit. Mehr denn je hängt in dieser Periode die Zukunft aller Menschen zuerst und vor allem von der Fähigkeit der Staaten und Völker ab, auf eine neue, auf gegenseitiger Achtung und Verständingungsbereitschaft beruhende Weise miteinander zu leben. In einer solchen Zeit muß der Wissenschaftler, wo immer er auch arbeitet und welche Überzeugungen er auch vertritt, ein Bekenner der Friedensidee sein.

Der ethische Imperativ des Wissens heißt: Gewissen.

In der Deutschen Demokratischen Republik ist der Friedensgedanke Staatsdoktrin, und die Wissenschaftler sind mit sozial bedeutsamen und auf eine friedliche Perspektive gerichteten Aufgaben befaßt. In der wissenschaftlichen Öffentlichkeit der Möge das Jubiläum der Pontificia Academia Scientiarum neue Impulse für eine fruchtbare Tätigkeit setzen — zum Fortschritt der menschlichen Erkenninis, zum schöpferischen Dialog, zu Frieden und Sicherheit auf unserer Erde.

REAL ACADEMIA DE CIENCIAS EXACTAS, FÍSICAS Y NATURALES (ESPAGNE)

Regia Academia Scientiarum Hispaniae Pontificiam Academiam Scientiarum quinquagesimam restitutionis annum feliciter celebrantem magnopere congratulatur ob veritatem ab ea diligenter perquisitam, pacem humanique generis fraternitatem efficaciter adauctam. Regia Academia Scientiarum Hispaniae sollemnibus adest commemorantibus consorti Pontificiae arcte concordem studioseque gratulantem animum testans.

En Sesión plenaria celebrada el día 25 de junio de 1986, la Real Academia de Ciencias Exactas, Físicas y Naturales acordó expresar su felicitación a la Academia Pontificia de Ciencias con motivo del Cincuenta Aniversario de su reconstitución.

AKADEMIA NAUK SSSR
(UNION DES RÉPUBLIQUES SOCIALISTES SOVIÉTIQUES)

On the occasion of the fiftieth anniversary of the Pontifical Academy of Sciences, the USSR Academy of Sciences extends its greeting to one of the most authoritative bodies of the world.

The Pontifical Academy is endowed with rather a conspicuous peculiarity. Its members represent many countries of the world. This opens up most favourable possibilities and perspectives to introduce into the minds and hearts of all people of our planet the idea of a future necessity for urgent actions for the sake of peace and the future of forthcoming generations.

The USSR Academy of Sciences and the Soviet community appreciate the steps undertaken by the Pontifical Academy of Sciences in this direction and, in particular, the declaration about the consequences of the application of the nuclear war, adopted on October 6, 1981, at the meeting of prominent scientists of the world, the declaration on the prevention of nuclear war adopted in Rome on September 24, 1982, at the Assembly of the Presidents of the Academies of Sciences of thirty countries, the representatives of the Pugwash Movement of the Scientists and the International Council of Scientific Unions arranged on the initiative of the Pontifical Academy of Sciences, as well as a summit document adopted by the international meeting of scientists dedicated to the study of the consequences of nuclear explosions which took place in the Pontifical Academy of Sciences in the Vatican on January 22-24, 1984.

The active role played by the representative of your Academy, Professor Marini-Bettolo, in the course of the Second National Conference of Scientists on the problems of peace and prevention of nuclear war, which took place in Moscow this year on May 27-29, as well as in the organization and carrying out of the International Forum of Scientists for the Banning of Nuclear Tests in Moscow,

July 11-13 of this year, is regarded by us as one more testimony to your striving to unite the efforts of your Academy with the efforts of the international scientific community and in particular with the efforts of the Soviet scientists in the fight for the existence of human civilization and of life itself on earth.

We are convinced that in order to resolve this really highly human task, it is necessary above all to reach the full understanding of all people by the good will of all individuals, of the character and scales of the threatening nuclear catastrophe, to unite all peace-loving forces of our planet and first of all, the efforts of the scientists.

Today, in the days of jubilee celebrations, the USSR Academy of Sciences greets all the members of the Pontifical Academy of Sciences. We wish you further successes in your scientific activities and in the fight for the peaceful future of mankind.

The Presidium of the Academy of Sciences, Moscow.

KUNGL. - VETENSKAPSAKADEMIEN
(SUÈDE)

As President Emeritus of the Royal Swedish Academy of Sciences I have the honour of conveying the Academy's congratulations by presenting the collected notes of one of the earliest members of our Academy, Carl Wilhelm Scheele who, more than 200 years ago, anticipated the presence of oxygen in the air, a vital part of our environment, the protection of which at present is in great need of our joint efforts.

BAYERISCHE AKADEMIE DER WISSENSCHAFTEN (RÉPUBLIQUE FÉDÉRALE ALLEMANDE)

Academiae Pontificiae
Scientiarvm
Annvm qvinqvagesimvm
nativitatis agenti
salvtem plvrimam
dicit
Academia scientiarvm
boica
Hanc sollemnitatem
votis precibvsque proseqvens
vt natvrae parens et origo
mvltos addat annos
favstos felices
fortvnatosqve

ACADÉMIE ROYALE DES SCIENCES, DES LETTRES ET DES BEAUX-ARTS DE BELGIQUE (BELGIQUE)

L'Académie Royale des Sciences, des Lettres et des Beaux-Arts de Belgique

adresse

à la Pontificia Academia Scientiarum ses plus chaleureuses félicitations à l'occasion de son cinquantième anniversaire.

Elle est heureuse de pouvoir lui exprimer ses sentiments d'admiration pour l'œuvre qu'elle a accomplie dans les domaines de la recherche fondamentale et de la recherche expérimentale.

Elle forme le vœu que cette œuvre se poursuive avec le plus grand succès dans la paix et la prospérité.

KONINKLIJKE ACADEMIE VOOR WETENSCHAPPEN, LETTEREN EN SCHONE KUNSTEN VAN BELGIE (BELGIQUE)

Regia Academia Belgica Litterarvm,
Bonarvm Artivm et Disciplinarvm
Pontificiae Academiae Scientiarvm
Sorori qvinqvagenariae
Salvtem plvrimam dicit.

Pergratus cum esset allatus nuntius Pontificiam Academiam Scientiarum in Urbe sollemni ritu et conventu celebraturam esse annum quinquagesimum a quo rursus saecularem academiae locum, dignitatem et honorem adepta esset gremiumque suum sodalibus doctis ab omni gente cooptandis aperuisset, Regiae Academiae Belgicae subito cordi fuit vobis summa, qua par est, laetitia gratulari eamque laetitiam manifesto declarare testimonio, ideoque professorem Georgium Smets, Academiae praesidem, cum his litteris Romam legavit ut illo«in nemore Palatii Apostolici» per dies festos una vobiscum adesset et Regiae Academiae Belgicae personam praesens gereret.

Academia enim Pontificia, novella simul et perantiqua, quippe quae Academiae Lynceorum olim successerit et post multas rerum et historiae vicissitudines in formam, qua nunc viget, reformata sit, ita semper aperta mente disciplinis severioribus promovendis incubit et sacrae Sancti Petri cathedrale senatus doctus eiusmodi consilia dedit ut maxima ex his muneribus merita consecuta sit identidemque nova persequatur. Nam et nostra etiam aetate gravissimas illas quaestiones tractare non desinit, quae homines vehementer commovent et turbant, ut sunt innumerae difficultates quae obruunt nationes anguntque dum ad provectum nituntur oeconomicum atque humanum, vel pericula ista bellica quae ex vi nucleari possunt oriri, vel demum arduas illas disciplinas quae bioethicen tangunt aut spectant.

Siquidem salutis atque incolumitatis humanae perpetua sollicitudo communis est utriusque academiae et concors provincia, non possumus non favere propositis et consiliis vestris, itaque summo studio et favore vota vobis mittimus ut eadem semper intrepidaque quaerendi et disputandi fide et gravitate disciplinas provehatis multosque etiam per annos in splendidissimis illis Villae Pianae aedibus — quo vix ausonia pulchrius extat opus — floreat immortale sophiae decus in gloriam et utilitatem Sancti Petri necnon omnium in terris hominum et nationum.

ACCADEMIA NAZIONALE DELLE SCIENZE DETTA DEI XL

(ITALIE)

L'Accademia Nazionale delle Scienze
detta dei XL

NELLA FAUSTA RICORRENZA DEL CINQUANTESIMO ANNIVERSARIO
DELLA

Pontificia Academia Scientiarum

memore della stretta collaborazione per il progresso della scienza e dell'umanità espressa dalle due istituzioni mediante l'opera di accademici comuni e in particolare nel passato dei presidenti Agostino Gemelli e Georges Lemaître della Pontificia Accademia delle Scienze e Aldo Castellani, Francesco Severi, Domenico Marotta e Beniamino Segre dell'Accademia Nazionale delle Scienze detta dei XL, porge alla Pontificia Accademia delle Scienze, oggi riunita sotto la presidenza di Carlos Chagas, uno dei XL, l'augurio più vivo di continuare con il medesimo spirito, fervore e sapienza nella sua opera di scienza e di pace.

AUSTRALIAN ACADEMY OF SCIENCE
(AUSTRALIE)

From the Australian Academy
of Science

GREETINGS

On the occasion of the 50th anniversary
of the Pontificia Academia Scientiarum
we join with your efforts to use science
for peaceful purposes.

DET NORSKE VIDENSKAPS-AKADEMI
(NORVÈGE)

On the occasion of the 50th anniversary
of the foundation of the Pontificia Academia Scientiarum

The Norwegian Academy of Sciences and Letters offers its warm congratulations. In the consciousness of your illustrious history and significant contributions to scientific knowledge and human understanding, we extend our best wishes for continued success and prosperity in all fields of intellectual endeavour.

NATIONAL ACADEMY OF SCIENCES (ÉTATS-UNIS)

The U.S. National Academy of Sciences
extends greetings to
the Pontifical Academy of Sciences
and its President on the occasion of its
50th anniversary celebration

We pay tribute to your truly cosmopolitan membership, whose distinguished contributions to science are universally recognized.

We acclaim the recent efforts of the Pontifical Academicians in putting their scientific expertise at the service of humanity in furthering human and moral concerns for peace and the welfare of all.

Vivant, sequentes.

I bring you greetings, congratulations and best wishes from the National Academy of Sciences of the U.S.A. and its President Frank Press; I am delivering this scroll as a special message for this auspicious occasion, your 50th anniversary. Frank Press regrets very much that he is unable to be present at this distinguished gathering, especially in view of the vivid memory that he has kept of the assembly of Academy Presidents in September 1982 which this Academy convened and which under your leadership, President Chagas, led to the declaration on the Prevention of Nuclear War.

We who have the honor of being present here bear testimony to the fact that science is indeed an international endeavor and that the laws of nature are the same under all skies — independent of religion, race and ideology.

J.R. Oppenheimer, speaking from the double perspective of a physicist and manager of the atom bomb project, coined the phrase

«exhilarating but oh so useful» as descriptive of the potential of science. Governments all over the globe have become increasingly aware of the usefulness of science and its applications. The developing countries are only too painfully aware of the fact that science and technology loom so importantly in the widening gap between their own way of life and that of the industrialized world.

While people in all walks of life without adequate scientific training have often exaggerated expectations concerning the ability of science and scientists to solve quickly difficult societal problems, they, together with those of us who are scientists, cannot help but express fears and concerns regarding scientifically sophisticated weapons and some unintended consequences of the applications of new technologies.

As scientists, we owe it to our ethical principles — which include objectivity, open communication and a commitment to the universal nature of science — to do our utmost to improve the human condition or, as Bacon put it, to "the relief of man's estate". In this worthy effort the National Academy of Sciences looks forward to cooperating with the Pontifical Academy in the next half century and beyond.

BULGARIAN ACADEMY OF SCIENCES (BULGARIE)

On behalf of the Praesidium of the Bulgarian Academy of Sciences and on my own behalf I have the honour and the pleasure to extend most sincere and cordial greetings to the Pontifical Academy of Sciences and to its President Carlos Chagas, on the occasion of the Academy's 50th anniversary.

We are most appreciative of this welcome opportunity to offer our greetings to a scientific institution that has inherited most glorious traditions dating from the early XVIIth century and that embodies a synthesis of knowledge and morality. The Bulgarian Academy of Sciences is most privileged to reaffirm its total support to the principles that motivate the Pontifical Academy in the yearning for peace and for using all potentials of science for a peaceful progress, general understanding and cooperation among the peoples.

Throughout its existence the Pontifical Academy has united the efforts of a pleiad of renowned scientists who have left indelible traces in the history of world science and of the spiritual progress of Mankind. Bulgarian scientists hold in high esteem the endeavours and contributions of the Pontifical Academy to the cause of peace and for the betterment of human life. In terra pax hominibus bonae voluntatis. We are confident that in the future the Pontifical Academy of Sciences will continue to be a consistent driving force for the advancement of science and will continue to foster the evolving of a peaceful and more reasonable humanity.

While we all, the national academies and research institutions of all countries, are restricted in our endeavours to do some more moves to prevent the nuclear nightmare and save humankind from an apocalyptic extinction, the Pontifical Academy, being supranational and acting under the aegis of the Roman Catholic Church, has a lot of advantages and considerably better potentials to persuade and act in the name of Christian ideas and truths, for the triumph of

the cause of peace and for the rescuing of Mankind. Moreover it has most powerful instruments of influence — moral values and, especially compassion. Our civilization could be saved solely by the prevalence of common sense in inter-state relations, by knowledge not opposed to natural order and to moral norms of conduct, because knowledge void of morality and compassion is unhuman.

I wish the Pontifical Academy every success in its most noble efforts directed to saving Humanity and fostering its prosperity.

Beati pacifici quoniam filii dei vocabuntur.

ACADEMIA NACIONAL DE CIENCIAS EXACTAS FÍSICAS Y NATURALES (ARGENTINE)

La Academia de Ciencias Exactas Físicas y Naturales
de la República Argentina
en este acto solemne
que recuerda el Cinquentenario de la renovación de la
Academia Pontificia de Ciencias
presenta sus votos màs fervientes de adhesión y reconocimiento
por la transcendente labor realizada y en la que han estado y
están empeñados dos de los màs destacados sabios argentinos:
Bernardo A. Houssay y Louis Leloir
que son orgullo común de nuestras Academias

NIPPON GAKUSHIIN
(JAPON)

The Japan Academy
to
the Pontifical Academy of Sciences

On the occasion of the celebration of the 50th Anniversary of your esteemed Pontifical Academy of Sciences, I have the privilege and honour of presenting a congratulatory message on behalf of the Japan Academy.

We know well that your Academy, ever since its re-establishment in 1936 as an international academy, has been playing a significant role in the academic circles of the world, with its members chosen for their scientific qualifications regardless of their religion and nationality. It is one of the distinctive features of your academy to promote science and serve as the Scientific Senate of the Holy See. You have all sorts of problems of global interest and importance in your scope and always preserve complete liberty in your scientific activities. We would like to pay tribute to the meritorious services rendered by your Academy to the improvement of human society.

I believe that all the academic bodies of the world should now be united in their efforts to attain the noble goal of peace and welfare of mankind. In this connection, I am pleased to know that our two Academies have some members in common. I most sincerely hope that the friendly relations between us will become closer and closer in years to come.

May your commemorative celebration be a great success and your efforts be rewarded with fruitful results!

JUGOSLAVENSKA AKADEMIJA ZNANOSTI EI UMJETNOSTI (YOUGOSLAVIE)

From the Yugoslav Academy of Sciences and Arts
to the
Pontifical Academy of Sciences

The Yugoslav Academy of Sciences and Arts is happy to send warm congratulations to the Pontifical Academy of Sciences on the occasion of the celebration of its fiftieth anniversary. The Yugoslav Academy of Sciences and Arts joins with great pleasure in the solemn celebration of a past in which the Pontifical Academy of Scences has distinguished itself by its brilliant scientific achievements. It expresses its sincere wishes that this outstanding activity may be continued in the future for the promotion of science, peace and the well-being of all the peoples of the world.

AKADIMIA ATHINON
(GRÈCE)

As Vice-President of the Academy of Athens, I am happy to have been given the opportunity of participating in today's fine ceremony. I would therefore like, on behalf of the Athens Academy, to pay to the Pontificia Academia Scientiarum the tribute of honour, recognition and admiration due to the notable work achieved to date by your Academy, which with particular gratification is celebrating its first fifty years of independence from the authority of the Italian State.

Allow me to remind you that the word "Academy" is of Greek derivation. It is composed of two roots: of "Aka" or "Ake" (according to others, "Ekas"), and of "demos". The root "Aka" or "Ake" signifies "quiet" or, according to Hippocrates, "therapy". The root "Ekas" means "distant" applied either to time or space. It is my belief that the root "Aka" or "Ake" meaning quiet more correctly renders the significance of the word "Academy", a term first chosen by the great Plato, who founded his Academy in a suburb of the Deme of Athens, so that he might in "quiet" investigate and study the problems of his philosophy. This first and most ancient Academy of Plato, whose continuation, it could be said, is the Athens Academy with its seat today in the same noble city of Athens, gave the right to all the Academies of the world to bear that name, provided that they pursue the same aims; that is, to study all areas of knowledge. At the same time, the Academies have the duty to enlighten, to guide and to direct mankind within the whole area of the human spirit, supreme intellectual powers of the nation in which each Academy acts and works.

The Academy, as a tutor to the spirit, always urges what is appropriate and offers its advice. It does not legislate; it opines and proposes. The irresistible force of the Academy — every Academy — shines forth through logos, that unique and divine gift bestowed by Almighty God on man alone. Thus viewed, the Academy could

be described as a haven for the spirit, untroubled by waves. It follows that the Academy is to be identified, insofar as its aims are concerned, with the nation within which it lives and works, acting for the good of the citizen and more generally of mankind — all mankind.

Pursuing this view, we could also say that the Academy is to be identified with the Church, if it is within a Christian state. The reasons for comparing the Academy with the Church are that the Church owes its foundation to God; the Academy is the temple of the human spirit. The Church possesses the truth of revelation; the Academy is a seeker after truth. The Church is a place of spiritual healing for the salvation of souls; the Academy is a foundation for the investigation and diagnosis of truth, for the benefit of man. For the Church, "the fruit of the spirit is love, joy, peace" (Galatians 5,22). The Academy, too, looks to reap the same harvest, for the good of mankind — all mankind. To use the happy Pythagorean term, the Academy is an "homacoeion", that is to say, a common auditorium or school and foundation in which the finest investigatory minds foregather to make known the achievements of their research (cf. Iamblichus: De Vita Pythagorica, 6, 30, and Porphyrius Tyrius: Vita Pythagorae, 20 et seq.). The Academy, then, far removed from any racial, religious, social, educational, cultural or any other form of distinction by class, has as its aim the betterment of mankind, in a spirit of mutual affinity, philanthropy and love, "than which none is greater" (Mark 12, 31), according to the teaching of the Christian Gospel.

It is my unshakable belief that the Pontificia Academia Scientiarum, with its enhanced self-awareness and self-confidence, will be able, through its accomplishments in research, ever to find the golden mean to the greatness of man, to his constant human and cultural betterment, in conformity with his divine origin and his destiny in this world as decreed by his Creator. It is in this world, in any case, that the greatest of good things are duly to be investigated and their acquisition urged: Faith in God, Hope which is always of benefit to man, that Love which crowns all virtuous acts and on which in turn brotherhood and affinity depend, Liberty and Peace. These are the things which are the concern of the Christian Church, and for which it prays that they may become the possession of man, of every man in the world. This is why I compared the Academy to the Church, and this is why we rejoiced that the Pontificia

Academia Scientiarum was placed under the protection of the Pontiff and the Church when, 50 years ago, it became independent of the Italian State.

The Athens Academy cordially wishes the Pontificia Academia Scientiarum constant and unimpeded success in its scientific research and pursuits. May its years be long, and may it always celebrate its jubilees in exultation.

THE ISRAEL ACADEMY OF SCIENCES AND HUMANITIES (ISRAEL)

The Israel Academy of Sciences and Humanities
extends its cordial congratulations and felicitations
to the
Pontificia Academia Scientiarum
on the occasion of its
Fiftieth Anniversary
Celebrations

The occasion of this anniversary is an auspicious moment to congratulate the Pontificia Academia Scientiarum for undertaking the exploration of global issues and ethical problems pertaining to the impact of science and technology, which are of such unique significance for the future of mankind.

It is a major responsibility of the scientific community and of the learned societies to promote and enhance the intellectual, cultural and moral values of science for the creation of a better world. To allude to a biblical term, science has the task of bringing mankind to the "Promised Land". The Pontifical Academy of Sciences, under the leadership of its distinguished President, Carlos Chagas, is making a seminal contribution towards this noble goal.

INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS (I.C.S.U.)

(FRANCE)

It is my great pleasure and privilege to convey the warmest congratulations of the International Council of Scientific Unions (ICSU) to the Pontifical Academy of Sciences on the occasion of this 50th anniversary celebration.

As most of you certainly know, ICSU is the world non-governmental federation of 20 international scientific unions in the basic sciences and of some 70 national academies and other learned societies, among them the Pontifical Academy of Sciences. In one respect, however, this Academy is different from other national members: its membership is international. The present 77 members of the Pontifical Academy come from not less than 35 nations and represent most major religions of the world. It is a unique national member of ICSU that is really and truly international.

You, Mr. President, have been actively engaged for many years in ICSU's activities. From 1968 to 1970, you have served as Vice-President of ICSU, and as late as last month you have represented your Academy at ICSU's 21st General Assembly in Berne, Switzerland, and have participated as Discussion Leader in a Symposium on "Consequences of Nuclear War" organized on that occasion. Likewise, several other distinguished members of your Academy have participated, and continue to participate, in various ICSU activities.

Conversely, several representatives of ICSU have had the privilege over the years to be invited as participants in different activities of the Pontifical Academy of Sciences, including the Assembly of Presidents of Scientific Academies concerning Prevention of Nuclear War, held in 1982, two Working Groups on "Nuclear Winter: A Warning" and "Weaponization of Space", organized in 1983 and 1985, respectively, as well as several Plenary Sessions of the Academy.

In closing, Mr. President, let me reiterate ICSU's warmest felicitations on the occasion of this anniversary and express our wish and hope that this fruitful collaboration between the Pontifical Academy of Sciences and ICSU shall continue in the years to come for the benefit of international science and peace.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

(A.A.A.S.)
(ETATS-UNIS)

On the occasion of the Fiftieth Anniversary
of
The Pontifical Academy of Sciences
the American Association for the Advancement of Science
extends its respectful congratulations
for a half century of scholarly contributions
to the progress of science in
the service of humanity

ORGANISATION DES NATIONS UNIES POUR L'ÉDUCATION, LA SCIENCE ET LA CULTURE

(U.N.E.S.C.O.)
(FRANCE)

Allocution
de
M. Amadou-Mahtar M'Bow

Directeur général
de
l'Organisation des Nations Unies
pour l'éducation, la science et la culture
(Unesco)

à l'occasion de la célébration du 50e anniversaire
de l'Académie Pontificale des Sciences

En ce 27 octobre 1986, alors qu'à l'initiative de Sa Sainteté le Pape Jean-Paul II, est célébrée *la prière pour la paix* à Assise, où naquit Saint-François dont la vie fut dédiée au service des pauvres et à la concorde entre les peuples, voici qu'à Rome est commémoré le 50e anniversaire de la création ou, plus précisément, de la restauration, par Pie XI, de l'Académie Pontificale des Sciences.

Il est heureux que ces deux évènements coïncident, car ils revêtent tous les deux la même portée universelle. Ils rassemblent tous les deux des hommes et des femmes qui, dans la prière ou dans la réflexion, orientent leurs pensées vers des matières qui intéressent au plus haut point le destin de l'homme et des hommes de partout.

Aussi voudrais-je exprimer ma profonde gratitude à mon très grand ami le professeur Carlos Chagas, président de l'Académie, pour l'honneur qu'il m'a fait en m'invitant à participer à cette cérémonie. Et je suis heureux d'y saluer la présence de tant

d'éminents savants et chercheurs parmi lesquels je compte bien des amis.

L'Académie Pontificale des Sciences a montré au cours de ces 50 dernières années qu'elle pouvait réunir en son sein des savants et des chercheurs de partout, mûs par une même volonté: celle de faire reculer sans cesse les frontières de l'inconnu, afin de contribuer au progrès des sociétés et au mieux-être de l'homme. Mais en accordant une importance particulière aux aspects spirituels et éthiques de la recherche, elle a ajouté à sa mission spécifiquement scientifique une dimension qui la complète très heureusement et lui donne dans le monde scientifique une place de choix. Elle constitue un forum unique de coopération internationale, mais surtout un lieu privilégié où, sans aucune contrainte politique ou gouvernementale et sans mettre en avant des intérêts spécifiquement nationaux, des hommes et des femmes voués aux travaux scientifiques les plus avancés de notre époque, peuvent réfléchir ensemble sur les finalités de leurs recherches et éveiller les consciences sur l'impact de ces dernières.

Au moment où les espaces de liberté ont parfois tendance à se restreindre, c'est là un acquis précieux pour l'humanité tout entière. L'Académie Pontificale des Sciences a démontré en maintes occasions, en effet, qu'elle pouvait constituer une autorité incontestée pour tout ce qui concerne, au regard de la science et de ses applications, la sauvegarde de la vie et des valeurs fondamentales sans lesquelles les sociétés humaines risqueraient de sombrer dans le chaos.

Aussi voudrais-je, au nom de l'Organisation des Nations Unies pour l'Éducation, la Science et la Culture, l'Unesco, et en mon nom personnel, vous redire notre profonde estime et souhaiter à votre Académie de poursuivre sans relâche sa mission de progrès, de paix et de fraternité humaine.

DISCOURS OFFICIEL DU PRÉSIDENT

En conclusion de la première journée des Célébrations, le Président Prof. Carlos Chagas a prononcé le discours officiel:

President and Representatives of Academies,
Ladies and Gentlemen,
Dear Colleagues, Academicians,

I would like now to comment on science and the modern world. These reflections can only translate my thoughts and, above all, transmit my own experience.

The aftermath of the 1945 war profoundly modified our world. The development of science and technology exploded, whereas, on the other hand, the configuration of the nations of the world suffered severe modifications. The extraordinary development of science and its applications provided man with the hope that he would achieve the dream of Bacon's "New Atlantis" and that humanity would joyously bask in material plenitude.

The hopes placed on science and technology have become a landmark of our times and have created a climate of confidence, the best proof of which is the enthusiastic way in which the nations of the world participated in the First Conference on Science and Technology Applied to Development, held in Geneva in 1963, and organised by the United Nations to launch the decade of development. Another proof could be the amazement with which common men follow the advances of modern technology.

However, in many circles, mainly intellectual, this wave of optimism is being replaced by one of skepticism. The question appeared in many places, and that question was: Where does Science lead to?

This skepticism created an anti-scientific mood easily discernible in the student movements of 1968 and is still heralded by many modern philosophers. But, science and technology provided a large

portion of humanity with the means of improving their standard of living.

On the other hand, the consumer society in which we live has led man in anguish to question the meaning of life. Many people have, unjustly, attributed the formation of this type of society to science and technology, which threatens to, if it hasn't already done so, destroy the ethical values which are essential to humanity. They have forgotten the sentence of St. Paul: "Good and evil live in the hearts of men". The loss of ethical values places men and women in a situation of extreme moral and physical distress.

The enchantment resulting from material progress probably made man forgetful of an incident which occurred in the Pacific during the month of August in 1945. I remember the anguish I felt when in 1949 I visited Fort Duaumont, around and in which took place the battle of Verdun in 1918, one of the bloodiest and most cruel episodes of the history of warfare. Contemplating Duaumont, I felt much closer to Thermopylae than to Hiroshima and Nagasaki.

A large number of scientists quite early became aware of the dangers of the liberation of atomic energy and tried to warn humanity by publishing the "Bulletin of Atomic Scientists". But humanity did not fully comprehend that the episode which ended the war in 1945 had also altered the course of our civilization.

I think it is germane to emphasize that scientists were the first to warn us of the dangers of atomic energy utilised for war, and that only after a long interval was this utilisation questioned and developed into one of the major preoccupations of our society.

However, science and technology must progress. Common man has placed his hopes on the furtherance of this progress, which should not be hindered by the fears of an inappropriate application of its achievements.

Scientific and technological progress is essential if humanity is to overcome the challenges of the days to come.

These challenges, among which famine, the production of food, deforestation, lack of sanitation, violence, are primarily resultant from political and socio-economic and demographic changes which have characterised the evolution of the human race in the second half of our century. Only scientific approach can allow us to understand them, albeit only partly. The changes introduced in the world after the Second World War have brought forth a broadening of the domain of science and technology. The utilisation of space, of

new forms of energy, the exploration of the ocean's riches, among others, and the problems of ecology, occupy each day a more prominent place in our anxieties.

This broadening of scientific and technological spheres, and its consequences, have been followed with attention by our Academy through its several specialised publications which dealt with problems that, under the most diverse forms, challenge human society. These problems must be solved by science and technology, bearing in mind the general context of human knowledge.

The Academy, in its activity, strongly believes that science and technology should be directed towards the fulfillment of the human being, meaning that they should be devoted to the establishment of a civilization of Being, to which must be subjected the civilization of Having.

Furthermore, one of the major preoccupations of the Academy is derived from the presence in the world of nations whose people, possessing ancient and traditional values, are unable to benefit from science and technology as did the nations who were capable of developing their own scientific and technological power. The development of science and technology in developing countries must be done without the destruction of those traditions and values.

We all know that two-thirds of the world's population live in poor nations and are prey to famine and misery. These poor nations face the impossibility of reducing the damages caused by natural catastrophes, such as drought, floods, and earthquakes, a constant threat to them. They became the prey of antidemocratic regimes and the political and economic interests of powerful nations craving for their natural resources or geographically strategic position. The diseases which afflict these people, as well as malnutrition, should already have been eradicated and become a nightmare of the past.

As has been said very recently by Pope John Paul II, "humanity should not be so proud of satellites orbiting the sky when millions of human beings die of hunger in the world and should not be content when the existing nuclear arsenal can totally destroy human life".

It is quite evident that the solution of problems of developing countries exceeds the frontiers of science and technology. But, they must be placed in the centre of the thoughts of all those who ponder the future of humanity. Scientists and technologists can evaluate the vicissitudes with which the people of these countries live, and

propose solutions to avoid the neocolonialism which invariably presents itself under the guise of science and technology and, unfortunately, begins to entrap them, should they not yet be so.

Many scientific and technological solutions, however, have been found or are in the stage of pilot projects. This is the case, for instance, of the new developments in agriculture. Regrettably, the application of science and technology to less developed countries is very often impeded by economic questions and even at the mercy of international markets, blocking their possibilities.

The Academy is, of course, very aware of the problems that the Third World faces. Meetings have analysed different problems, many of which require urgent solutions. However, prompt progress cannot be expected without international economic support.

During the Second Conference for the Application of Science and Technology in Latin America and the Caribbean, which took place in Brasilia in August 1985, it became evident that the scientific and technological progress of this geographical region is terribly inhibited, if not practically paralysed, by the heavy external debt, created by the imprudence of its governments and by the greed of international financiers.

I would like to point out, as I have done many times, that the scientific and technological development of a poor nation depends essentially on the creation of research centres, which must be supported with entire freedom of action by local governments and private enterprises.

The establishment of autochthonous centres for science and technology is essential for developing countries. These centres give birth to an autonomy of thought which reflects the need of a nation, and only these centres can determine the correct mechanism for the transfer of the most appropriate technology for the receiving country. Furthermore, they alone are capable of providing the space where research may develop its creative influence, provide the incentive necessary to the promotion of science and technology, allowing scientists an independent study of the consequences of a scientific discovery or technological application. I must add that the upgrading of science and technology for the Third World can be helped by imaginative creations, of which some of the best examples are the Centre for Theoretical Physics in Trieste, and the Institute for Insect Physiology and Environment of Nairobi, and also by the establishment of active academies like the Third World Academy of

Sciences (TWAS) and the Academy of Sciences of Latin America and the Caribbean.

The creation of universities essentially as research institutions which can thus become centres for higher education, is mandatory for developing countries. To this task must be added on-the-job training provided by industrial training centres and the creation of technical colleges of higher or medium level.

On the other hand, the academic or technical corps, carefully chosen, must occupy an acceptable niche in the social strata.

The governments and the society of developing countries, due to the allegedly high cost of basic research — a minimal when compared to their military expenditures — tend to abstain from it. These governments and ruling classes, on the contrary, advocate the idea that development can be achieved by the import of science produced by developed countries — a very wrong manner of asserting their own future.

The Pontifical Academy of Sciences, publishing its documents, wishes to avoid the repetition of previous errors.

The Pontifical Academy of Sciences has witnessed, in the past fifty years, the integration of science and technology, a unity which confirms Pasteur's assertion that "la science et ses applications ne font qu'un continu".

Whereas in the past, science and technology were, one could say, practically non-communicating vessels, gradually the technical results became, in their majority, short- or long-term applications of previous basic scientific discoveries.

Today science and technology are perfectly united, to the point that one can say that the impulse and progress given to scientific knowledge nowadays are given by their interaction.

The extraordinary breakthrough in astrophysics, or the progress in the field of elementary particles, as well as genetic coding, the determination of molecular configuration by x-rays, electronic and magnetic resonance, among others, are enlightened examples of the importance of the advanced technologies for scientific progress.

While on this subject, let us not forget the important contribution that the science of Informatics, and all the technology it permeates, have brought to science, and the important role it plays in all fields of research today.

However, it is a fact that the scientist has more freedom to pursue his work than technologists, who are harassed by political

and economic pressures exerted upon them by the State or Society.

With this perspective in mind, we could say that the real scientist is free to refuse to cooperate in the armament race, which, to my way of thinking, is his duty. At the same time, it is his duty to follow — under whichever perspective and pressure — the results of his discoveries to their final consequence, so as to comply with his duty of making public the dangers they may bring.

By recognizing that scientific activity is among the intellectual endeavors most oppressed by economic and political powers, I pledge my admiration and applause to all those who have abandoned laboratories dedicated to the research in nuclear weapons and the dangerous manipulation of human embryos. They are the disarmed prophets, of whom John Paul II spoke to us on the 12th of November 1983. I would like to quote from him: "Should they not be heard unanimously by the scientific community in order that the laboratories and factories of Death would be substituted by the laboratories of life?"

My admiration is also directed to the academic corps who refuse to work for war or to accept funds allocated to the development of weapons.

The Pontifical Academy of Sciences sees with satisfaction the gradual integration of science in a nation's culture. In many young nations this integration progresses energetically. However, should we still speak of "two cultures", as C.P. Snow referred to the state of our knowledge nearly forty years ago? It is clear that this division still exists, but it is confined to individuals requiring specialization, each day more restricted. But in the sense of our knowledge as a whole, the domain in which the Pontifical Academy of Sciences is active, the natural and exact sciences, is being expanded by the collaboration which comes from the humanistic sciences. This characteristic may be observed in the work of our Academy dealing with global problems.

This can also be appreciated in many international activities, such as programs organized by governmental agencies, among others UNESCO and the International Council of Scientific Unions. The development of programs such as "Man and the Biosphere" or "Geophysical Year" are good examples of this tendency, as well as the International Geologic-Biologic Program, commencing in 1990.

On this subject we must point out as an example the activities

of the International Federation of Institutes for Advanced Studies (IFIAS), which by means of a network of institutes around the world, deals with problems concerning the whole globe.

Present-day science came forward from behind locked doors to achieve the human configuration our world requires. Should we refer to a scientific humanism? It is difficult for me to accept this denomination. The real humanism reaches all human activity; it is culture in its wider sense, permanently integrating religion, metaphysics and philosophy. Furthermore, it comprises the activities of creation or invention, poetry, art, architecture and literature. These, coupled with the daily activities of men and women, constitute the true anthropological culture able to provide man with better conditions to survive and solve everyday problems. It is the function of the academies of science of the world to bridge the gap which was so poignantly described by Snow.

Science and technology are the essential elements integrating present-day culture. But they should not be adopted as the determining factors in the establishment of a civilization which would then become based purely on quantitative evaluations.

It is the duty of the Pontifical Academy of Sciences to study not only the influences science applies to man's activities, but also how science reacts to these activities. In this sense I would like to state that the transcendental does not frighten "Homo scientificus" as it did in the past. For some scientists this seems a paradox. Why is it that the progress of science has not abolished the transcendental, some may ask. Those are the ones still influenced by a division, considered irreconcilable, between the material and the immaterial. However, I dare to say that anyone who asks himself what is the purpose of life is overriding this barrier.

I am far from admitting, as said Rogogine, the character created by Dostoievski in "The Prince", that only civilizations built on immanent values are acceptable. If the validity of the transcendental is denied or received with reservation by a number of scientists, many others accept it as irrefutable. We are also far from the times in which faith was considered proof of intellectual inferiority or as a primitive form of human intelligence.

However, the activities of the Pontifical Academy of Sciences are way above these questions. The Pontifical Academicians consider that ideas, as well as emotions, are the domain of one's self and should be respected.

The Pontifical Academy of Sciences meets with the sole aim of promoting scientific understanding and human progress, and wishes to enhance the ethical and moral values that must convey humanity towards its destiny. Thus, it remains loyal to the thoughts of Pius XI and his successors.

In this context, the battle for peace and against nuclear war has played, and will play again, a special role in the Academy's actions.

Peace is not only the absence of war. It is primarily the difficult creation of a state of understanding among people. Peace cannot be achieved without the overall understanding of the different national cultures and the adamant desire to respect the life and plenitude of each nation. To this must be added the promotion of a universal social justice and the total absence of racial or religious discrimination. Only peace will allow the total fulfillment of humanity's highest values.

Contributing to world scientific and technological development and aiding developing nations to bridge the existing gap between science and technology, the Pontifical Academy of Sciences in its deep concern for human life will contribute to world peace, in accordance with Paul VI, who proclaimed that the new denomination of Peace is Development.

The Academy makes this contribution because it is capable of linking the nations of the north and of the south, those of the east and of the west, the rich and the poor. This international link is forged by means of working groups that have, in the course of these years, brought to Rome more than 900 scientists of all nations, in addition to 330 Academicians, in the last fourteen years. This linkage is reinforced with a wide distribution of documents stemming from these meetings.

Furthermore, the Pontifical Academy of Sciences, following the directives of John Paul II, has vigorously launched itself in the battle against the dangers of nuclear war. Numerous meetings were organized, many documents conveyed to the Holy Father, three publications of which were widely distributed. The first of these three publications, "Declaration on the Consequences of a Nuclear Conflict", was presented to the heads of those nations which possess nuclear armaments, by delegations composed of members of the Academy. The second one, demanding the abolition of nuclear warfare and signed on the 24th of September 1982, with the unanimity of 37 representatives of Academies of Sciences of the

world and 24 eminent scientists with a high international reputation, has had worldwide repercussion. The Pontifical Academy of Sciences stands against war. Thus, taking this position, the Academy follows its vocation because science and technology should be, above any other consideration, an activity of participation and understanding, which are a part of the ingredients of peace.

By choosing the stand against nuclear war as a permanent subject for debate and inquiry for the Academy, we believe that, joined by all those with the same purpose, the holocaust which menaces humanity can be avoided, mainly by the pressure exerted by better informed people over their governments.

The Academy also believes that by denouncing the horrors of nuclear war it will also be aiming against any form of warfare. The deliverance of so many people engaged in numerous conflicts cannot be retarded. Humanity runs the risk of a worldwide war, whose proportions cannot be judged. Peace, in respect of human dignity and freedom, must be established. Peace cannot wait for tomorrow, or for the arrival of the XXIst century.

Today John Paul II, in a gesture of indescribable beauty, has convened at Assisi religious chiefs of the whole world for a day of prayer for peace. He has also called on nations at war to make truce for a day. What an extraordinary gesture!

Let us join the Holy Father in a minute of prayer or meditation.

Ladies and gentlemen, let me thank you once more for being with us at this commemoration.

Dans la soirée, les invités présents au Vatican, ont été les hôtes de l'Académie à l'occasion d'une réception qui a eu lieu dans la cour ovale *de la Casina Pie IV.*

DEUXIÈME JOURNÉE

28 octobre 1986

SESSION PLÉNIÈRE

LE PROGRÈS DE LA SCIENCE ET L'AVENIR DE L'HUMANITÉ

La matinée a été consacrée à deux conférences sur les aspects historiques, scientifiques et artistiques de l'Académie Pontificale des Sciences et à l'intervention de la gagnante de la Médaille d'Or Pie XI pour 1986.

En présence des Académiciens Pontificaux, des représentants des Académies étrangères, des autres Institutions Culturelles et de nombreuses personnalités, l'Académicien Pontifical Prof. Giovanni Battista Marini-Bettòlo a développé une relation sur l'histoire et sur l'activité scientifique de l'Académie.

Le Prof. Carlo Pietrangeli, Directeur des Monuments, Musées et Galeries Pontificales, a ensuite tenu une conférence consacrée aux aspects artistiques de la Casina Pie IV, siège de l'Académie.

La séance de la matinée s'est terminée par la communication scientifique du professeur Elizabeth Anna Bernays, «Medaille d'Or Pie XI» pour 1986, qui a reçu cette distinction pour les recherches et études réalisées dans le domaine de l'écologie et de l'entomologie. Le prof. Elizabeth Anna Bernays est née le 31 décembre 1940 à Chinchilla, dans le Queensland en Australie; elle réside maintenant aux Etats Unis où elle exerce son activité scientifique au «College of Natural Resources - Agricultural Experiment Station, Division of Biological Control» de l'Université de Californie à Albany, et est professeur d'entomologie à l'Université de California à Berkeley.

Les travaux de la séance de l'après-midi ont été ouverts par une brève présentation par le prof. Carlos Chagas qui a illustré le thème de cette Session Plénière: «Le Progrès de la science et l'avenir de l'humanité».

Ont alors pris la parole les académiciens pontificaux: les professeurs Anatole Abragam, Rudolf Mössbauer, Carlo Rubbia et André Lichnerowicz qui sont intervenus sur le sujet proposé en relation avec leurs disciplines scientifiques respectives.

Giovanni Battista Marini-Bettòlo

HISTORICAL ASPECT OF THE PONTIFICAL ACADEMY OF SCIENCES

In the last year many colleagues from various countries, invited to join us for the celebration of the fiftieth anniversary of the Pontifical Academy of Sciences, have expressed their amazement realizing that our Academy was only established in 1936.

This is the reason I have been asked by the President to present to the audience a rapid sketch of the main lines of the very particular history of our Academy.

Just in this room two marble inscriptions condense in very few Latin sentences all the history of the Academy. I thought that this would be the best guideline for my presentation of the main events which have characterized the evolution of the Academy since its foundation.

To better understand the history of the Academy I wish to recall that Italy was a nation since the tenth century but that only in 1861 it became a state, as Regno d'Italia, under Vittorio Emanuele II, which even did not include the Pontifical States, which were annexed in 1870. Italy was in fact, since the fall of the Roman Empire in the IV century, divided into many States, e.g., in the XIX century the Pontifical States, the Kingdom of Naples, the Republic of Venice, the Grand-Dukedom of Tuscany, the Austrian Dominion over Lombardy, the Kingdom of Sardinia, including Piedmont, the Dukedoms of Parma and of Modena.

The Foundation

About the foundation, the inscription says: "*Lyncaeorum Academia a Friderico Cesi Principe fundata MDCIII*". This means that the foundation took place in 1603 on the initiative of Federico Cesi and his fellows, John Heck, Francesco Stelluti and Anastasio de Filiis, in Rome.

Federico Cesi was the son of the Duke of Acquasparta, a Roman prince of great power and authority, and was at that time only 18 years old. His colleagues were also very young, the eldest being Heck, a Dutch medical doctor graduated from Perugia, who was 27 years old.

The Academy founded by Cesi and his colleagues must be considered the first Academy with exclusively scientific interests, that is, the first scientific Academy of the world.

The idea of an Academy was rather common during the Renaissance in Italy. On the model of the Platonic Aristotelian school of Athens in the IV-III Century B.C. — gathering in the garden of Academus in Athens — in the 15th century many Academies were founded in Italy, the first being in 1459, the Platonic Academy of Marsilio Ficino in Florence, during the great revival of Greek learning in Western Europe after the conquest of Constantinople by the Turks. The scope of these Academies was to debate about philosophy, literature, history and other fine arts, as an expression of a world finding again after a long period its ancient cultural roots.

Cesi's Academy was completely different in its scope; the name given is already a program in itself: Lincei, from the Lynx, considered to possess the sharpest vision of all animals, because the Lincei should rely only on the "acute observation of nature and its phenomena and on experimental work". Even more, according to the rule found in the famous manuscript, the Lyncaeographum, members should be faithful and pray before their work, but no religious, or philosophical or literary or even historical argument should form the object of their discussions and research [1].

The Lincei, interpreting the spirit and aim of their times, adopted a new form of collaboration between scientists in the Academy in order to understand nature according to the new inductive and later experimental method, and discover its laws. We know that their example was followed a few years later in many other countries. I might mention the Royal Society of London, founded in 1662, and the Académie des Sciences, established in Paris in 1666.

Even the first years of Cesi's efforts were not easy. Cesi's father

[1] *Lyncaeographum*, Cod. IV, Archivio Linceo. Biblioteca Accademia Nazionale dei Lincei.

was not very convinced of the experiments made by the four young persons in his palace in Rome, in the old palace still today dominating the houses between the Tiber and Piazza Navona, and suspecting necromancy or alchemy, he dispersed the group. But Federico had a firm character and clear ideas. A few years later — in 1609 — the four joined together again. New famous and influential scholars joined Cesi, and among the Italians, the famous Neapolitan scientist G.B. della Porta, the botanist Fabio Colonna, the Roman Virginio Cesarini, as well as Giovanni Ciampoli and Cardinal Francesco Barberini — all from Rome, which had a great influence in the Vatican — and above all Galileo Galilei, at the time already famous for his fundamental work in physics and astronomy.

Among the foreign members we recall Johannes Schreck, called Terrentius, and Johannes Schmidt, known as Faber, both Germans [2].

It is impossible to give here, even synthetically, the history of the first Lincei [3-7]. I should like only to mention the most important points of their short fruitful activity.

1. Going back to our inscription, we read "*inter primores socios a Galilaeo illustrata*". The Academy became famous because of Galileo, one of its first members. The work done by the Lincei supported Galileo's ideas on the solar system and the experimental method. The Lincei published in Italian the book *Il Saggiatore* (The Experimentalist), containing the most advanced ideas of Galileo on the experimental method. Moreover, they supported his position on the interpretation of the solar system, and so long as Ceci was alive, Galileo had nothing to fear. The dispute regarding Galileo was in effect a scientific dispute between two different schools, based on

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[2] *Proponimento Linceo*. Ann. 1603-1625. Vat. Lat., 9679-9684.

[3] B. ODESCALCHI, *Memorie istorico critiche dell'Accademia dei Lincei e del Principe Federico Cesi*. Roma, L.P. Salvioni, 1806.

[4] F. CANCELLIERI, *Memorie aneddote dell'Accademia Romana dei Lincei*. Ann. 1823. Vat. Lat., 9679-9683.

[5] G. GABRIELI, *L'orizzonte intellettuale e morale di Federico Cesi*. «Rend. R. Accademia dei Lincei», VI (5), 58-95 (1929).

[6] *Federico Cesi ed i Primi Lincei*. Catalogo della Mostra organizzata dalla Pontificia Academia Scientiarum e dalla Bibliotheca Apostolica Vaticana, Città del Vaticano, 1986.

[7] E. DI ROVASENDA and G.B. MARINI-BETTÒLO, *Federico Cesi nel IV Centenario della nascita*. «Scripta Varia», 63 (1986).

the rivalry between the two Roman universities of the Sapienza and the Collegio Romano.

The fellows of the Lincei had great admiration for Galileo as we can read in the work of Faber [8]. The new science began to affirm its position regarding the past knowledge.

2. The name of Lincei would have been only an empty expression if the Lincei, in the brief period from the foundation of the Academy to Cesi's death, had not discovered something with their keen vision and observation of nature. The lynx has no limitations in its view and the Lincei discovered the scientific use of two tools produced by the quasi-anonymous ingenuity of German or Dutch artisans, the *tubum opticum* or *occhialino* which they called *microscope*, and the *telescope* [9].

The microscope was used for the first time to examine the anatomy of insects (beginning with the bee, which was of particular interest at that time, as it was in the Barberini coat of arms of Pope Urbano VIII), as well as of plants and fungi. The first drawings made from the observation of nature with the microscope were made under the direction of Federico Cesi.

We all know of Galileo's use of the telescope in the discovery of the satellites of Jupiter and other celestial bodies, but perhaps not that of Federico Cesi, when, aware of the possibilities of this instrument, he ordered some artisans to construct a number of telescopes. Then he invited to a dinner on the Gianicolo hill the most distinguished scholars of Rome as well as the Aristotelian peripatetics, and asked them to look at the sky through the telescope to see the details that Aristotle had never imagined [10].

The microscope permitted the eye of the Lincei to penetrate what was very small; the telescope on the other hand opened up the

[8] «Sed quantulum est mi Plini quod... ille in Lunae facie observavit... si cum hoc... Galileaeum Galilaeum Lynceum comparate velint?» (*Thesaurus*, p. 462).

[9] «Vidimus ... ante pauculos dies domi meae per Tubum opticum mirae perspicuitatis artificiosissime elaboratum, a duobus Germanis ... quem a Telescopii imitatione et rerum minutarum conspectu *Microscopium* denominare libuit». (*Thesaurus*, p. 473).

[10] «Eodem tempore Lynceorum Princeps Ill. Federicus Cesius rumore tantum audito e Belgio, idipsum instrumentum composuit et inter complures in urbe Magnates distribuit, nomenque *Telescopii* excogitavit et indidit». (*Thesaurus*, p. 473).

immensity of the universe. The lynx had now really a very sharp vision. It remained in history.

3. Another aspect of the Lincei activity, intended as a cooperative effort, not an individual research, is its work in the botanical field. After Caesalpinus and before Linnaeus, the research in botany was done by Cesi and by Fabio Colonna on a very important advanced taxonomical basis. Cesi prepared for his *Theatrum Historiae naturalis* the *Phytosophical Tables*, one of the first attempts at a classification of plants, which included even some plants not known to Theophrastus, having been recently imported from the Americas. Colonna was the scientist who defined in botany the *genus*, the basis of modern taxonomy.

4. The scientific and cultural background of the first Lincei, animated by the "natural desire for knowledge" as expressed by Cesi, can be found in a collective volume published in 1628 by the Lincei with the baffling title of *Rerum Medicarum Novae Hispaniae Thesaurus* [11]. This book is not only a pharmacopoeia of Mexican drugs but an encyclopedia of the knowledge of the early XVII century in Europe in accordance with the new view of science produced by the experimental method. More than six hundred pages are devoted to natural history, observations, criticism of old theories and even to reports about contemporary events such as those quoted above regarding the microscope and the telescope. As far as I know, the book, which had great success and importance in its century, has not been translated from its difficult Renaissance Latin into a modern language. A full translation could be of great interest in order to make available to many people a knowledge of the Lincei and the history of science in a period characterized by Galileo, Bacon, Descartes and Kepler.

The name of the Lincei was very highly regarded among scientists of all Europe, being an international Academy. Thus European scholars were eager to participate in it, as for example, Sir Francis Bacon, whose name is in the list of the possible Lincei in the documents of the Academy [12].

With the death of Federico Cesi in 1630, the Academy lost its

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[11] G.B. Marini-Bettòlo, *Osservazioni e considerazioni sul Tesoro Messicano*. Atti dei Convegni Lincei, 1987 (in press).

[12] F. Cancellieri, *Indice Memorie anedotte dell'Accademia Romana dei Lincei*. «Giornale Arcadico», f. LV (1823).

Maecenas but also a scientist and man of wisdom, although in the hands of the extremely active Count Francesco Stelluti it did survive a few years. The Galileo trial in 1633 would not have occurred if Federico Cesi was living.

After 1651, the date of the last issue of the *Thesaurus*, the Academy was no longer a body. Only the glory of its name has remained through the centuries.

The sentences of the inscriptions mention the period between this date and the re-establishment in 1847 as: "*post variam temporum rerumque fortunam*".

The name of the Lincei was so famous that learned societies would have liked to adopt it. An attempt to resuscitate the Lincei was made in 1745 by a group of scientists in Rimini, on the Adriatic coast, among them Giovanni Paolo Bianchi, known as Joannes Plancus, Stefano Galli and Giuseppe Garampi. But this Academy had only an ephemeral life.

A more important and successful effort to reconstitute the Lincei was made in the early 1800s by Father Feliciano Scarpellini, in Rome, who gave the name of the Lincei to a private Academy he had founded in 1795. Lacking adequate financial support, this Academy had a rather difficult existence. Scarpellini had, however, the great merit of saving the name of the Lincei from oblivion after two centuries and gathering in a single academic body the most distinguished scientists, operating mainly in the Pontifical States. Among them I might mention the mathematician Fr. Chelini, the naturalist Carlo Bonaparte, the anatomist Flajani, the chemist Domenico Morichini, the learned Prince Baldassare Odescalchi, and Pietro Peretti, professor of pharmaceutical chemistry at the Sapienza, the physicists Gioacchino Pessuti and Paolo Volpicelli and the clinician Benedetto Viale [13].

The impact of science on society had at that time created the first industrial revolution with the introduction of steam machines: electricity was moving rapidly in creating new communication systems and chemistry was coming out of its infancy.

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[13] P. VOLPICELLI, *Sull'Accademia dei Lincei dal terzo suo risorgimento del 1795, sino alla governativa istituzione del 1847*. «Atti Pont. Accademia dei Nuovi Lincei», *1*, 10-79 (1847-1848).

Restoration

We come now to another sentence of the inscription: *Pii IX P.M. cura restituta MDCCCXLVII* (Restored by Pius IX in 1847). Pope Pius IX was very open to scientific problems (as student Mastai Ferretti he had published a scientific monograph on optics). In 1847 he restored the Lincei as the Pontifical Academy of the New Lincei, the official Academy of Sciences of the Pontifical States, with the scope of promoting science and advising the Government about the new technologies to be adopted, and even about the approval of industrial patents.

According to the Statutes, the Academy had 30 ordinary resident members and 40 correspondents. The Statutes provided that the Academy "will promote the study, the progress and the development of sciences, with the exception of theology, moral sciences, medical sciences and political sciences". The Academy should also «promote knowledge and, through the techniques based on it, the activities and industries related to these sciences".

It should also, when requested, help the government and society with its knowledge and the results of research. For its time it was a very advanced Academy having direct interaction with the developing society.

The Pope assigned to the Academy as its seat the second floor of the Palazzo Senatorio on the Capitol in Rome.

Consisting mainly of the members of the Lincei's former academy of Father Scarpellini, having, among others, such distinguished astronomers as Father Francesco de Vico, Father Angelo Secchi and Prince Baldassare Boncompagni, one of the most interesting personalities in the field of natural sciences in Italy, the Academy began to work. One of its first tasks was the introduction of the metric system in the Pontifical States [14].

One year later, in 1848, the national revolution in Italy brought changes into Rome, where the Roman Republic was established, with Mazzini and Garibaldi, two of its best known political and military representatives. During the first months the Academy was not disturbed by the Roman Republic. Even Garibaldi asked for an assessment on a water supply problem during the siege of Rome by the French army. Later the Republican Government asked the

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[14] Atti Accademia Pontificia dei Nuovi Lincei, II, *10* (1849).

Academy to leave its seat on the Capitol [15]. The Academy resisted by bureaucratic tactics, which enabled it to remain at the Capitol until the restoration of the Papal Government in 1849 after the intervention of the French and Austrian Armies in the Pontifical States.

In the Proceedings of the Academy we find some interesting remarks about the dispute with the Republican Government about its request that the Academy sign a document accepting the new State. The Academy delayed the aswer so that a few months later they could write: "We did not obey the anarchist government" [16].

The Academy continued its scientific work during the years between 1849 and 1870. It was rather modern in its ideas; as an example, in 1856 a lady, Countess Fiorini, professor of botany in Rome, was elected to membership. The work of astronomers like Father Secchi and Lorenzo Respighi was outstanding; the modern classification of the stars according to their spectrum was proposed. The *Acta* and *Commentationes* of this period are rich in important scientific material, especially regarding the observation of the sun.

Meanwhile the political unification of Italy under King Victor Emanuel II proceeded at a growing rhythm. In 1859 practically all of north and central Italy except Venice united with the Kingdom of Sardinia. In 1860 came the annexation of Naples and Sicily; in 1866, after the Austrian-Prussian War, the Venetian territories also were annexed. In 1870 the Italian *Bersaglieri* broke into Rome. The Pope retired to the Vatican, the Pontifical State was abolished and Rome, after a plebiscite, was annexed to the Kingdom of Italy, becoming its capital.

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We are now at a new stage of the Academy's evolution, which is not mentioned in the inscription, but which is rather important for its history and becomes known from a reading of the proceedings of the Academy.

Like all the governmental bodies belonging to the Pontifical States, the Academy became nationalized in 1870 and changed its name from Pontifical to Royal; i.e., the Pontifical Academy of the

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[15] Atti Accademia Pontificia dei Nuovi Lincei, II, *9*, *14*, *16*, *17* (1849).
[16] Atti Accademia Pontificia dei Nuovi Lincei, I, *9* (1848).

Nuovi Lincei, through the intervention of the Commissioner of Education of the Italian Government, the mathematician Francesco Brioschi, a brilliant scientist from Milan, became the Royal Academy of the Lincei.

At this point, after some days of confusion, there was a division of the Academicians: of the 25 members, 14 accepted to become members of the Royal Academy, but the other 11 did not want to abandon Pope Pius IX and confirmed their adherence to the Statutes of 1847 and their loyalty to the Pope, thus preserving the continuity and tradition of the Pontifical Academy of the Nuovi Lincei [17]. From this point on, there were two Academies of the Lincei in Rome.

Through the intervention of the famous mineralogist and economist Quintino Sella, Minister of Finance, the Royal Academy of the Lincei was recognized as the national academy of science of Italy, and changed its Statutes, incorporating a class of moral sciences. The seat was moved from the Capitol to the beautiful Palazzo Corsini at La Lungara [18]. The Nuovi Lincei were lodged

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[17] Atti Accademia Pontificia dei Nuovi Lincei, XXIV, *52* (1871), «I convenuti lamentando che taluni colleghi, abbandonando lo Statuto Accademico, abbiano mutato arbitrariamente il titolo dell'Accademia, né potendo trovare giusto questo fatto né mostrarsi ingrati al munificientissimo Restitutore e nuovo Fondatore dell'Accademia, e perciò volendo mantenere i diritti dei quali si trovano legittimamente investiti quali membri ordinari della Pontificia Accademia dei Nuovi Lincei, pregano unanimamente l'Em.o Card. Protettore perché volesse farsi interprete dei loro sentimenti ed intenzioni presso il Santo Padre...».

[*Proceedings, Pontifical Academy of the New Lincei, XXIV, 52 (1871), «The participants, regretting that certain colleagues have abandoned the Statute of the Academy and arbitrarily changed the name of the Academy, not considering this just, nor wishing to be ungrateful to the very munificent restorer and new Founder of the Academy, and wishing therefore to keep the rights which they legitimately have as ordinary members of the Pontifical Academy of the New Lincei, unanimously request the Eminent Cardinal Protector to convey these their wishes and intentions to the Holy Father...»*].

[18] Atti Reale Accademia dei Lincei, XXIV, *115* (1870), Approvazione della proposta di Terenzio Mamiani di includere le scienze morali e filosofiche nell'Accademia. Ibid., p. 462, April 6, 1872: «lo scisma, fatto da quei lincei, che confondendo la scienza con la politica, si ricusarono di fare parte dell'Accademia nostra; perché la medesima dovette cangiare in reale la denominazione pontificia lo che avvenne in ogni altro stabilimento governativo».

[*Proceedings of the Royal Accademy of the Lincei, XXIV,* 115 *(1870), Approval of the Proposal by Terenzio Mamiani to include the moral and*

for about 50 years in different historical buildings of Rome, property of the Holy See, like the Propaganda Fide and the Palace of the Apostolic Chancellery. In these years the Pontifical Academy had difficulty in developing its action for the progress of science.

Coming back to the inscription, it is mentioned that in 1922 Pius XI gave to the Academy as its seat the Casina of Pius IV, where we now are: "*Villula Pii. IV P.M. sede propria donavit*".

During these years, under Father Giuseppe Gianfranceschi, professor of physics at the Gregorian University and President of the Academy since 1921, the Academy took on a different form, and in 1923 changed its name to Pontifical Academy of Sciences - New Lincei. Gianfranceschi began to appoint foreign members to give it an international character. Famous Italian scientists were also appointed, such as Guglielmo Marconi, Tullio Levi-Civita and Vito Volterra.

After years of diplomatic work, the political events led to the reconciliation between the Italian Government and the Holy See on February 11, 1929, by the Treaty of the Lateran. The Città del Vaticano was recognized as an independent State, seat of the Holy See.

Most probably, among the various problems discussed during the diplomatic negotiations leading to the Treaty, there was also the definition of the two Academies originating from the Lincei tradition. The Pontifical Nuovi Lincei were to be renewed according to the worldwide interest of the Holy See. Father Gianfranceschi devoted himself to this difficult task under the direct supervision of Pius XI. Gianfranceschi, the last President of the Nuovi Lincei, died in 1934 before the end of his work. Father Agostino Gemelli was appointed the new President and followed the work.

On October 28, 1936, Pius XI issued his *Motu proprio* establishing the Pontifical Academy of Sciences as a "Collegium" of Scientists, but also as a kind of scientific senate of the Holy See, as we see from the other inscription in this room: *Collegium et quasi senatum doctorum hominum Naturae viribus cognoscendis illustrandis Feliciter instauravit Pontificiam Scientiarum Academiam.*

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philosophical sciences in the Academy. Ibid., p. 462, *April 6th, 1872: «the schism, caused by those Lincei who, confusing science and politics, refused to become part of our Academy; therefore the latter had to change the Pontifical title to Royal, which occurred in every other governmental establishment.»*].

The Academy now became international and began its work for the progress of science and the benefit of humankind. At first great difficulties, due to World War II, hindered the start of its activity.

Since 1949 Plenary Sessions and restricted meetings for the study of particular arguments began to take place regularly — Study Weeks and later also Working Groups, — formed by Academicians and other scientists from the international community.

The Academy, under the chairmanship of Father Gemelli, Georges Lemaître, Daniel O'Connell and now of Carlos Chagas, has followed and interpreted the evolution of science and its impact on our society, centering its debates and works on the most important scientific problems of our times.

Five main lines have been followed in these years:

— Fundamental science.
— Science and technologies for global problems.
— Science for the problems of the Third World.
— Scientific policy.
— Bioethics.

An important aspect of the Academy's activity is its action for peace.

It would be too long, at this moment, to say more about the Academy's work. I have tried to summarize it in a booklet which you will receive now. You can find there a chronology of facts and the highlights of its activities in these years [19].

Allow me only to read the conclusions — written for this booklet — which resume and comment the work done and our future goals:

"During its fifty years of activity, the Pontifical Academy of Sciences has always been an important point of reference and a forum for the world scientific community to study the problems of basic science, and to promote initiatives to put science at the service of humanity.

"While its seat has remained in the beautiful Casina Pio IV in the Vatican gardens, its activity today extends to the whole world, without limits.

"An Academy of great prestige — because of its ancient tradition and its present representativity — it has come out from its

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[19] G.B. Marino-Bettòlo, *Oulines of the Activity of the Pontifical Academy of Sciences* (1936-1986). «Scripta Varia», *67* (1986).

ivory tower, combining with the 'natural desire to know' (Cesi's heritage to all Academies), the study and probing of the great problems of the contemporary world, which it approaches with its scientific experience and with profound wisdom.

"Science can indeed conquer hunger and disease, by furnishing means to combat them, and promote the development of peoples, also with regard to the environment.

"In its zeal for truth and good, the Academy has also, in its highly qualified role, raised ethical and moral problems concerning scientific research — not only in areas such as those regarding life processes but also in the problems of transferring, sometimes too rapidly, the discoveries, of science to a society often unprepared to receive them, either on the individual or global level.

"In recent years the Academy, with a great step forward, has added the weight of its undisputable prestige and that of its members to the opposition to the wrong use of scientific discoveries, especially in the development of new armaments such as nuclear weapons, in its endeavor to assure peace to the world and to avoid the woeful equilibria based on mutual deterrence.

"Hope and anxiety today illuminate and shade our future.

"The Academy is now entering its second half-century — which coincides with the beginning of the third millennium of our Christian era — and it will promote with an always vigilant spirit the progress of science, directing it to the search of truth and the benefit of mankind".

Bronze Medal in honour of Federico Cesi. On the reverse the figure of the Lynx with the inscription «Linceis institutis» recalling the foundation of the Academy (Biblioteca Apostolica Vaticana - Medagliere XXVIII, 15).

Carlo PIETRANGELI

LA CASINA PIE IV AU VATICAN

Depuis la Renaissance, les Pontifes ont éprouvé le besoin de disposer d'un siège alternatif au Palais du Vatican où, loin du faste de la cour, ils pouvaient jouir de quelques heures de repos, adapté aussi à la méditation religieuse et pour bénéficier également d'un climat plus agréable et d'un paysage plus reposant que l'habituel.

C'est ainsi qu'Innocent III fit construire par Pollaiuolo un édifice sur la hauteur du Belvédère, donnant sur la verte colline du Monte Mario; il fut aggrandi par Jules III, de l'oeuvre de Pirro Ligorio, architecte de génie, archéologue et antiquaire napolitain (Naples 1510-Ferrare 1583). C'est le même qui, comme «architecte de palais» créera pour Paul IV Carafa, dans le cadre des jardins du Vatican, la dite «Casina del Boschetto», la villette du bosquet qui fut menée à terme, moyennant des modifications profondes de la conception originale tant au point de vue architectonique que décorative, par son successeur Pie IV. L'édifice, avec ses agrandissements successifs, est celui où nous nous trouvons aujourd'hui.

Comme il est attesté par la vaste documentation d'archives, la construction de la Casina commença en 1558 et se limitait au seul rez-de-chaussée; il s'agissait donc d'un bâtiment à un seul étage, avec une terrasse devant et une fontaine; dans l'ensemble, une structure plutôt modeste et austère qui convenait au caractère ascétique du Pape Carafa; un lieu de méditation au milieu de la verdure que l'on disait inspiré par une villa romaine retrouvée près du lac de Castiglione (Gabii).

L'édifice fut mené plus avant si bien que le nom du pontife, corrigé successivement, se lit encore gravé dans l'inscription qui surmonte le portique d'entrée.

Après la mort de Paul IV (18 août 1559), un nouveau plan fut étudié par Pirro Ligorio entre janvier et mai 1560, un plan beaucoup plus élaboré qui constitue non seulement la *somme* de la culture

archéologique de l'artiste mais aussi celle de la politique idéologique et de la formation humaniste du nouveau pontife; de ces éléments s'inspire toute la décoration dans laquelle les études récentes de Graham Smith et surtout de Marcello Fagiolo et Maria Luisa Madonna ont identifié toute une série d'allégories complexes et géniales, dans lesquelles je ne voudrais pas m'engager pour ne pas allonger excessivement ma présentation du monument qui veut surtout donner une idée générale de l'édifice dont la construction, reprise par Pie IV, fut réalisée entre 1550 et 1561 et menée à terme, dans toutes ses parties, à la fin de 1562.

La Casina dite de Pie IV est constituée d'une cour ouverte vers l'extérieur, sur le bosquet environnant comme l'étaient les villas romaines avec leurs portiques.

La cour, de forme ovale, dans laquelle on a voulu voir l'écho d'une naumachie romaine, réévoquée par la culture archéologique de la Renaissance, est la clef de voûte autour de laquelle s'organisent, pour ainsi dire, tous les édifices qui constituent l'ensemble: le principal, à deux étages, qui s'ouvre par un portique sur la cour elle-même; derrière le portique, il y a une grande salle, une petite salle, une chapelle et la cage d'escalier; le plan se répète, avec peu de variantes, au premier étage.

En face de l'édifice principal, se trouve une loggia à double portique qui donne par un côté sur *le jardin* et de l'autre, domine, du haut, *les jardins*.

Aux deux extrémités de l'ovale, se trouvent deux accès vers l'extérieur, de forme monumentale: ce sont deux propylées à l'architecture élaborée et somptueusement décorés.

Dans cette architecture, on a voulu voir la reconstruction sur un mode renaissant, d'une villa romaine; il ne faut donc pas négliger les relations avec l'architecture de la Renaissance; il suffit de penser au Nymphée de la villa Giulia d'Ammannati.

La décoration également, qui à l'extérieur est de caractère à prédominance mythologique et à l'intérieur à sujet plus typiquement religieux, évoque des motifs renaissants; par exemple en ce qui concerne l'extérieur, les façades gravées et peintes et celles décorées de sculptures antiques et de stucs: je signale, entre toutes, celles des villas Medicis et Pamphili.

A présent, essayons de visiter ensemble les différentes parties de l'édifice.

La Loggia

La façade s'ouvre sur la cour par un portique à colonnes de granit oriental, sur les côtés duquel se trouvent deux panneaux décorés de têtes de Méduse; au-dessus, il y a un haut attique couronné d'un tympan.

Aux extrémités de l'attique, se dressent deux cariatides; en allant vers le centre, deux fausses fenêtres richement encandrées de personnifications de la *Vérité* et de *Mnémosyne*, mère des Muses.

Suivent deux panneaux avec les représentations des *Muses* et d'*Apollon* et de *deux figures* extraites du thiasos bachique; au centre, dans une fausse fenêtre surmontée du blason de Pie IV, se dresse une *figure féminine* qui soutient un masque sur lequel on lit l'inscription *Pierius*, faisant allusion au mont de la Thessalie où naquirent les Muses de l'union de Jupiter et de Mnémosyne; l'attribut du masque ferait penser à *Calliope*.

Dans le tympan, l'*Aurore* sur le char du Soleil tiré par les quatre chevaux mythiques dont les noms figurent sous chacun d'entre eux; autour se disposent les signes du zodiaque, *Flore* et une autre figure féminine, *Pomone*.

Le fronton est couronné, en guise d'acrotère, par une statue antique de *Salus*.

Sur chacun des flancs, une fenêtre à laquelle est superposé le même attique flanqué de cariatides, comme sur la face.

Dans le grand panneau de stuc apparaît une figure féminine, l'*Aurore*, à côté d'une figure masculine étendue dans un berceau, figure où il faut reconnaître son mari, *Titeon*, qui tient une lyre en main.

Dans le tympan courbe superposé, revient encore l'*Aurore* sur le char qui se dirige vers une divinité fluviale en qui on a voulu reconnaître *Apollon*. Le motif assez fréquent de l'Aurore, ferait allusion à l'apparition d'une ère nouvelle avec l'avènement de Pie IV.

Du côte opposé, dans le panneau flanqué de cariatides, se trouve *Jupiter enfant élevé par la chèvre Amalthée*, sur le mont Ida.

La corne d'abondance, attribut d'Amalthée, se rattache au mythique âge d'or; Pie IV avait été élu pontife sous le signe du capricorne; la présence du blason du Pape évoque donc le retour de l'âge d'or, avec son avènement au trône.

Sur le tympan supérieur, outre le blason déjà mentionné, il y a

ceux d'Urbain VIII et de l'un des cardinaux Barberini, évoquant une restauration.

Sur la façade donnant sur le jardin, le portique, dont nous avons déjà parlé, est surmonté d'une longue inscription; en dessous, se trouve un vivier modifié au 18ème siècle.

Trois statues féminines assises, antiques, se reflètent dans l'eau; la plus intéressante, au centre, représente Cybèle et fut acquise en 1561 de la collection du sculpteur Nicolò Longhi; elle a été restaurée récemment, la partie supérieure n'est pas antique mais offre un splendide exemple de restauration du 16ème siècle.

Entre les niches, jusqu'au siècle dernier (ou peut-être même au début de l'actuel), il y avait de grands bifrons en stuc, de *Pan*, sous forme de cariatides; on n'en a pas de photographies, mais ils sont représentés dans les vieilles gravures. Maintenant, ils n'existent plus et ont été substitués par des surfaces mosaïquées. Toute la décoration stuquée de l'extérieur de la loggia a été exécutée entre 1560 et 1561 par un stuqueur cité dans les documents sous le nom de «mastro Rocco» qui est à identifier à Rocco da Montefiascone.

L'intérieur de la loggia, avec des pavements de marbres antiques exécutés par le tailleur de pierre Nicolò Bresciano, est très élaboré, riche en stucs et en peintures, oeuvre de Féderico Zuccari (Vasari: «le même Federico Zuccari peignit en ce lieu, la logette qui donne sur le vivier») et du Borghini qui rappelle que le même peignit quelques historiettes de Vénus et Adonis, et la naissance de Bacchus et autres fables, de manière charmante.

Zuccari (1542-1609) venu à Rome de sa ville natale S. Angelo in Vado en 1550, fut d'abord collaborateur de son frère aîné Taddeo et ensuite il assuma une position autonome à son égard; c'est un des principaux représentants du maniérisme romain du 16ème siècle.

Au centre de la voûte, trois scènes qui se rapportent à l'*exode des Hébreux de l'Egypte*, le *passage de la Mer Rouge, Moïse et Aaron devant le Pharaon*.

Sur les côtés de la voûte, la décoration stuquée prédomine et alterne avec des scènes figuratives se rapportant au *mythe d'Adonis*.

La loggia se termine par deux absides éclairées par les fenêtres déjà décrites à l'extérieur, qui sont flanquées de niches contenant des statues antiques; devant chaque niche, se dresse une très gracieuse fontaine qui porte sur la base de la vasque le blason de Pie IV.

Les propylées d'entrée

A l'extrémité de l'ovale de la cour, deux entrées entièrement décorées de mosaïques (très restaurées), de stucs et de statues.

Les quatre figures de jeunes qui surmontent les candélabres en guise de chapiteaux représentent les *quatre saisons*.

A l'intérieur, au-dessus de la décoration en mosaïque, où se répètent des motifs marins, les voûtes portent toutes des décorations en stuc.

A l'intériur du propylée de gauche, sont représentés *Diane et Actéon*, le *rapt de Déjanire*, la *naissance de Vénus* et *Latone avec les bergers Lyciens*.

Dans le propylée de droite figurent: *Persée délivrant Andromède, le rapt d'Europe, le triomphe de Neptune* et celui de *Galatée*.

Toutes les scènes mythologiques représentées en stuc sont reliées par le motif de l'eau, que nous avons déjà rencontré dans les mosaïques.

La place

Elle est de plan ovale, avec un pavement à motifs et au centre, une vasque de «marbre taraudé» décorée de deux putti chevauchant des dauphins, exécutés par Iacopo da Casignola et Giovanni da Sant'Agata (1560-1565).

La décoration des vases qui surmontent les sièges banquettes est d'époque récente (19ème siècle?); autrefois, il y avait des bustes et plus avant encore, peut-être certaines des nombreuses statues qui furent enlevées à l'époque de Pie V.

La très riche décoration de sculptures antiques qui caractérisait autrefois aussi bien l'intérieur que l'extérieur de la Casina est réduite aujourd'hui à très peu d'exemplaires; le reste a disparu.

Pie IV avait acquis beaucoup de sculptures par le commerce des antiquités, puisant également aux fouilles pour les précieux matériaux colorés.

La petite Villa

La façade comporte deux étages dont l'inférieur comprend également le haut attique surmontant le portique, et l'étage supérieur est caractérisé par trois fenêtres flanquées de cariatides et de

niches contenant des statues antiques. Sur les côtés du portique, il y a deux panneaux, symétriques à ceux de la loggia d'en face.

Sur le portique s'étend un bandeau avec une inscription de Pie IV qui est un palimpseste en tant qu'on y lit en dessous le nom de Paul IV.

A l'extrémité de l'attique, apparaissent deux figures que l'on identifie à Pan et Cyparis (ou Olympe); au-dessus, deux médaillons avec des divinités fluviales allongées.

La partie centrale de la composition décorative, encadrée de candélabres à enroulements, porte au centre le blason du Pape soutenu par deux anges et en-dessous de ceux-ci, ceux de quatre cardinaux créés par lui (Charles Borromeo, Jean Antoine Serbelloni, Jean de Medicis et Pier Francesco Ferreri) et de deux dignitaires de cour, parents du Pape: un Borromée et un Serbelloni. Dans les deux panneaux, sur les côtés du blason papal, se trouvent deux fausses niches avec des figures féminines; à droite *les Heures* (filles d'Apollon et de Eglé identifiées sous les noms d'Eirené (La Paix), Dice (La Justice) Eunomye (le bon gouvernement), qui pouvaient représenter soit les saisons, soit le présent, le passé et le futur; à gauche *Apollon* et *Eglé*.

L'espace supérieur est occupé par la grande inscription de dédicace qui rappelle, en un latin élégant, comment Pie IV «construisit et décora cette place dans le bosquet du palais apostolique, avec le portique, la fontaine et le bâtiment pour son usage personnel et celui de ses successeurs en l'année 1561».

Dans l'attique qui surmonte le premier étage, on voit deux médaillons ovales dans lesquels sont représentées la *Renommée* et la *Paix*, toutes deux sur des globes; elles alternent avec des panneaux de motifs floraux sur lesquels se superposent une amphore et deux patères.

A présent, en entrant dans la petite villa, on trouve d'abord la

Galerie inférieure

La voûte est en stucs et peintures; les parois sont recouvertes de mosaïques composées de plusieurs matériaux; le pavement est de marbres colorés.

Sur la voûte sont représentées les *épisodes de la création* et d'*Adam* (admonition des premiers parents, création d'Adam, Adam

cueille la pomme de l'arbre); ce sont des oeuvres du vénétien Giovanni da Cherso.

De la même main sont les peintures des deux niches à l'extrémité, avec des *histoires de Moïse* (Moïse qui frappe la roche, récolte la manne etc...). Les niches de cette loggia sont également décorées de très élégantes fontaines.

Le salon

C'est l'endroit le plus prestigieux de la Casina.

La voûte est richement décorée de stucs et de peintures; sur les petits côtés, on aperçoit des blasons en stuc de Pie IV soutenus par des putti; aux quatre angles, quatre écussons ovales portant le nom du pontife, tenus par des allégories relatives à ses vertus et surmontés par une Artémis d'Ephèse.

Ensuite, la voûte est divisée en bandeaux par des candélabres en une série de panneaux avec de petites figures, d'oiseaux et de groupes d'amours. Chacun de ces oiseaux constitue un ravissant élément décoratif.

Dans les bandes, à la base de la voûte, on voit des paysages de forme allongée, d'autres scènes sont au centre de la voûte et des longs côtés.

Au centre de la voûte: *la Sainte Famille* avec *saint Jean, sainte Anne et saint Joachim*; sont également représentés *le baptême du Christ, la vocation de saint Pierre, la Samaritaine au puits, le Christ et la femme adultère.*

La voûte est l'exemple le plus significatif de l'activité de jeunesse de Federico Barocci (1528-1612), avec l'assistance d'un aide, probablement Pierleone Genga. Zuccari fond des modes picturaux repris à Corrège avec des motifs dérivant de Raphaël.

La description de Bellori dans la vie de Barocci est précise: «Il peignit aux quatre angles d'une chambre, les vertus assises et chacune d'elle tient un écusson avec le nom du Pontife et il y a des putti dans la frise».

Au milieu de la voûte figurait la Vierge avec l'Enfant Jésus qui tend puérilement la main vers saint Jean enfant, dans le geste de lui présenter la croix faite de canne; saint Joseph et sainte Elisabeth sont également présents.

La voûte fait actuellement l'objet d'une restauration qui restitue à l'ensemble une fraîcheur extraordinaire des couleurs, éliminant les

taches blanches dues à de vieilles infiltrations d'eau qui avaient obscurci presque complètement la lecture de certaines parties.

Deuxième Salle (dite de l'Annonciation)

La salle est carrée; aux quatre angles, groupes de figures féminines en stuc; stucs et peintures s'alternent dans la décoration, la rendant très riche. Dans les panneaux peints, *histoire de Joseph, l'hébreu*; dans les ovales, *scènes de la vie de Moïse*, au centre de chaque côté, une grande scène allégorique, tandis qu'au centre de la voûte, on observe une charmante *Annonciation*, oeuvre certaine de Barocci comme l'atteste également Bellori. Le reste est probablement dû à Pierleone Genga.

La chapelle

La nouvelle chapelle remplace probablement un ancien endroit réservé au culte; la voûte est décorée de stucs et de peintures et certaines de celles-ci, avec des figures d'apôtres, semblent avoir été enlevées dans le passé.

L'escalier

Un escalier aménagé dans l'une des trois pièces, à l'arrière du salon, conduit au premier étage.

Sur la voûte, des fresques sont attribuées à Santi di Tito (1536-1623) représentant de la seconde génération des maniéristes florentins, arrivé à Rome, venant de Florence, en 1558; est mis en page un ensemble de rectangles à angles arrondis et de médaillons ovales, entre lesquels apparaît le blason papal en stuc.

Dans les oves, apparaissent les *quatre saisons* et dans les espaces rectangulaires, des scènes de genre qui ont pour fond quatre monuments créés sous Pie IV: *la cour du Belvedère, la Porte du Peuple* avec la rue Flaminia; les *dyoscures de Montecavallo* et la rue Pia et la *villa Pia* où nous nous trouvons aujourd'hui.

Au premier étage, la première pièce et le salon n'ont pas de décoration, mais en revanche, la salle au-dessus de la chapelle, appelée aujourd'hui Salle de Santi di Tito, est bien décorée. Ici, on revient à la très riche décoration de l'étage inférieur, avec stucs et peintures; dans les angles, *huit vertus* flanquent le blason papal ou les symboles de l'Eglise modelés en stuc.

Au centre, dans un ove, *Jésus au jardin de Gethsémani*; dans d'autres panneaux, la *Tentation dans le désert, la Transfiguration, le Dernier Repas, le Christ sur le chemin du Calvaire.*

L'attribution des fresques est discutée; l'hypothèse la plus plausible est qu'elles seraient l'oeuvre de Giovanni Ricci et de Galeazzo Guidone (Friedlander) d'après des dessins de Federico Zuccari (Smith).

La galerie au-dessus du portique est dite

Salle de la sainte famille

La dénomination est inspirée de la fresque au centre de la voûte. La décoration de la salle rappelle celle des loges de Raphaël ou celle de la Stufetta du cardinal Bibbiena, tant sont nombreuses les influences de style antiquisant que l'on y observe.

Il s'agit probablement d'un ensemble conçu par Federico Zuccari et réalisé par Giovanni da Cherso.

Dans les lunettes des extrémités, se trouvent des perspectives architectoniques avec des figures en stuc qui flanquent un blason de Grégoire XIV (1590-1591), un pape qui n'a régné que quelques mois mais a réussi à laisser ses traces sur de nombreux endroits du Vatican.

Dans la partie inférieure, on observe douze bandeaux du temps de Grégoire XIV, avec des motifs de grotesques exécutés par Fabiano di Riofreddo, l'auteur des copies des loges de Raphaël qui existent dans la Salle des Dames au palais du Vatican.

Pie IV ne jouit pas longtemps de cette «délice» vaticane; il mourut, en effet, le 9 décembre 1565.

Après sa mort, survinrent des faits qui ne furent pas toujours favorables à la Casina du bosquet. Pie V (1566-1572), dans les rigueurs de la Contre-réforme, voulut la débarrasser d'une grande partie des statues d'origine classique qui la décoraient («sunt idola antiqua» disait-il); presque toutes les sculptures furent alors données au Grand duc de Toscane. Peu à peu, l'intérêt des papes allait en s'affaiblissant, à l'avantage d'autres demeures qui surgissaient dans des endroits plus plaisants; d'abord le palais et la villa sur le Quirinale, ensuite la résidence d'été de Castel Gandolfo.

Autour de la Casina, se développa alors ce que l'on appelait, à cette époque, «le jardin des simples», c'est-à-dire le jardin botanique où poussaient les plantes médicinales qui, depuis le moyen-âge,

étaient cultivées au Vatican sur le mont S. Egidio, dans le jardin botanique le plus ancien existant en Italie.

Ici, par disposition de saint Pie V, opérait Michel Mercati, l'auteur génial de la «Métallothèque Vaticane» qui fut le premier «herboriste de Notre Seigneur».

Mercati était en relation avec d'autres naturalistes italiens fameux, parmi lesquels Ulysse Aldovrandi, avec qui il échangeait des exemplaires de plantes rares pour enrichir le jardin du Vatican.

Il fut pourvu d'un sauf-conduit qui recommandait «de ne pas molester, mais au contraire de prêter toute aide et assistance à M. Michel Mercati, herboriste de Notre Seigneur, qui va faire provision de simples et les arrache en des lieux différents».

Le jardin botanique du Vatican fut lié pendant près d'un siècle, à la chaire universitaire de botanique de la Sapienza et cela fut vrai aussi longtemps que l'Université n'eût pas son propre jardin botanique sur le Janicule (1660).

Après Mercati, s'alternèrent à la chaire universitaire et à la conservation du jardin, Andrea Bacci da S. Elpidio et Castore Durante de Gualdo Tadino et l'académicien des Lincei Giovanni Faber da Bamberga qui allait se procurer des exemplaires de plantes rares sur les monts Abruzzes, et Antonio Nani da Narni et Pietro Castelli qui alla ensuite enseigner à Messine.

Après la création du jardin sur le Janicule, le jardin botanique du Vatican commença à décliner, si bien qu'en 1768 Clément XIII fit abaisser le terrain, le fit orner d'espaliers de buis, avec des dessins et des vases d'agrumes; il agrandit le vivier et créa autour la place des obélisques que l'on atteint par deux bordures en ciseaux sur les côtés de la loggia de la Casina. Le réalisateur de la nouvelle sustentation qui est encore conservée, fut l'architecte pontifical Paolo Posi.

Mais désormais, la Casina du bosquet était tombée en décadence, de sorte que Léon XII, en 1823-24, y fit exécuter diverses restaurations, spécialement à la façade au-dessus du vivier, comme le rappelle une inscription.

Grégoire XVI s'intéressa de nouveau à la Casina, qui fut nouvellement meublée et transformée en 1832 en un musée accueillant spécialement les collections de terres cuites ayant appartenu au Comte Seroux d'Agincourt et à Antonio Canova.

L'histoire de la Casina se poursuit sans évènements d'importance particulière jusqu'à une époque plus récente quand, en 1922,

Pie XI voulut destiner cette splendide demeure au siège de l'Académie Pontificale des Sciences.

Le corps postérieur fut alors construit: dessiné par l'architecte Giuseppe Momo, il comprend aussi le salon où nous nous trouvons aujourd'hui, et les décorations furent restaurées, particulièrement celles en stuc et en mosaïque.

Ce fut certainement un choix heureux, tant par la beauté de l'endroit que par la noblesse de la construction et de sa décoration, mais aussi parce que les sciences se remirent à vivre là où avaient opéré, voici quelques siècles, Michel Mercati, Castore Durante, Giovanni Faber et d'autres savants illustres qui, aux 16ème et 17ème siècles, avaient entretenu le «jardin des simples de Notre Seigneur».

Elizabeth A. Bernays

PHYSIOLOGY AND BEHAVIOR IN THE STUDY OF INSECT ECOLOGY

Biology texts define ecology as the study of interactions of organisms with each other and the environment. Ecology texts strive for more precision, and focus variously on the dynamics within an environment, the functional relationships between organisms and the analysis of controlling mechanisms in the ecosystem. Ecology is still a young science: few theories go unchallenged and few have universal value and we are still defining basic phenomena in the interaction of organisms. In the quest for fundamental principles insects have special importance because of their diversity and abundance, and because of their significance in agriculture and medicine.

Much of my work has been at the interface of ecology, physiology and behavior of insects. My approach has been to seek understanding at the level of the individual — the primary unit of natural selection. From here the relevance of ecological generalization may often be measured, and novel applications of pest control devised. I believe that the combination of a broad framework of wholistic ecology with the narrow focus of reductionist physiology and behavior has been the key to many successful studies.

Today I shall start with the theme of the significance of plant secondary metabolites for insect herbivores, but my emphasis is largely on how the very detailed studies of physiology and behavior can impact ecology and agriculture. A search of the literature shows us that the majority of insect herbivores are restricted to one or a few genera of plants, or a single plant family. It appears that deterrent compounds, or feeding inhibitors, play a major role in this selectivity. For example, in an extensive survey we demonstrated that in grasshoppers which specialize on grasses, the non-hosts, and certainly all dicotyledons, yielded deterrent compounds.

Many hundreds of deterrents or antifeedants have been identified for a wide variety of different insect species — by me and by

others in chemical or entomological laboratories throughout the world. They are from all chemical classes and may be found in the majority of plant species. Our studies showed that the more restricted the host range of the insect, the more sensitive it is to secondary compounds in plants, and the more compounds there are which deter feeding. Thus there is a very large selection of compounds which may have potential in protecting crops by spraying, and the work suggests they would generally be most effective against pests with a narrow host range.

At the level of ecology and evolution, the conventional view of this situation is that plants must defend themselves, that their armory includes untold numbers of noxious compounds to which the insect must adapt either by developing physiological detoxification capabilities or evolving rejection responses to the chemicals. The numerous and diverse insect herbivores are seen as having exerted continuous selection pressure on the plants for the evolution of diverse chemical defenses.

We do know that every plant species, even when it is toxic to mammals, has its suite of insect herbivores and that insects in general have a wide range of remarkable detoxifying abilities. In any case, ecological theory has invariably invoked the idea of plant chemical defense and assumes that insects provide a major selective pressure on them. That the world is green is taken as evidence that plants are well defended. In view of the numbers of herbivorous insects and their effects on crops it seems a reasonable stand to take. Further, the reciprocal stepwise coevolution of defense and counter-defense has been seen as a process by which plant and insect diversity both multiply.

Comparisons of widespread phenolic substances on the one hand, and the diverse substances which are toxic to mammals, such as alkaloids, on the other, have given rise to ideas of plant groups having different types of defense strategies. Phenolic compounds such as tannins have been considered to be of particular general importance because of their assumed role as antidigestive agents. In short, current popular theories about the evolution of insects and plants take for granted the overall theme that unless plants produce defensive compounds against insects they are bound for destruction by them. My own work on antifeedant effects of so very many plant compounds did not itself run counter to these ideas, but was the starting point for the development of a new approach.

We have shown that the physiological effects of potentially noxious or poisonous compounds on insects is surprisingly small, and that the insects are endowed with specializations of the digestive system, nervous system and excretory system which give them tolerance of many chemicals including alkaloids and tannins which were expected to be detrimental simply because they are avoided behaviorally. Some compounds can only be tested physiologically by masking their tastes, and this we achieved by making mini-gelatin capsules by hand. Insects can then be dosed with these capsules, repeatedly if chronic effects are to be examined. Many compounds which are very toxic to mammals were found to be relatively non-toxic to insects. Even cyanogenic compounds were tolerated in large quantity, while moderate amounts of some traditional «toxins» even stimulated growth. Tannins had no effect on digestion *in vivo*, and in the locust we showed the variety of mechanisms employed to prevent the expected effects on digestion.

The interesting general outcome of all this detailed physiological work is that most insects are highly sensitive behaviorally to compounds which are relatively harmless to them. The consequences of this discovery are manifold. It indicates that the conventional patterns of plant-insect evolution may not be so simple. The insects respond to compounds for reasons other than the essential avoidance governed by toxic effects, and many plants rejected in nature will, when force fed, allow normal growth and development. In addition to the need to reject those compounds which are toxic to them, there must be reasons of a completely different nature causing them to reject plants which could support normal growth. What are those reasons?

I propose that a major driving force in the evolution of phytophagous insect diversity does indeed concern behavioral selectivity leading to narrow host range, but that is driven in turn by a host of individual ecological needs and in particular, patterns of avoidance of parasites and predators. It is the natural enemies which are mostly responsible for regulating insect populations, and for keeping them, in general, below levels where serious damage to plants is incurred. The concept of plant defense is not so clear. The actual protection that plants can obtain by the presence of many secondary compounds should be seen as a product of many evolutionary processes; the secondary compounds as cues used by insects, both plant-feeding species and their natural enemies. The

cues aid many species in selecting the perfect habitat for which each is uniquely adapted for minimizing discovery or developing a defensive strategy. The cues are one or two that are positive in relation to the host, and many thousands that are negative in relation to the non-hosts.

I believe that the coevolutionary theories of plants and their insect herbivores are much too simple to explain the patterns we presently see; that the role of the third trophic level has had and continues to exert a more important pressure on the insects than the plants themselves; that the feedbacks from plants on insect populations probably relate to limitations and variations of plant tissues as sources of protein. We have a long way to go but the study of behavior and physiology is helping to bring us to a new level of understanding of evolutionary ecology of phytophagous insects.

In agriculture, the repercussions of this new approach are several. It helps us to understand why insects may rapidly adapt to antifeedants and why crop plant resistance to insect pests can break down rapidly. If it is a behavioral change alone, without the need to develop specialized detoxification ability, failures of this nature are not surprising. Progress in the development of useful antifeedants probably depends on the combination of two or more compounds with different individual effects, the combination of compounds with synergistic activity, the combination of chemical and physical factors, or the combination of antifeedants with substances having other known detrimental effects.

If complex behavioral patterns are driven by signals which do not relate to nutritional factors or avoidance of toxicity, perhaps there is a range of behaviors to exploit in regulating pests? One example comes from a joint study with colleagues on a pest in Nigeria. The pest was a grasshopper, *Zonocerus variegatus*, which seriously damaged the cassava crop and thereby reduced an important staple food of the human population.

In the laboratory it was found that by comparison with over one hundred common plants in the environment, cassava was the best food for the pest insect and its pest status was reasonably assumed to be related to increased cultivation of cassava. Detailed field studies revealed a paradox however. Individuals would die rather than feed on cassava and the living, turgid plants were a poor diet. The key to the paradox was that in this cyanogenic plant hydrogen cyanide released during feeding was influenced by the

degree of wilting of the plant: as the plants wilted the rate of release of the gas during insect chewing was reduced. Rapid release of hydrogen cyanide prevented feeding on the turgid plants, even though the insects were quite unaffected by the cyanide if it was force fed. The behavioral importance of the hydrogen cyanide was proved experimentally by using insects which had had very small cannulae inserted through the lower lip. From a distance, then, individuals which were actively feeding on palatable food rejected it immediately when small quantities of hydrogen cyanide were released into the region of the mouth.

Knowing the details of this behavior led to two useful facts. Firstly, the vulnerability caused by dry season wilting of cassava may be overcome by irrigation, which prevents wilting and allows growth of certain weeds, thus providing alternative foods for the pest. Secondly, the insect is highly gregarious and the wilting caused by single bites of multiple individuals causes crop vulnerability.

The gregariousness of the insect is part of the strategy of this species for protection from predation by birds. It feeds also on plants containing pyrrolizidine alkaloids which it sequesters and the alkaloid gives it a protection from predators. As is known for many other species, the combination of bright colors and the congregation in groups increases the rapidity of avoidance learning by birds. Once again the real details were of value. The grasshoppers in the field fed avidly on the flowers of an introduced weed, *Chromolaena*, rich in pyrrolizidine alkaloids. The insects' pest status was associated with the spread of the weed, which provided it with the materials for self defense. The chemicals are possibly also precursors of a gregarization pheromone.

Finally, it was the gregarious behavior of the insects which led to a means of cultural control. We found that eggs are laid in very large masses, and by devising simple methods for identification of these masses, and slightly altering the depth of cultivation normally used by the farmers, a ninety percent reduction in population size could be achieved.

One other crop pest study will serve to illustrate my theme. It concerns the stem-boring caterpillar *Chilo partellus*, a serious pest of maize and sorghum which we studied in India. Crop plant resistance is an obvious approach to management of pests in poor countries, yet breeding programs for sorghum had not been very successful in respect of this pest. Important reasons relate to the

limits of the usual empirical methods by selective breeding. For example, pest impact varies and minor but important differences go unnoticed even when there is genetic potential for such differences to be successfully increased in the direction of resistance. If, on the other hand, the mechanisms of resistance are identified, they can be individually bred in logical sequence, and perhaps in the future used in genetic manipulations. This insect species lays its eggs at the base of the plant but young larvae must first feed at the top in the whorl. Newly hatched insects must therefore climb up to one or two meters to reach their sites of feeding. The task for an insect of two or three millimeters is complex: the stem leads readily out onto leaves, and to reach the top the individual must have a mechanism that makes it turn down and back to the stem to continue its climb. We found that on some resistant cultivars the insect does not turn back so readily and the essential turning behavior is associated with a combination of leaf characteristics. With perfect leaf replicas, constructed from rubber molds and resin casts we demonstrated that upwardly directed leaf trichomes and the chemical profile of the surface wax were of particular importance in the details of the insect behavior. But so were many other details of plant structure.

To the uninitiated, lying out in the muddy fields for weeks obtaining data from thousands of insects, and then experimenting with jeweller's resin, may seem an unlikely means of progress, yet the findings are already of value. Since the climb of the newly hatched insects is so hazardous, delays also mean exposure to vagaries of the weather and to many natural enemies. This indicates that there must be important reasons for the insect to lay eggs so low down on the plant. With egg parasitism being the major cause of mortality we believe that eggs laid in the fold of the old basal leaves are indeed less vulnerable to parasites.

To finish, I would say that the large scale questions and the theories concerning ecology and evolution are most successfully aswered if attention is paid to the individual; the progress of environmentally sound pest control measures go forward best when they are based on the accurate study of the fine details of animal behavior and its underlying mechanisms. To theoretical ecologist and agriculturalist alike my message is that physiology and behavior make the ground rules in any system, and understanding them is basic to progress.

Anatole ABRAGAM

OÙ VA LA PHYSIQUE?

Je ne me risquerai pas à répondre à cette question. Nous pourrions peut-être y réfléchir ensemble lorsque j'aurai consacré les quelques minutes à ma disposition à essayer de répondre à cette autre question: d'où vient la Physique? en prenant comme point de départ, un peu arbitrairement peut-être, la fin de la Guerre Mondiale en 1945. Où en était-on alors?

La révolution de la Relativité et des Quanta était depuis longtemps derrière nous, la découverte du positron avait scellé leur alliance, les spectres atomiques, où les effets des moments magnétiques nucléaires n'étaient qu'un détail infime surnommé structure hyperfine, avaient livré leurs secrets. Une théorie appelée électrodynamique quantique permettait de calculer au premier ordre tous les processus atomiques de façon satisfaisante malgré sa fâcheuse tendance à donner des résultats infinis dès qu'on essayait d'aller au delà. La Physique du Solide et la Mécanique Statistique, développées dans le cadre de la Théorie Quantique, avaient permis de comprendre la conductivité thermique et la conductivité électrique même si le mystère de la Supraconductivité demeurait entier. Il existait une théorie des transitions de phase, satisfaisante sauf pour des détails que l'on jugeait mineurs. L'Optique était devenue une discipline classique, entendez morte. La Physique Nucléaire avait connu ses premiers succès, sublimes ou effrayants. On connaissait le neutron et la fission nucléaire, l'hypothèse du neutrino avait restauré la foi dans la conservation de l'énergie, Yukawa avait expliqué les forces nucléaires par l'échange de particules lourdes que l'on avait cru identifier dans le rayonnement cosmique et appelé mésotrons. La conservation de la parité c'est-à-dire l'identité de l'univers et de son image dans un miroir était un dogme. Des cyclotrons et des bétatrons qui paraissaient géants permettaient d'accélérer protons, deutons, particules alpha et électrons à des énergies qui paraissaient fabuleuses, de l'ordre de la centaine de millions d'électron-volts ou Mev.

Enfin, nées pour répondre aux besoins des militaires pendant la guerre, des machines à calculer électroniques géantes, capables d'effectuer des centaines d'opérations à la seconde, ne voyaient leur capacité limitée que par l'encombrement, l'échauffement et la fréquence croissante des pannes des tubes à vide dont elles étaient constituées.

Le paysage allait changer et vite.

Dans tous les domaines que j'ai énumérés, pendant quarante ans, théorie et expérience allaient progresser, chacune stimulant l'autre, forgeant au passage de nouveaux outils et perfectionnant les anciens.

En physique atomique, dans la structure fine du spectre de l'atome d'hydrogène, ce fleuron de la synthèse de la relativité et des quanta, on décela par les techniques nouvelles des ondes courtes, nées du radar, une anomalie minuscule mais lourde de conséquences, puisqu'elle contenait en germe, avec une anomalie similaire des propriétés magnétiques de l'électron, la clef des divergences inexplicables et insupportables de l'électrodynamique quantique. Confortés par l'expérience, les théoriciens eurent l'audace de soustraire l'un de l'autre des termes infinis pour en extraire des termes finis qui correspondaient à ces minuscules corrections. Ce fut la naissance de la théorie de la renormalisation qui devait s'étendre à l'ensemble de la physique théorique. On inventa des méthodes de diagrammes qui permirent de mener à bien, parfois dans des domaines très éloignés de l'électrodynamique quantique, des calculs, inextricables sans elles.

Les minuscules moments magnétiques nucléaires convenablement excités par des méthodes de résonance donnèrent naissance à des signaux dont la détection devait fournir sous le nom de Résonance Magnétique Nucléaire, ou RMN, un des outils les plus pénétrants pour sonder la matière condensée, puis les molécules biologiques et aujourd'hui, par une technique appelée imagerie RMN, les coeurs et les reins.

La physique des solides et singulièrement celle d'un type particulier de solides, appelés semi-conducteurs, devait conduire à ce qui est peut-être la plus formidable révolution de notre temps en donnant naissance au transistor puis à des circuits intégrés qui ont multiplié par des millions et avant longtemps par des milliards, la capacité de calcul des ordinateurs, tout en divisant par un facteur encore plus grand leur encombrement. J'exprimerai un avis person-

nel en disant que contrairement à beaucoup de mes collègues je vois leur importance plus grande pour la société que pour la science. C'est ainsi que, pour parler de ce que je connais un peu, l'imagerie RMN, fille des ordinateurs, a apporté beaucoup à la profession médicale mais aucune idée nouvelle au Magnétisme Nucléaire en tant que discipline scientifique.

Et là, si je peux ouvrir une parenthèse, vous savez qu'il y a des théoriciens très éminents qui pensent que la tâche principale des physiciens théoriciens est de s'attacher à la construction d'ordinateurs spécialement adaptés à la physique théorique, et que les physiciens devraient abandonner toute autre tâche pour se consacrer à celle-là. Je voudrais vous confier ma réaction personnelle à cette thèse: elle rappelle celle de la bonne épouse de l'évêque Wilberforce, lorsqu'elle apprit que selon Monsieur Charles Darwin l'homme descendait du singe. Elle avait dit, cette brave dame: «si cette horrible nouvelle se révèle véridique, prions Dieu pour qu'elle ne se répande pas».

Le mystère de la superconductivité fut résolu et parallèlement un nouveau type de matériaux superconducteurs dont on comprenait mieux la nature en même temps que l'on en améliorait les performances, permit de multiplier par un facteur important l'intensité des champs magnétiques produits dans les laboratoires, tout en diminuant par un facteur incomparablement plus grand leur consommation d'énergie.

L'optique fut réveillée: d'abord par un usage ingénieux de la lumière polarisée combinée avec le rayonnement hertzien, mais surtout par l'invention du laser qui, devenu rapidement accordable, donna naissance à une science nouvelle, l'optique non-linéaire, et révolutionna la spectroscopie. Les applications du laser aux communications, à l'holographie, à l'ophtalmologie, à l'industrie sous toutes ses formes, et aussi, hélas, aux armes, sont innombrables.

On trouva la particule de Yukawa qui n'était pas celle que l'on croyait, on démontra que le neutrino était plus qu'une ingénieuse fiction, on découvrit que dans les intéractions dites «faibles» responsables de la radioactivité beta, la parité était violée avec violence.

L'énergie des accélérateurs s'accrut par trois ordres de grandeur créant des nuées de particules éphémères que l'on s'efforçait non sans mal de classer de façon rationnelle. La réversibilité du sens du temps, que l'expérience quotidienne dément à notre échelle, mais

qui était un dogme à l'échelle microscopique, se révéla elle aussi inexacte quoique légèrement. Renonçant à décrire de près la réalité, on élabora des théories d'une grande sophistication mathématique mais dont le contenu physique semblait pour le profane se résumer dans l'affirmation: «tout est dans tout».

Puis à la suite de belles découvertes expérimentales et théoriques faites au cours des quinze dernières années tout rentra dans l'ordre, du moins provisoirement. Il existe aujourd'hui un ensemble de théories, reposant sur un ensemble de données expérimentales incontestable, que l'on appelle le «modèle standard». Dans ce modèle il y a deux types de constituants ultimes de la matière: d'une part les quarks, trois dans chaque nucléon, soumis à des intéractions dites «fortes», régies par une théorie appelée «chromodynamique quantique», d'autre part les leptons dont l'électron et le neutrino sont un exemple, qui intéragissent entre eux et aussi avec les quarks dans le cadre d'une théorie appelée électrofaible, synthèse de l'électrodynamique quantique et de la théorie des intéractions faibles. Le rêve actuel des physiciens des particules est une synthèse de ces deux théories dans le cadre de ce qu'ils appellent «la Grande Unification». Selon eux une telle théorie était une description correcte de la réalité dans les tout premiers instants d'un Univers incroyablement chaud, après le Big Bang. C'est pour recréer en laboratoire des conditions comparables à celles-ci qu'ils réclament avec insistance des accélérateurs toujours plus puissants. Une étape encore plus lointaine est le vieux rêve d'Einstein, la synthèse avec la gravitation.

La physique de la matière condensée ne fut pas en reste. Des concepts nouveaux bouleversèrent la théorie des transitions de phase, montrant qu'à travers l'immense variété des phénomènes physiques, leur comportement au voisinage des transitions était identique. Ces prédictions furent vérifiées expérimentalement avec une très grande précision. Des méthodes nouvelles pour l'étude de la matière condensée furent élaborées, dont au premier plan le laser, mais aussi la diffraction des neutrons et des électrons lents, la spectroscopie des rayons gamma sans recul, la RMN, d'autres encore.

On s'intéressa aux systèmes à deux dimensions, dont les surfaces offrent un exemple physique d'une importance capitale, qu'un outil nouveau, le microscope à effet tunnel, permet d'étudier avec une précision inégalée.

Enfin les systèmes désordonnés sous toutes leurs formes, se révélèrent d'un intérêt théorique et pratique considérable. Une nouvelle mécanique statique, où l'ergodicité fait défaut, passionne les physiciens. Enfin se répandent les méthodes de simulation, ou «expériences» sur ordinateurs, où l'on se passe complètement de la nature.

Me voici arrivé au terme de cet inventaire où chaque branche de la physique pourra se considérer comme négligée, incomprise ou oubliée. Que les collègues qui se sentent lésés me pardonnent s'ils le peuvent.

Je me tourne pour finir vers nos collègues biologistes dont les progrès foudroyants seraient, selon certains, de nature à rendre jaloux les physiciens. N'en croyez rien: si nous nous réjouissons sincèrement de vos succès c'est parce que nous vous considérons comme étant des nôtres. Vous avez adopté nos appareils et nos techniques c'est-à-dire notre hardware, c'est là peu de chose. Mais vous avez adopté notre manière de raisonner, en quelque sorte notre software, et cela est capital. Camarades physiciens de la matière vivante, je vous salue.

Rudolf Mössbauer

PRESENT TRENDS IN NEUTRINO PHYSICS

It is a pleasure for me to talk to you this afternoon on the present trends in the domain of neutrino physics. Research on neutrinos is at the moment being actively pursued in the domain of nuclear physics, astrophysics and elementary particle physics. In talking about this subject it will be appropriate to go back in history to the early 30s, when the neutrino was introduced into physics in a hypothetical way by Wolfgang Pauli. It was known already early in this century that there exists a phenomenon called radioactive decay; the general public became most recently awkwardly aware of this process in connection with the Chernobyl incident. In the most simple case of such a radioactive decay, there is initially a nucleus in an excited state. This nucleus may then decay to another nucleus differing in atomic charge by one unit. The decay is associated with the emission of a beta particle, which is nothing else than an electron with a rather high velocity. Such a decay, which is illustrated in Fig. 1, is called a radioactive beta decay. Since both the initial and the final nuclei have well defined energies, one would expect that the emitted electron would likewise appear with a well defined energy. Consequently, the electron spectrum should consist of a monochromatic line at an energy which is determined by the energy difference of the two nuclei involved and by the mass of the electron. This expectation is demonstrated in Fig. 1. However, it was already well known in the 20s, that the electrons emitted in radioactive beta decays did not exhibit such a single monochromatic line, but showed instead a whole distribution of energies. A representative experimental spectrum is likewise shown in Fig. 1.

The observation of a continuous energy spectrum of the electrons emitted in radioactive decay posed a very serious problem for physics. If the electron emitted in the transition from an initial nucleus of fixed energy to a final nucleus of fixed energy showed a spread in energies, then the necessary consequence would be a violation of the conservation of energy. This was a very serious

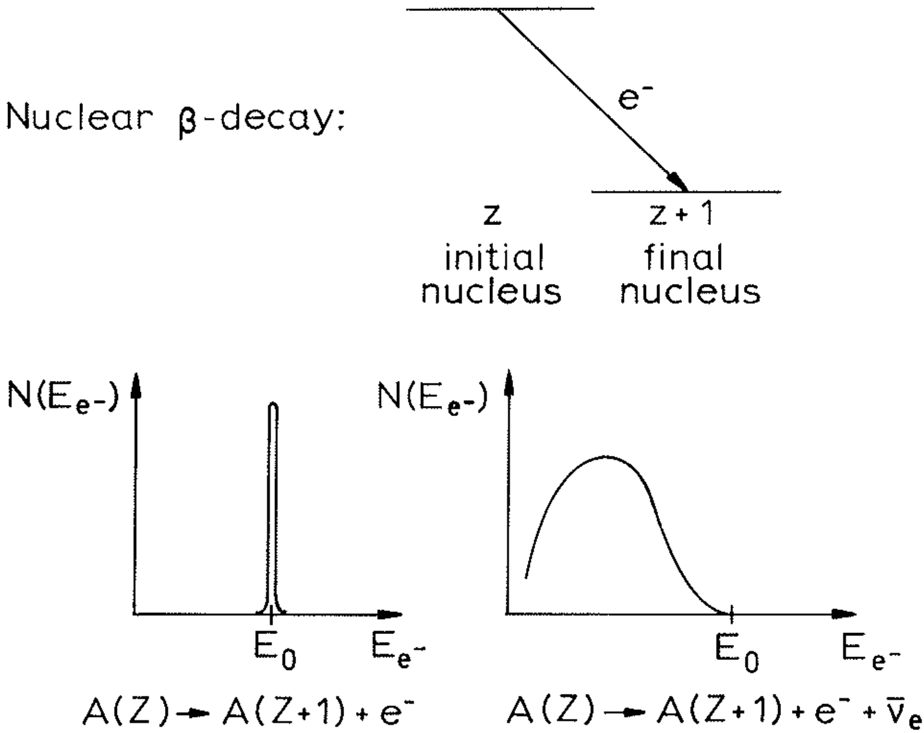

Fig. 1: Nuclear Beta Decay: A nucleus with atomic charge Z decays via the emission of an electron (e^-) to an energy state of another nucleus with atomic charge Z + 1. In the case of a two body decay, where only the new nucleus (Z + 1) and the emitted electron appear in the final state, one expects a monochromatic electron spectrum, as shown on the left side. In the case of a three body decay, where in the final state after the decay one has the new nucleus (Z + 1), an electron and an electron antineutrino, one expects a continuous electron spectrum as shown on the right hand side. The energy E_0 is now shared between electron and antineutrino, thus providing energy conservation.

matter, with the principle of energy conservation being one of the most important and strictly obeyed laws in physics. A number of physicists, including Niels Bohr, were willing to give up this conservation law for the individual beta decay process, though still considering the law to be valid in the average over many processes.

Wolfgang Pauli was violentely opposed to this idea and tried to remedy the situation by postulating the beta decay to be a three particle process. He predicted, that besides the electron there would be the emission of another particle. The combined energies of the electron and of the additional particle would be constant, and energy conservation would thus be fulfilled. Pauli was at first assuming the additional particle to be a photon and the distribution of the total available energy over the electron and the photon would then permit both an electron and a photon spectrum. An intense search for the photon postulated to appear with each radioactive beta decay was performed by many physicists in the late 20s, but without any success. Wolfgang Pauli in a famous letter attributed this failure at first to a lack of experimental skill. He finally convinced himself that the experiments apparently were correct and that the new particle, if it existed at all, therefore had to be of a nature which made its experimental observation impossible. He therefore advanced the ingenious hypothesis, that in nuclear beta decay besides the electron another particle would be emitted with such a weak interaction that it would escape any experimental observation. He created the name neutron for the new particle, a notation which after the discovery of another particle called neutron today was later on changed to neutrino, the Italian word for little neutron.

This notation is rather misleading, since the neutrino is a particle of its own, not related in any sense to the neutron. The neutrino hypothesis by Wolfgang Pauli turned out to be correct. The extraordinarily weak interaction of the neutrino with any matter imposes very severe difficulties for its observation and this is in fact the reason why it was only in 1956 when Reines and Cowan were the first to demonstrate the existence of the neutrino in a direct nuclear reaction. Indirect manifestations of neutrinos via recoil effects had been observed already earlier. The decay of a neutron into a proton, which is a somewhat lighter particle, is accompanied by the emission of an electron and an antineutrino $\bar{\nu}_e$. One may also

perform the inverse process, shooting an antineutrino upon a proton and observing the reaction products neutron and electron:

$$n \rightarrow p + e^- + \bar{v}_e \qquad \textit{radioactive } \beta - \textit{decay}$$
$$p + \bar{v}_e \rightarrow n + e^+ \qquad \textit{inverse } \beta - \textit{decay}$$

It was in fact the latter reaction by which Reines and Cowan made their first direct observation of neutrinos.

Today we know three different flavours of neutrinos, the electron neutrino v_e, the muon neutrino v_μ and the tauon neutrino v_τ together with their antiparticles. In spite of the fact that more than 50 years have passed since Pauli has proposed the existence of neutrinos, we still have very little information concerning the properties of these particles. Neutrinos, which play a crucial rôle in many areas of physics, have many puzzling properties. We do not know why there are three types of neutrinos. We could exist quite well if there would be only one such type. It may well be that there exist more than the three types of neutrinos mentioned, but we do not know the actual number of such flavors. We do know that the various types of neutrinos are distinct and that we therefore may introduce a quantum number, which distinguishes them. It is not clear, however, whether this quantum number describes an exact conservation of neutrino type, or whether this conservation is only approximate. We furthermore do not know whether the particles are stable or not.

An instability would allow them to decay into some other lighter particles; it may also mean that they have the possibility to fluctuate between themselves. An electron neutrino might oscillate into a muon neutrino or into a tauon neutrino and back into an electron neutrino. All this is possible, but we don't know whether it works this way or not. One of the most important issues is the question of the mass of the neutrino and I will especially concentrate on this question during this talk. The question of the rest masses is a rather general problem in physics. We do know, for instance, that the electron has a mass and we do know that the proton has a mass. We can measure these masses, but we do not know their origin and we do not know why the particles have the particular rest masses which we observe. Why is the electron mass so much different from the muon mass, why is it so much different from the proton mass, and so on?

In the case of the neutrino, we do not even know whether it has a rest mass or whether its mass is zero. If the mass would be exactly zero, this would imply some kind of symmetry principle in nature and it is not very likely that such a symmetry exists. One therefore presumes that neutrinos have a finite mass, but this question must eventually be settled experimentally.

Another problem concerning neutrinos is the question, whether a neutrino is a Dirac or a Majorana particle, i.e., whether particle and antiparticle can be distinguished. Such a distinction is possible in the case of the electron, which is negatively charged and its antiparticle, the positron, which is positively charged. In this case we can distinguish particle and antiparticle by their charges. Neutrinos do not carry a charge and therefore it is not a priori clear whether the necessity to distinguish between a neutrino and antineutrino does exist. It may well be that it suffices to distinguish neutrinos by their helicities and that besides it is not necessary to introduce a further distinction between particle and antiparticle. If such a distinction would be necessary, a neutrino would behave as a Dirac particle, while if not, it would be called a Majorana particle. Thus far, it has not been possible to settle this question experimentally.

What knowledge do we have today about the mass of the neutrinos? From a theoretical point of view, the question is quite open. There are theories which incorporate a zero rest mass of the neutrino and there are other theories which allow for finite masses. The standard minimal electroweak theory, for instance, is compatible with a mass zero, but a small modification would also allow for a finite mass and the grand unified theories (GUT's), which try to combine the electroweak and strong interactions, have likewise space for mass zero and for finite masses. Thus, in short, as experimentalists, we get hardly any advice from theory in the sense that theory can tell us whether the neutrino has a mass and in which range we would have to look for it.

On the experimental side, we can state, there is no clear evidence for a neutrino mass in any experiment. All experiments performed so far can be explained on the basis of a zero rest mass for the neutrinos. Experiments, of course, are always associated with certain errors and therefore allow at present to deduce limits on neutrino masses. These experimental limits are shown in Table 1.

Table 1:
Summary of experimental limits for neutrino rest masses

Neutrino	Method	Limit	Ref.
$\bar{v}_e$	^{3}He - decay	$m_{v_e} < 18$ eV	[1]
v_μ	$\pi \rightarrow \mu_{v_\mu}$ at rest	$m_{v_\mu} < 270$ keV	[2]
v_τ	$\tau \rightarrow 3\pi v_\tau$	$m_{v_\tau} < 70$ MeV	[3]

There has been for a number of years a claim by a group at the ITEP in Moscow [4] for the observation of an electron neutrino mass, but the experimental value is in contradiction with the results of ref. [1] and the analysis has been questioned in the literature. A search for the mass of the electron neutrino in a range of a few eV or below is very difficult to perform, since possible excitations in atoms or solids are likewise of the order of eV and a mass contribution is very diffcult to distinguish from such excitations.

There exists also a cosmological limit on the masses of the neutrinos, which states that the sum of the masses of neutrinos of all flavors should be smaller than about 100 eV. This cosmological limit applies to stable neutrinos and is obtained by attributing the entire possible mass in the universe to neutrinos.

Neutrino oscillations

I would now like to say a few words about the possibility that the various types of neutrinos, the electron neutrino, muon neutri-

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[1] M. Fritschi, E. Holzschuh, W. Kündig, J.W. Petersen, R.E. Pixley, and H. Stussi, Phys. Lett. B173 (1986), 485.

[2] B. Jackelmann *et al.*, Phys. Rev. Lett. 56 (1986), 1444, and R. Abela *et al.*, Phys. Lett. 146B (1984), 431.

[3] ARGUS Collaboration, H. Albrecht *et al.*, Phys. Lett. 163B (1985), 404.

[4] V.A. Lubimov *et al.*, Phys. Lett. 94B (1980), 266; S. Boris *et al.*, Proc. Int. Europhysicis Conf. on High Energy Physics (Brighton, UK, 1983) p. 386; S. Boris *et al.*, Proc. 22nd Int. Conf. High Energy Physics (Leipzig, DDR, 1984), Vol. 1, p. 257; S. Boris *et al.*, Phys. Lett. 159B (1985), 217; V.A. Lubimov at 6th Moriond Workshop on Massive Neutrinos in Particle and Astrophysics (1986).

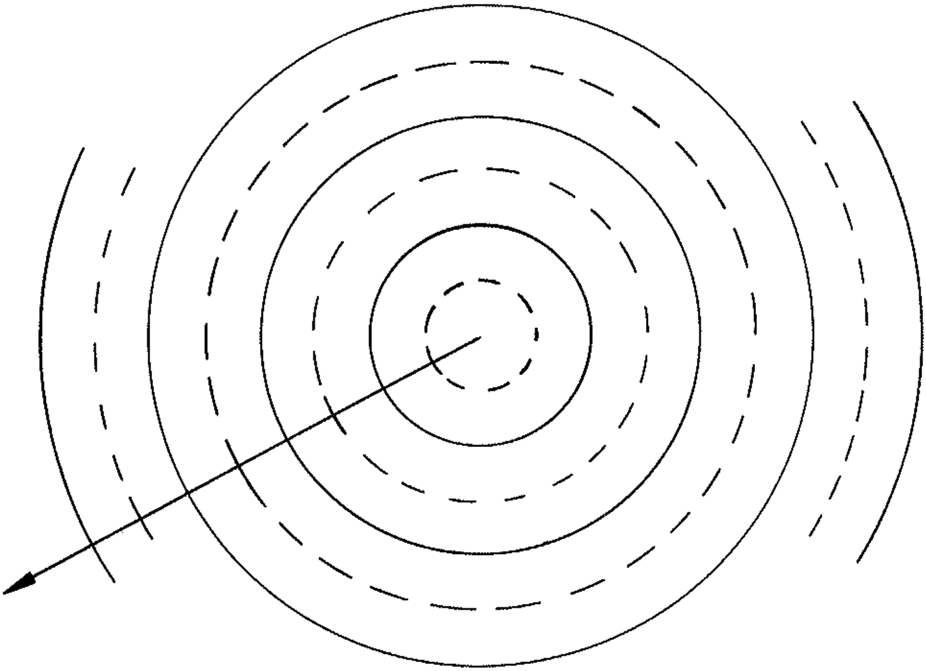

Fig. 2: Illustration of the maxima and minima expected for neutrino oscillations: The source is located in the center. Intensity maxima of the type of neutrinos emitted by the source are indicated by solid circles, minima are indicated by dashed circles. The oscillation length depends on the oscillation parameters, i.e., on mixing angles and on neutrino masses.

no, tauon neutrino and possibly others, might transform into each other. To simplify matters, I will describe such transformations in terms of a two-particle model, where one type of neutrino, say a v_e, transforms into another type, say a v_μ, back into a v_e and so on. Let us assume, then, that there is a source located at the center of the circles in Fig. 2, which emits neutrinos of one type. As these neutrinos fly away from the source in all directions, they will transform into the other type at the position of the innermost dashed circle. Flying further, they will become re-transformed into the original type at the solid circle, transform again into the second type at the next dashed circle and so on. If we would have a detector which responds only to one type of neutrinos, for instance the type emitted by the source, then we would observe a maximum in neutrino intensity at all solid circles, and a minimum at the position of the dashed circles. In other words, the neutrino intensity would oscillate. The existence of such oscillations would be indicative of the fact that the neutrino types, also called flavors, are not stable and that the flavor quantum number is not an exact but only an approximate one.

A search for such neutrino oscillations can be performed by employing different types of sources. It is impossible to employ a radioactive source, because such a source would be much too weak for actual experiments. Neutrinos are weakly interacting particles and their detection therefore is very difficult. The interaction is indeed so weak, that neutrinos can pass through the earth or even through the sun without undergoing hardly any absorption at all. An effective absorption would only occur if one would place several light-years of material into their flight path. The detection of such weakly interacting particles in a laboratory-size detector is only possible if one employs neutrino beams with enormous intensities, out of which occasionally a single neutrino will leave a trace in a laboratory-size detector. Radioactive sources would be much too weak for this purpose, but nuclear power reactors are very copious neutrino sources. In such reactors happen enormous numbers of fission processes. In each individual process a fissionable nucleus, such as ^{235}Ur or ^{239}Pu fissions into two or three lighter nuclei, thereby generating these nuclei in highly excited states. These nuclei are very neutron rich and will therefore undergo radioactive decays, where neutrons are converted into protons, while at the same time electrons and electron-antineutrinos are being emitted. Reactors,

therefore, are powerful sources of electron-antineutrinos. Such reactors are used as sources for neutrino oscillation experiments. The electron-antineutrinos emitted by the reactor-core fly away in all directions and in large quantities and after a certain time of flight or equivalently after a certain distance may transform into other types of neutrinos and finally back into the original one. Using a detector which is sensitive only to electron-antineutrinos, one may then search for anomalous changes in the neutrino intensities as a function of distance between reactor and detector.

We have done such a search for neutrino oscillations in the framework of an American-German-Swiss-collaboration at the Swiss power reactor at Gösgen [5]. For neutrino detection, we have employed the reaction $p + \bar{v}_e \rightarrow n + e^+$, which has been mentioned above. The detection principle is demonstrated in Fig. 3, with the incident reactor neutrinos making occasionally a reaction with a proton within the detector, thereby generating simultanously a neutron and a positron. The target protons form part of a liquid scintillator within the detector, which serve not only as neutrino absorber, but also as detector for the generated positrons. The generated neutrons drift from the liquid scintillator into adjacent ^{3}He-chambers where they initiate electric signals following their absorption, this way manifesting themselves. The simultaneous arrival of a neutron and of a positron serves as indicator for the occurrence of a neutrino absorption event. The active detector is quite compact, with a size of roughly 1 m^3. It is arranged in a modular fashion, consisting of 30 targets of liquid scintillators arranged in five planes, with four intercalated ^{3}He chambers. The central detector unit is surrounded by heavy active and passive shielding, which allows to discriminate against background radiation. The passive shielding of this detector comprises about 1200 t of shielding material, exclusively directed against cosmic radiation. The detector is located outside the reactor confinement building and there is no background from the reactor itself. It is very illustrative to compare the number of neutrinos which pass through the detector with the number of neutrinos which actually cause a reaction within. While there are roughly 10^{20} electron neutrinos arriving at the detector per hour, we have an actual reaction rate of

[5] MUNICH-CALTECH-SIN-Collaboration, G. Zacek *et al.*, Phys. Rev. D34 (1986), 2621.

$$\bar{\nu}_e + p \longrightarrow n + e^+$$

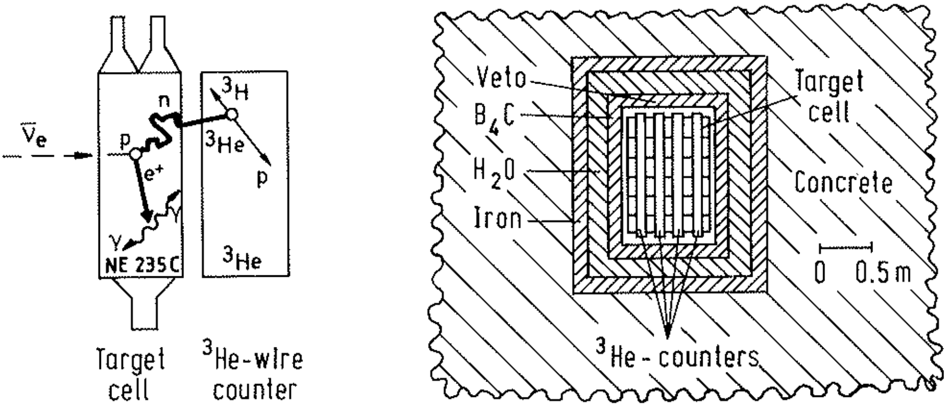

Fig. 3: The left side of the figure shows the principle of the neutrino detection, using the reaction $\bar{\nu}_e + p \rightarrow n + e^+$: An electron antineutrino $\bar{\nu}_e$ coming from a nuclear reactor hits a proton in the target cell filled with a liquid scintillator and generates a neutron (n) and a position (e^+). The positron, which slows down in the target cell, generates light which is picked up by the photomultipliers mounted at both ends of the target cell. The neutron slows down in the target cell and drifts into an adjacent ^{3}He-wire chamber where it becomes absorbed and generates an electric pulse. The simultaneous detection of a positron and a neutron is indicative of a neutrino absorption event. The right side of the figure shows schematically the composition of the actual detector, consisting of 30 target cells and 4 intercalated ^{3}He chambers. The central detector unit of about one m^3 size is surrounded by active and passive vetos shielding against cosmic radiation.

about one per hour. These numbers drastically demonstrate the meaning of "weak interaction". It now becomes apparent why we are justified to consider the entire earth as being essentially transparent to neutrinos. Fig. 4 shows on the left side the analysis of our data.

Our measurements are compatible with the absence of neutrino oscillations. They may nevertheless be used to establish ranges of oscillation parameters, where neutrino oscillations can no longer exist, contrasted with ranges where such oscillations may still be possible. Our measurements exclude the areas to the right of the curves, while oscillations are still possible in the parameter ranges to the left of the curves. For comparison we show in the right half of Fig. 4 some equivalent exclusion plots obtained with neutrinos generated in high energy accelerator experiments at CERN. Again the parameter ranges to the right of the curves are excluded, while oscillations in the parameter ranges to the left of the curves would still be compatible with the experiments. A comparison of the experiments involving neutrinos from reactors on the left side and neutrinos from accelerators on the right side demonstrates that the reactor experiments are more suitable to study the range of small mass parameters, while accelerator experiments are somewhat more sensitive to mixing angles.

Neutrinos in astrophysics

After the preceding discussion on terrestrial neutrino experiments I will now continue to make a few remarks about neutrinos in astrophysics. Astrophysics relates to the physics of stellar objects and of interstellar space, as distinguished from cosmology, which deals with the development and the structure of the universe as such. In astrophysics, there are two problems of particular interest, which involve neutrinos. One is the solar neutrino problem, which I will discuss in some detail. The second one is the possibility to detect neutrinos coming out of supernovae explosions. Such explosions are very rare, typically one in every ten to a hundred years within our own galaxy. The enormous energy liberated in such explosions will be essentially carried away by neutrinos, because they are the only particles which have a chance to escape rapidly due to their extraordinarily weak interaction. Supernovae explosions are

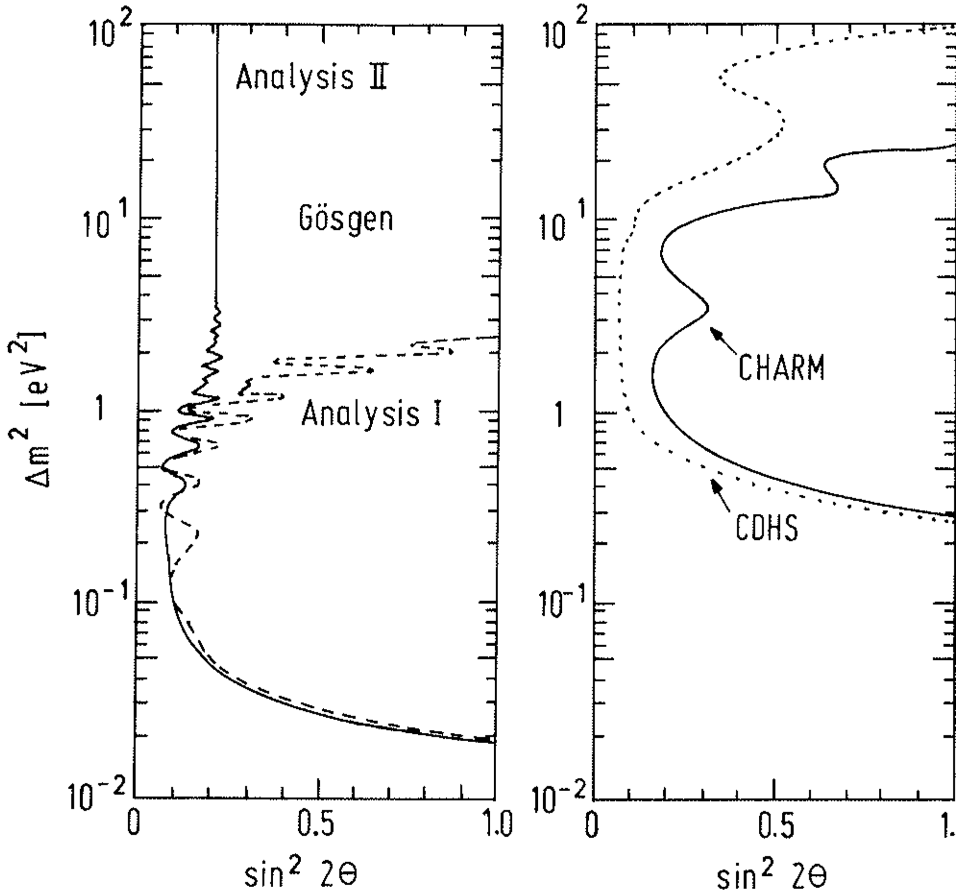

Fig. 4: Permitted and excluded ranges for neutrino-oscillation parameters $\Delta m^2 = m^2_1 - m^2_2$ and $sin^2 2\theta$, obtained for a two-flavor neutrino model. Excluded are in all cases with 90% confidence the parameter ranges right of the curves, while oscillation parameters left of the curves would still be compatible with the experimental results. The left side pertains to experiments with reactor neutrinos performed at the nuclear power reactor at Gösgen/Switzerland [5]. Analysis I relies exclusively on measured neutrino intensities at three different distances between reactor core and neutrino detector (37.9 m; 45.9 m; 64.7 m). Analysis II employs additional information, in particular a knowledge of the reactor neutrino spectral distribution and of the absolute value of the integrated flux. The right side of the figure shows similar experiments performed at CERN/Geneva [6, 7], using accelerator produced neutrinos.

indeed expected to be associated with an extremely strong burst of neutrinos in a time range of the order of milliseconds, which might be detectable by a terrestrial neutrino detector. The rare occurrence of such events and the short duration of the pulse make such experiments extraordinarily difficult, but preparations are nevertheless in progress which aim at permanently supervising our own galaxy for such rare events.

The more attractive experiment to be carried out in the near future is a measurement of the solar neutrino flux and I will now make some remarks about this type of experiment, in which my own laboratory will participate. The studies of the solar neutrino flux will in fact be carried out in the vicinity of the site of this conference. About 100 kilometers east of Rome is the Gran Sasso mountain range. A highway tunnel is crossing this range and a big system of excavations has been made right in the center of this tunnel in order to allow for experimental studies under conditions well shielded against cosmic radiation. The solar neutrino experiment will be located in one of the cavities of this big underground laboratory. The experiment, the so-called EUROPEAN GALLEX PROJECT, will be carried out in the framework of a large international collaboration, involving groups from Germany, France, Italy, Israel and the United States [8].

Why is the sun a big source of neutrinos and why is it so interesting to measure the solar neutrino flux? According to our understanding, the sun is liberating enormous quantities of energy as a consequence of the fusion processes which are continuously going on in its interior. The basic process is the fusion of four hydrogen nuclei into a ^{4}He nucleus:

$$p + p + p + p \rightarrow p + p + n + n + e^+ + e^+ + \nu_e + \nu_e$$

$$^4\mathrm{He}$$

[6] F. Bergsma *et al.*, CHARM-Collaboration, Phys. Lett. 142 (1984), 103.
[7] F. Dydka *et al.*, CDHS-Collaboration, Phys. Lett. 134B (1984), 281.
[8] Grenoble-Heidelberg-Karslruhe-Milano-Nice-Rehovoth-Rome-Saclay-Brookhaven Collaboration.

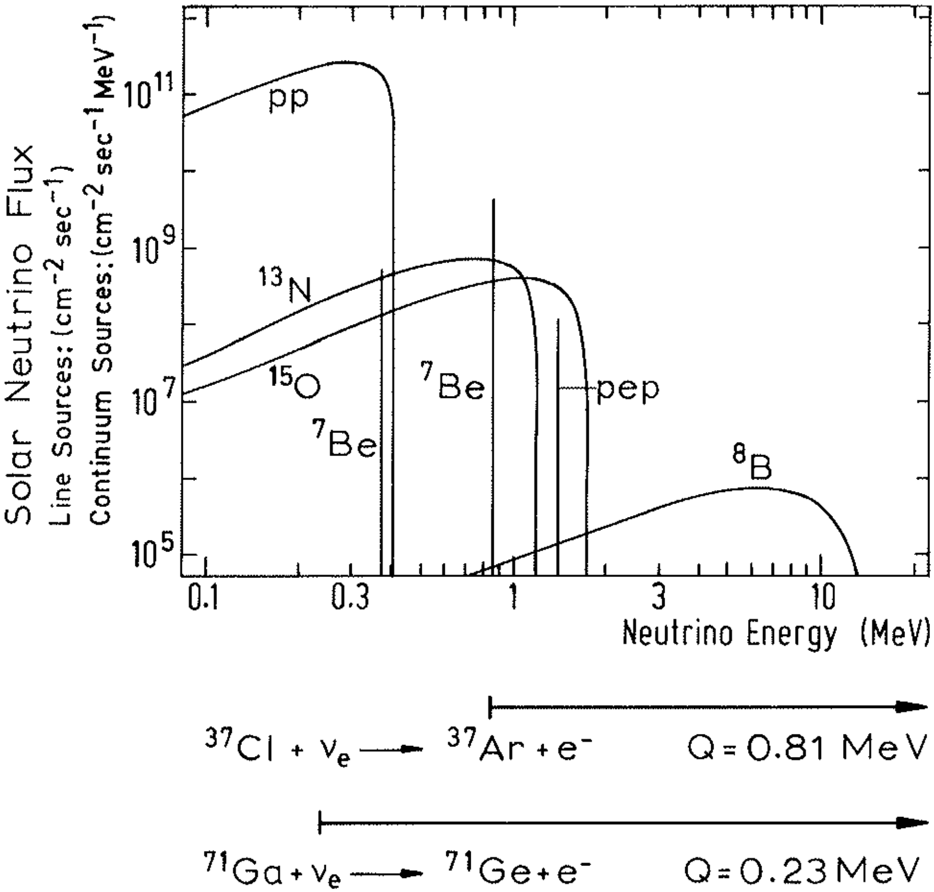

Fig. 5: Solar neutrino energy spectrum: Solar neutrino flux at the earth plotted versus neutrino energy for the different neutrino generating reactions occurring in the sun.

This fusion process, which in reality proceeds via several intermediate stages, is characterized by the transformation of two protons into two neutrons, and this inverse beta process automatically involves the emission of two protons into two neutrons, and this inverse beta process automatically involves the emission of two neutrinos, as had been explained above. The formation of each nucleus of ^4He is therefore accompanied by the emission of two electron neutrinos. The solar luminosity reflects the heat produced in the thermal nuclear reactions that fuse light elements into heavier ones, thus converting mass into energy. According to the standard solar model, more than 98% of the energy required to produce the observed solar luminosity originates in the proton-proton chain of nuclear fusion processes. Neutrinos are at present the only way to obtain information on the thermal nuclear fusion processes proceeding in the solar interior, because neutrinos are the only particles which can leave the sun without undergoing absorptive interactions, arriving at the earth some 8 minutes after their creation. The visible light causing the solar luminosity, by contrast, is associated with photons, which were generated in the interior of the sun some 100,000 to 1 million years earlier, as a consequence of the intense scattering processes which the photons undergo in the solar interior and which make photon diffusion a very slow process. Thus, neutrinos are presently our only chance to learn instantly something about the reactions within the solar interior and with the sun being our nearest star, solar neutrinos are our only chance to learn something about stellar reactions in general.

Because the solar luminosity originates essentially from the proton-proton fusion process in the sun, we have a rather accurate knowledge of the relation between solar luminosity and solar neutrino flux supposedly arriving on earth. The solar neutrino flux expected according to the standard model is shown in Fig. 5 as a function of neutrino energy E_ν. The spectrum demonstrates the dominance of the contributions from the proton-proton fusion process. Experimental studies of the solar neutrino flux were performed by R. Davis for more than 15 years, in an effort to substantiate our knowledge of the fundamental stellar energy conversion processes [9]. These terrestrial measurements of the solar

[9] R. Davis Jr., Proc. Neutrino Mass Miniconf. Telemark, Wisconisn (1980), ed. V. Barger and D. Cline, p. 38.

neutrino flux were performed in the Homestake Gold Mine in South Dakota, using the reaction

$$v_e + {}^{37}Cl \rightarrow e^- + {}^{37}Ar$$

The detector employed a tank filled with 615 t of perchlorethylene. Within this huge detector, the solar neutrinos produced a conversion of less than one ^{37}Cl nucleus to a ^{37}Ar nucleus per day. The extraction of this excessively small number of ^{37}Ar atoms and their counting by means of their electron capture radioctivity was an extraordinary experimental achievement. The determination of the solar neutrino flux based on the observed experimental reaction rate gave a measured rate of $(2.1 \pm 0.3)\ 10^{-36}$ captures per sec and per ^{37}Cl-atom as compared to a standard model prediction of $(7.6 \pm 1.5)\ 10^{-36}$ captures per sec and per ^{37}Cl-atom, revealing a shortage of solar neutrinos by more than a factor of 3.

This so-called solar neutrino puzzle is very disturbing. It may originate from two different sources. First of all, there may be something wrong with our understanding of the high energy branch of the solar neutrinos spectrum. The ^{37}Cl capture process used for the detection of the solar neutrinos has a rather high energy threshold of 0.81 MeV and therefore according to Fig. 5 is essentially measuring the ^{8}B-part of the solar neutrino spectrum, this part being only a small side branch of the solar fusion processes. The intensity of this side branch is rather sensitive to the temperature of the interior of the sun and to the size of the fusioning core. The predictions of the standard solar model may be in error concerning this branch, though this is not easy to believe.

A second and more likely reason for the deviation between the measured and the expected solar neutrino fluxes may originate from the behavior of the neutrinos themselves. Neutrinos may oscillate during their passage from the sun to the earth. They are generated during the nuclear fusion processes as electron neutrinos and during their flight to the earth might convert into muon and into tauon neutrinos. Assuming maximum mixing, it might then well be that the entire neutrino intensity is equally distributed over the three types of neutrino flavors and a detector of ^{37}Cl, being sensitive only to electron neutrinos, would then register an intensity reduction by a factor of three, roughly in agreement with the observations. However, the assumption of maximum mixing is difficult to justify

and therefore this particular explanation of the observed shortage of solar neutrinos appears very unlikely.

There exists, however, another possibility, the appearance of neutrino oscillations intiated by the solar matter. This explanation is based on the work of Wolfenstein [10] and on the neutrino resonance conversion possibility proposed by Mikhejev and Smirnov [11]. Neutrino oscillations in matter can arise because of the fact that electron neutrinos in the sun will interact with the solar electrons more strongly than is the case with all the other types of neutrinos. In technical terms, electron neutrinos interact via charged and neutral currents and other neutrinos only via neutral currents. As a consequence, one may have a cancellation of vacuum and matter oscillation terms in the scattering of electron neutrinos into their own kind, while the scattering into other kinds for this very reason becomes dominant. Electron neutrinos generated in the solar interior may therefore become preferentially transformed into other kinds of neutrinos, with corresponding reductions of the terrestrial solar electron neutrino flux. It is presently not possible to judge on the basis of the ^{37}Cl experiment whether the shortage of solar electron neutrinos is due to a misunderstanding of the solar model or due to an oscillatory behavior of the neutrinos. It therefore becomes crucial to study the main solar neutrino branch from the proton-proton fusion process, where the number of neutrinos can be readily related to the observed solar luminosity. A measurement of this low energy part of the solar neutrino spectrum requires detectors with a substantially lower threshold energy than used so far. One possibility with a threshold of only 0.23 MeV is the reaction

$$^{71}Ga + \nu_e \rightarrow {}^{71}Ge + e^-$$

and it is in fact this reaction which will be used by the European Gallex Collaboration. The experiment will employ 30 t of Ga in the form of $GaCl_3$, which is rather costly. The experiment will start taking data in late 1989. It takes this long to mount the detector and to procure the necessary Ga. The Gallium experiment, like the

[10] L. Wolfenstein, Phys. Rev. D17 (1978), 2369.

[11] S.P. Mikhejev and A. Smirnov, 10th International Workshop on Weak Interactions, Savonlinna, Finland, June 1985.

Chlorine experiment, will once more be a radiochemical experiment, with an expected reaction rate, where about one atom of ^{71}Ga would be daily converted to ^{71}Ge. The extraction procedure of this minute amount of activity, again, will be very difficult. This extraction problem is solved in principle, but the technical realization will still be a difficult process.

The European Gallex Project, being a radiochemical experiment, is integrating over the entire solar neutrino spectrum residing above the reaction threshold. Though measuring a sizeable fraction of the main solar fusion process, it cannot yield the spectral distribution of the solar neutrinos. The combination of different experiments employing reactions with different thresholds could provide some coarse spectroscopic information. A genuine solar neutrino spectroscopy will have to wait for the arrival of new types of detectors, such as for instance bolometers, capable of measuring neutrino induced recoil phenomena. Efforts in this direction are in progress in a number of laboratories including our own, but in view of the large number of problems to be solved and due to the very low reaction rate the progress is expected to be slow and measurements cannot be realized in the immediate future.

Carlo RUBBIA

PHYSICS

We know very little of what is happening inside the Sun. Professor Mössbauer has pointed out very clearly the big difference between the 5,000 degrees, which is the temperature at the surface of the Sun and the 10-15 million degrees which are expected to be in the core. The basic phenomena in the Sun do not occur on the chromosphere, they are inside. To grasp the complexity of the problem we should remember that today we don't even know well what happens 100 km underneath this place, on our earth. Our knowledge of the centre of the earth is close to zero. Think about the Sun which is so far away!

The understanding of the interior of the Sun is fundamental because it is for us the model of other stars. Knowing better our Sun will help also our understanding of all other stars. We have near by a beautiful example of an object which is so widely diffused in the rest of the Universe.

Inside the Sun, energy is generated by many nuclear reactions, in which nuclei transform into other nuclei. We are very fortunate that one of the products of these reactions, namely the neutrino, is sufficiently weakly interacting so as to be able to escape and to arrive essentially unperturbed to our detectors. The spectroscopy of solar neutrinos, namely an accurate determination of the energy density spectrum, which reflects the complexity of the reactions at its interior, is absolutely fundamental. It seems to me there is no better way of learning about the origin of the energy emitted by the Sun.

It should be mentioned that there are also other extremely intelligent and powerful methods. Very recent is the one in which one observes oscillations on the Sun's surface. The Sun's surface has

coherent oscillations. Observing these movements which are very tiny but they can be detected today, one can have some ideas about the density inside. Very interesting from the scientific point of view, they really give you mainly global information. They don't pinpoint to the real engine which is inside the Sun. For this purpose neutrinos are in fact the key, they are fundamental and unique.

André LICHNEROWICZ

LE PROGRÈS DES MATHÉMATIQUES ET LE FUTUR DE L'HUMANITÉ

Les mathématiques, nées d'une très longue histoire, continuent à jouir, dans notre monde contemporain, d'un statut ambigu. Ces mathématiques, il convient de les prendre ici en un sens large et j'y engloberai — comme il se doit dans les dernières années du XX^e^ siècle — la logique et une grande part de l'informatique théorique parce que tout cela est parfaitement homogène aux mathématiques.

D'une part cette mathématique importe, par son existence même, à l'esprit le moins préoccupé de techniques ou de connaissance scientifique de l'univers concret; elle importe parce qu'elle est témoignage, un témoignage aseptique, parfois trop aseptisé, sur une part essentielle du fonctionnement de notre esprit. Mais il arrive qu'hors du champ des spécialistes, beaucoup se demandent comment et en quel sens il peut y avoir progrès en mathématiques, ce qui est la marque d'un échec certain en ce qui concerne «la communication», comme nous disons.

D'autre part, il est devenu de plus en plus clair, du XVIII^e^ siècle à nos jours, que, dans les parties les plus développées de notre science, la mathématique, loin d'être seulement fournisseuse d'*outils extérieurs*, a été obligée d'assumer un rôle plus ambitieux et plus nécessaire. Elle s'est fait *mode de pensée* pour appréhender la réalité et ne prétend à son intelligence que lorsqu'il a été possible de construire, pour l'ensemble des phénomènes étudiés, un modèle mathématique cohérent et efficace. Les grandes théories physiques de notre temps, relativité, mécanique quantique, comme la mécanique classique elle-même, se sont constituées à partir de l'élaboration de tels modèles et le développement constant de nouveaux concepts mathématiques originaux a souvent été étroitement lié à notre exigence d'intelligence du réel.

De ce point de vue, l'une des difficultés de mon propos est la

suivante: une théorie physique n'a pas deux sens, un *sens ésotérique*, traduisible seulement dans un jargon sophistiqué et à l'aide de formules, et un *sens vulgaire* qu'il serait permis d'exprimer dans notre langue usuelle, héritière d'expériences quotidiennes et modelée par telle ou telle culture. Une telle théorie est nécessairement basée sur des concepts mathématiques qui présentent toujours un premier caractère d'universalité dans l'esprit des hommes quelle que soit leur culture; pour certains concepts, il existe aussi une universalité pratique qui en fait les matériaux avec lesquels toute théorie physique est bâtie. Nous en verrons un exemple tout-à-l'heure. Toute tentative d'expression de la physique en langue vulgaire est, peu ou prou, à base d'analogies, variables selon les cultures et capables de nous trahir, analogies sans doute nécessaires, mais qui ne disposent que d'un pouvoir heuristique, capable de stimuler notre imagination. A chaque instant, nous pensons notre univers physique en termes des mathématiques disponibles.

Il y a ainsi unité, universalité des mathématiques face à la diversité nécessaire des cultures et, au fil du temps, le développement des mathématiques, leur réflexion sur elles-mêmes, a puissamment contribué à modeler l'esprit humain, que nous en ayons conscience ou non. Sous une forme à peine paradoxale, on pourrait dire que les mathématiques, grâce à leur long travail, nous ont appris que ce que nous avons baptisé *raison*, démarche *rationnelle*, n'est pas du tout figé de toute éternité, sauf comme ambition, mais laborieusement construit, et que parfois ce qui fut considéré comme rationnel ne l'est plus pour nous. Nous allons y revenir. Il s'agit là, à mes yeux, d'une conséquence essentielle des progrès passés, présents ou futurs des mathématiques. Philosophes comme théologiens auraient grand intérêt à ne pas la sous-estimer, mais à en tenir grand compte, soit pour surmonter leurs propres difficultés, soit pour assurer leur communication avec les hommes de leur temps. Il est vrai qu'il s'agit là d'un énorme travail, à peine entamé. C'est en fait la démarche intellectuelle même, mise en oeuvre au sein des mathématiques, qui importe à tous, beaucoup plus que tel ou tel résultat.

* * *

C'est à travers l'activité mathématique, prise dans sa longue histoire, que nous pouvons saisir à quelle sorte de vérité les

mathématiques nous donnent accès. La mathématique n'est point cette science de la quantité et de l'étendue qui fut trop longtemps décrite par les philosophes et certains mathématiciens eux-mêmes. Elle est science des relations, ou comme nous dirions, science des structures, nous éclaircirons ce point. De ce point de vue, elle se présente comme science hors de la Science.

D'où venons-nous? Cette «science» est née dans quelques ports de l'ancienne Grèce, d'hommes qui aimaient se poser des questions et discuter sur les phénomènes célestes comme sur les problèmes de la cité, sur la manière de convaincre l'autre et souvent soi-même, et aussi sur les pouvoirs, les prestiges et les pièges du langage, finalement sur l'adéquation de l'esprit au monde. Parmi ces hommes, certains ne se satisfaisaient point d'histoires, d'apologues ou de jeux verbaux, encore moins de l'autorité donnée à l'autre par la rhétorique. Ils conçurent le projet d'un type de discours sans quiproquo ni malentendu, un discours cohérent et contraignant pour l'autre, capable par sa forme même d'interdire le refus de son contenu. De tels discours, ils réalisèrent quelques exemples, d'abord locaux, mais fonctionnant à peu près clairement, moyennant quelques doses «d'évidence». Les mathématiques étaient nées avec la notion de démonstration. Où une démonstration contraignante était-elle possible et quel était le degré de cette contrainte? que fallait-il pour qu'elle fonctionne? Il nous faudra attendre Hilbert et les grands logiciens mathématiciens de ce temps pour pouvoir apporter à de telles questions des réponses un peu précises.

Chez les grecs, mathématiques, logique, philosophie naissent simultanément, s'entremêlent pour une part en se prêtant des appuis mutuels douteux, usent d'un langage peu différencié, variant seulement selon la nature des objets. La logique explicite est celle qui concerne ce que nous appellerions les ensemble *finis* et elle se dégage difficilement de toute considération sémantique. Les mathématiques, elles, mettent en oeuvre, implicitement et presque inconsciemment, une logique notablement plus ambitieuse, ainsi qu'il apparaît par exemple chez Euclide. Dans la démarche mathématique grecque, deux obstacles graves cependant, qu'il va falloir des siècles pour sourmonter. Le discours n'est pas conçu, même chez Euclide, comme *hypothétiquement contraignant*: les axiomes sur lesquels repose la construction ne sont point posés par des actes libres, mais se veulent doués d'une évidence commune, antérieure et extérieure à l'activité mathématique elle-même. D'autre part, il existe, pour cette

mathématique, un plan privilégié des objets mathématiques, *des êtres mathématiques*, êtres idéalisés venus de la contemplation du Ciel ou des problèmes de la Terre, relevant de l'arpentage ou de l'architecture, du commerce ou de la navigation. Ces deux obstacles marqueront fortement tout le développement mathématique jusqu'au XIX^e siècle.

* * *

Venons-en au XIX^e siècle. De 1830, date où Galois introduit, à propos des racines d'une équation algébrique, la notion de *groupe*, mais est conscient de l'universalité de cette notion, jusqu'aux années 1870, où la notion d'*ensemble* a mûri, les mathématiques ont beaucoup réfléchi sur elles-mêmes et sur leur ambition, et mis en évidence les limites de cette ambition.

Pour nous, la notion première adoptée est généralement la notion d'ensemble, d'ensemble, il faut le dire, de n'importe quoi. De nombres, par exemple l'ensemble des entiers, de points de l'espace, mais aussi ensemble des livres de toutes les bibliothèques du monde, des phrases d'une langue naturelle ou des échanges au sein d'une économie. Une telle notion prise naïvement, comme un langage commode et précis, se révèle fort utile, même si, au niveau élémentaire, aucune théorie n'en est faite. Elle présente cependant des pièges dont nous avons fait l'expérience et que nous savons désormais systématiquement éviter. Il est inutile d'entrer dans plus de détails. Ce qui importe, c'est pour certains couples d'ensembles, la possibilité entre eux de ce que nous nommons bijections, c'est-à-dire de *dictionnaires parfaits*. Ce qu'on peut appeler la première opération mathématifiante, le fait élémentaire de compter, est l'établissement d'un dictionnaire parfait entre un ensemble (fini) et une partie des nombres entiers naturels. Mais on peut trouver des exemples élémentaires plus raffinés: à tout entier associons l'entier pair qui est son double, et inversement à tout entier pair sa moitié. Nous obtenons ainsi un parfait et étrange dictionnaire entre un ensemble, celui des entiers, et une partie stricte de celui-ci, celui des entiers pairs; cette possibilité d'un dictionnaire parfait entre le tout et une partie caractérise pour les mathématiciens les *ensembles infinis*. Il n'en est jamais ainsi pour un ensemble composé d'un nombre fini d'éléments.

Si l'on dispose d'un ensemble déterminé E, fini ou infini, il admet des transformations, c'est-à-dire des dictionnaires parfaits

avec lui-même. Une transformation de E fait correspondre à tout élément de E un autre élément de E, qui peut éventuellement coïncider avec le premier, *et inversement*. On obtient ainsi une notion de transformation inverse. De telles transformations se composent naturellement de manière associative. Nous rencontrons là nécessairement la notion de *groupe*.

Tout au long du XIX^e^ siècle, ce concept va s'incarner en géométrie, en mécanique et dans l'électromagnétisme de Maxwell sous forme de groupes de transformations. En fait cette notion de groupe sous-tend depuis longtemps certaines activités de l'esprit des hommes. Dans la géométrie grecque, qui culmine avec Euclide, on voit figurer dans les axiomes concernant «l'égalité» des figures les énoncés suivants:

1) Une figure est égale à elle-même;

2) Si une figure est égale à une seconde, la seconde figure est égale à la première;

3) Si une figure est égale à une seconde et cette seconde égale à une troisième, la première figure est égale à la troisième.

Dans ces trois énoncés se trouvent sous-jacents, les axiomes de groupes, mais sous une forme encore bien maladroite. Seule l'apparition du langage ensembliste a permis de construire des énoncés ayant un caractère universel. Un ensemble G de transformations de E est un groupe de transformations si:

1) il contient toujours la composée de deux transformations appartenant à G;

2) il contient la transformation identité, celle qui fait correspondre à tout élément de E cet élément même;

3) il contient la transformation inverse de toute transformation appartenant à G.

On perçoit qu'à l'ordre près, ces axiomes correspondent à ceux concernant l'égalité des figures en géométrie euclidienne.

Cela posé, la géométrie euclidienne du plan ou de l'espace repose toute entière sur le *groupe des déplacements*, groupe dont les éléments sont obtenus par composition des rotations, et des translations et qui est un groupe de transformations de l'espace préservant les distances. Les translations, pour leur propre compte, forment un groupe dont la loi de composition, décrite par l'addition des vecteurs, est commutative. Un groupe laisse inchangés, invariants certains éléments ou certaines quantités, ici la distance par exemple et cela est fort important.

Deux groupes sont dits isomorphes s'il existe entre eux une bijection faisant correspondre leurs lois de composition. S'il n'en est pas ainsi, les groupes sont radicalement distincts. Dès l'apparition avec Riemann et Lobatchevski des *géométries non euclidiennes*, le groupe fondamental d'une géométrie (jouant un rôle analogue au groupe des déplacements, mais non isomorphe à lui) devint l'instrument essentiel de son analyse et cette analyse s'est étendue à la mécanique et à l'électromagnétisme.

La mécanique newtonienne s'est exprimée, dès ses premiers développements, en termes de masse, d'accélérations de forces. Il en est en particulier ainsi pour la théorie newtonienne de la gravitation. Mais quel était donc le groupe qui laissait invariantes les équations de cette mécanique? Il fut très tôt reconnu que ce groupe était le groupe engendré par composition des déplacements de l'espace, des translations dans le temps et des mouvements rectilignes uniformes. Le groupe en question, dont chaque transformation est décrite par les valeurs de dix paramètres ou, comme nous disons désormais, est de dimension 10, est ce que nous nommons le *groupe de Galilée*, en hommage au savant qui rendit pleine justice au rôle du mouvement rectiligne uniforme. L'invariance des équations de la dynamique newtonienne par le groupe de Galilée est la meilleure manière d'exprimer le principe de relativité galiléen qui se traduit par l'impossibilité, par des moyens mécaniques terrestres, de mettre en évidence par exemple «une vitesse absolue» de la Terre.

Vers 1865 Maxwell réussissait à unir champ électrique et champ magnétique en une seule entité, le *champ électromagnétique*, régi par des équations qui portent son nom. Au sein de cette entité, vont se trouver réunies les différentes radiations alors connues, ou créées au cours des quarante années suivantes, la lumière certes, mais aussi d'un côté rayons X ou γ, de l'autre les ondes dites radio. Il s'agit là de la première grande unification d'un domaine de la physique. La synthèse de l'électrique et du magnétique mettait en évidence l'importance d'une constante C ayant les dimensions d'une vitesse et qui se révélait, à l'étude théorique, n'être rien d'autre que la vitesse de propagation dans le vide commune aux ondes électromagnétiques, donc celle de la lumière. Les équations de Maxwell conduisaient à une «*équation des ondes*», analogue à celle connue en mécanique des fluides, dans laquelle G jouait le même rôle que la vitesse du son par exemple.

Vers 1900, plusieurs théoriciens, dont Lorentz et Poincaré,

procédaient à des études qui revenaient à déterminer le groupe d'invariance du premier membre de l'équation des ondes (correspondant, sous des hypothèses convenables, à un groupe d'invariance du système des équations de Maxwell), groupe qui, quoique de même dimension, apparaissait profondément différent du groupe de Galilée. Il s'agissait là de la première apparition de ce qu'on a nommé le *groupe de Poincaré*, sur lequel est fondée la théorie de la relativité et désormais toute notre physique.

Laissons cela. Nous avons analysé, à titre d'exemple, une structure élémentaire, celle de *groupe*, qui d'une part est devenue l'une des clés de notre intelligence mathématique, d'autre part a acquis dans notre monde un rôle tel que nous ne pouvons penser notre univers physique, fait de champs ou particules, qu'en termes de groupes.

* * *

Qu'avons-nous appris laborieusement en cent cinquante ans? D'abord que la mathématique est une, en droit et en fait. Par l'élaboration d'un langage commun, la construction de structures communes, comme celle de groupe, la mathématique a brisé de vieux cadres historiques qui auraient pu tendre, en se remplissant à la fragmenter, en disciplines distinctes, évoluant de manière divergente.

Cela a été permis par la prise de conscience de ce que *la nature des choses n'importe pas au mathématicien*. Ce qui importe, c'est la possibilité de ces dictionnaires parfaits, dont j'ai parlé et l'isomorphisme correspondant des structures étudiées. C'est la notion d'isomorphisme et sa substitution à celle d'identité qui, pour une large part, fonde les mathématiques. Pour faciliter son langage, le mathématicien *identifie* bien souvent, sans scrupules, des objets d'origines différentes, lorsqu'un isomorphisme l'assure qu'il ne ferait que prononcer deux fois exactement le même discours, dans deux langues rigoureusement équivalentes.

Il m'est arrivé de parler d'«être mathématique», mais au vrai cette expression n'a pas de sens. Un ensemble peut être, j'ose le dire, un ensemble de n'importe quoi, s'il satisfait à quelques règles générales de définition, élaborées au cours du temps et qui éloignent tout paradoxe. Par suite tout donné peut être considéré comme mathématifiable, s'il consent à se soumettre au traitement des ensembles et des isomorphismes, c'est-à-dire précisément dans la

mesure exacte où ce que nous négligeons ainsi — tout le contenu ontologique — ne nous importe pas. Il est essentiel de noter que ce que nous devons négliger ne peut être *défini* une fois pour toutes, sous peine de contradiction.

Ce caractère radicalement non ontologique — l'Etre des choses doit être, au mieux, mis entre parenthèses — qui caractérise les mathématiques, elles le transportent partout avec elles, dans les domaines où elles se font servantes, et c'est lui qui leur confère leur puissance, leur polyvalence, leur fidélité. Le discours mathématique apparaît comme un filet aux mailles arbitrairement serrées mais qui laisse nécessairement s'écouler l'onde de l'Etre.

Qu'avons-nous appris? Que tout discours qui se veut sans quiproquo ni malentendu, tout discours dépourvu de contradictions, ne peut être qu'un discours soumis à l'ascèse mathématique. Tout autre discours porte toujours en lui-même ses contradictions. Mais l'ironie mathématique ajoute: *il nous est impossible de prouver mathématiquement que le discours mathématique n'est point contradictoire.*

Approfondissons ce point qui nécessite quelques considérations concernant la métamathématique. Le paysage que j'ai décrit est grosso modo celui de la mathématique proprement dite, fondée sur une théorie des ensembles axiomatisée à la Gödel et conçue comme point de départ.

Mais nous savons désormais, grâce à Gödel en particulier, que la vieille ambition d'un discours qui trouve en lui-même sa propre justification, ne peut qu'être contradictoire en elle-même. Plus positivement, cela veut dire qu'il faut avoir recours à une métamathématique pour tenter de prouver dans celle-ci la non-contradiction de la mathématique elle-même et ainsi de suite. Mais entre activité mathématique et activité métamathématique, il n'est point de différence, de solution de continuité, et ce n'est que conventionnellement que nous plantons, ici ou là, un drapeau: «Ici commence le pays des mathématiques». La mathématique au sens large a appris qu'*elle est inépuisable vers l'aval* — cela, elle l'avait deviné depuis toujours — *mais aussi vers l'amont.*

Nous avons enfin appris, avec Gödel et Paul Cohen, qu'il existe *des* théories des ensembles, comme il existe des géométries, euclidiennes ou non. Ces théories induisent d'une manière générale, au plan des mathématiques proprement dites, une démarche unique correspondant à notre théorie usuelle et à sa naïveté. Nous disposons de plusieurs *logiques de l'infini*, dont certaines apparaissent comme ce

que les philosophes appelleraient des logiques de l'infini actuel.

Ainsi, comme nous le voyons, *Epiménide règne et tout mathématicien se ressent parfaitement crêtois, à travers des degrés de vérité* qui pourraient être interprétés par décalage du point de vue, comme degrés de mensonge. *Ainsi notre vieille tentation d'un discours s'autoprouvant apparaît ce qu'elle est: un rêve.*

Quel est, pour le mathématicien, le statut d'un logique qui fut chère au philosophe? Un statut ambigu et polymorphe, dans les détails duquel je n'entrerai pas. En tout cas, une logique stricto sensu ne peut être constituée en une discipline normative, extérieure à la mathématique et s'imposant à elle et ne saurait, comme la mathématique, être fixée une fois pour toutes. On pourrait dire que la mathématique porte en elle une stratégie privilégiée, plus ou moins explicite: à chaque choix logique possible, elle choisit toujours ce qui est capable de lui donner le maximum de puissance et de fécondité, sans nuire à sa cohérence.

Quelles conséquences peuvent avoir les progrès des mathématiques sur notre futur? Il semble, comme je l'ai dit, que les conséquences essentielles portent sur le fonctionnement même de l'esprit humain, et qu'il y a là irréversibilité à chaque étape.

La Science n'est pas affaire de mode, au moins sur le long terme, et ce que nous avons durement appris au cours du temps, nous le savons bien. Le premier devoir d'une théorie nouvelle, quelle qu'elle soit, est de rendre justice à ses devanciers, de comprendre le pourquoi de leurs succès encore trop limités, *de les englober, non de les abolir.*

Ce qu'ont commencé à nous apprendre les mathématiques, c'est qu'il n'est point de raison humaine intemporelle et statique, mais une raison dynamique, laborieusement construite à chaque instant, que *scientifiquement* nous ne pouvons avoir accès qu'à un espace ironique de *vérités abstraites* (à la fois hypothétiques et efficaces) ou à des *espaces de vérités approchées*, à un extraordinaire degré d'approximation. Ainsi le concept originel de vérité scientifique s'est révélé naïf et inadapté.

Nous avons aussi pris conscience (prenons garde aux délires positifs ou négatifs de l'informatique) qu'à chaque instant la capacité de l'esprit humain apparaît comme *sans limite énonçable* et c'est cet adjectif qui est important. Les mathématiques nous conduisent à jeter sur ce que nous nommons raison, vérité scientifique, ou capacité, un regard neuf, mais qui a perdu toute innocence.

AUDIENCE SOLENNELLE PONTIFICALE

Dans l'après-midi, Sa Sainteté Jean Paul II a reçu en audience solennelle dans la Salle Regia *du Palais Apostolique du Vatican les membres de l'Académie Pontificale des Sciences et les représentants des Académies des Sciences et des autres institutions culturelles venus au Vatican, du monde entier, pour les célébrations du Cinquantenaire de l'Académie.*

Etaient présents les Eminentissimes Cardinaux: Agostino Casaroli Secrétaire d'Etat; Sebastiano Baggio, Camerlingue de la Sainte Eglise romaine, et Président de la Commission cardinalice pontificale pour l'Etat de la Cité du Vatican, William Wakefield Baum, Préfet de la Congrégation pour l'Education catholique. Les archevêques étaient également nombreux, parmi lesquels Messeigneurs Jan Schotte, Antonio Javierre Ortas, Lucas Moreira Neves. Avec les membres du Corps diplomatique accrédité auprès du Saint-Siège — qui étaient conduits par le Doyen S.E. Josef Amichia, Ambassadeur de la Côte d'Ivoire — étaient placés S.E. Mgr. Eduardo Martinez Somalo, Substitut de la Secrétairerie d'Etat avec l'Assesseur Monseigneur Giovanni Battista Re, et S.E. Mgr. Achille Silvestrini, Secrétaire du Conseil des Affaires Publiques de l'Eglise, avec le Sous-Secrétaire Monseigneur Bačkys.

Parmi les nombreux invités, l'on comptait le Directeur général de l'UNESCO, S.E. Amadou Mathar M'Bow, et le Ministre de la Recherche scientifique de la République italienne, M. Luigi Granelli.

Après l'exécution d'un motet par le choeur de la Chapelle musicale pontificale, dirigé par Monseigneur Domenico Bartolucci, le Saint Père a prononcé l'allocution suivante:

Sa Sainteté Jean Paul II prononce son Allocution au cours de l'Audience Solennelle.

ALLOCUTION DE SA SAINTETÉ JEAN PAUL II

Messieurs les Cardinaux,
Monsieur le Directeur Général de l'UNESCO,
Monsier le Ministre de l'Italie pour la recherche scientifique,
Excellences,
Mesdames et Messieurs,

C'est avec une grande joie que je célèbre avec vous le cinquantenaire de l'acte par lequel le Pape Pie XI a renouvelé l'Académie Pontificale des «Nuovi Lincei» pour en faire l'*Académie Pontificale des Sciences* par le Motu proprio *In multis solaciis*, du 28 octobre 1936.

1. Le mot «Linceo» appartient à votre histoire et à votre être même, chers Académiciens, puisque vous tirez votre origine et votre inspiration fondamentale de ce groupe de jeunes scientifiques qui, réunis autour du Prince Federico Cesi, donnèrent naissance, en 1603, à l'Académie des «Lincei», dont fit partie, en 1610, Galileo Galilei, qui depuis lors signa toutes ses oeuvres avec le titre de «Linceo».

Les liens entre l'Eglise et l'Académie sont devenus particulièrement intenses sous Pie IX, qui lui confia des tâches de recherche scientifique au service des Etats pontificaux, et ils s'approfondirent encore sous ses successeurs, surtout Pie XI, qui lui conféra le titre et la fonction de *Senatus scientificus* de l'Eglise, constitué de soixante-dix membres, auxquels le Souverain Pontife demanda de «favoriser toujours plus et toujours mieux les progrès des sciences», ajoutant: «Nous ne leur demandons rien d'autre, car ce noble but et cette tâche élevée constituent le service que Nous attendons d'hommes étroitement liés à la vérité».

Mes vénérés prédécesseurs Pie XII, Jean XXIII et Paul VI ont encouragé l'Académie Pontificale, pleinement convaincus du rôle indispensable de la science au service de la vérité créée, et finalement

au service de la Vérité Première qui est Dieu, en suivant le chemin du fini à l'infini, qui est inscrit dans l'esprit humain. Les Souverains Pontifes ont été activement secondés par les Présidents qui se sont succédés, le Père Agostino Gemelli, Monseigneur Georges Lemaître, le Père Daniel O'Connell, jusqu'àu Professeur Carlos Chagas, auquel j'adresse des remerciements chaleureux pour l'oeuvre importante qu'il a accomplie. Grâce à ces Présidents, grâce aussi à la collaboration de tous les membres et de la Chancellerie, cette Académie a acquis un prestige insigne et un rôle scientifique de très haut niveau, en suscitant d'ailleurs la participation à d'importants travaux de nombreux représentants de la communauté scientifique mondiale.

2. Au cours de vos cinquante ans d'histoire, vous avez, Mesdames et Messieurs les Académiciens, accordé très justement la primauté à la science pure, en revendiquant sa légitime autonomie. En vous adressant mon premier discours, ici-même, le 10 novembre 1979, j'ai proclamé la dignité et la haute valeur de la science en ce qui concerne son versant théorique: «La recherche fondamentale doit être libre face aux pouvoirs politique et économique, qui doivent coopérer à son développement sans l'entraver... Comme toute autre vérité, la vérité scientifique n'a, en effet, de comptes à rendre qu'à elle-même et à la vérité suprême qui est Dieu, créateur de l'homme et de toute chose».

En plus de la science pure, vous vous êtes consacrés à l'étude de ses conséquences sur la science appliquée qui, comme je le disais dans ce même discours, «a rendu et rendra à l'homme d'immenses services, pour peu qu'elle soit inspirée par l'amour, réglée par la sagesse, accompagnée par le courage qui la défend contre l'ingérence indue de tous les pouvoirs tyranniques». Votre Académie s'est activement occupée des sciences appliquées pour ce qui regarde les besoins de l'humanité entière, ayant toujours conscience des exigences de la loi morale.

3. L'existence et l'activité de cette Académie, fondée par le Saint-Siège, en liens constants avec lui, composée de membres nommés par lui, illustrent avant tout ce fait: il n'y a *pas de contradiction entre la science et la religion*. L'Eglise estime la science, elle se reconnaît même une certaine connaturalité avec ceux qui y consacrent leurs efforts, comme avec tous ceux qui cherchent à ouvrir la famille humaine aux plus nobles valeurs du vrai, du bien et du beau, à une intelligence des choses ayant valeur universelle (cf.

Gaudium et spes, n. 57, § 3). L'Académie Pontificale manifeste également, de son côté, que la science a besoin de s'accorder avec la sagesse et avec l'éthique, afin de satisfaire les exigences les plus profondes de l'esprit et du coeur de l'homme, afin de sauvegarder sa dignité.

Un nouveau type de dialogue s'est désormais instauré entre l'Eglise et le monde scientifique. Dans mon discours aux hommes de science et aux étudiants, le 15 novembre 1980, à Cologne, j'allais jusqu'à dire: «L'Eglise prend la défense de la raison et de la science, à laquelle elle reconnaît la capacité d'atteindre la vérité..., de la liberté de la science, par laquelle elle possède sa dignité de bien humain et personnel...». Si des divergences peuvent apparaître entre l'Église et la science, «le motif doit en être cherché dans la finitude de notre raison, limitée dans son extension et donc exposée à l'erreur».

4. Nous avons la chance de vivre aujourd'hui l'aboutissement de toute une histoire, où l'harmonie entre la culture scientifique et le christianisme n'a pas toujours été facile (cf. *Gaudium et spes*, n. 62). J'ai évoqué, en commençant, l'institution qui, autour de 1600, préfigurait l'Académie. Mais il importe surtout de considérer la façon dont se sont posés alors les rapports entre la théologie et les sciences naturelles, au seuil des temps modernes.

Isaac Newton synthétisa et porta à leur achèvement les découvertes de Kepler, de Copernic, de Galilée, de Descartes; il fut le témoin et l'acteur décisif de la révolution scientifique du dix-septième siècle. C'est alors que la science moderne franchit ses frontières traditionnelles, qui étaient auparavant déterminées par une vue géocentrique de l'univers et par une conception plus qualitative que quantitative des éléments de la nature. Ces grands savants, versés dans une étude expérimentale de l'univers, avec de plus en plus de précisions et de spécialisations, n'en demeuraient pas moins dans une attitude de recherche sur le sens global de la nature; leurs spéculations de penseur sur le cosmos en témoignent. Leurs recherches audacieuses ont aidé à mieux définir les frontières entre les ordres du savoir. Ils n'ont pas toujours été acceptés sur ce point, et l'Eglise elle-même a mis longtemps à se réconcilier avec leurs points de vue.

L'expérience de *Galilée* en est une illustration typique. Pour douloureuse qu'elle fut, elle a rendu un service inappréciable, au monde scientifique et à l'Eglise, en nous amenant à mieux

comprendre les rapports entre la Vérité révélée et les vérités découvertes empiriquement. Lui-même excluait une contradiction véritable entre la science et la foi: toutes deux proviennent de la même Source, et doivent être référées à la Vérité première.

Les chrétiens ont été amenés à relire la Bible sans y chercher un système cosmologique scientifique. Et les savants eux-mêmes ont été invités à rester ouverts à l'absolu de Dieu et au sens de la création. En soi, aucun domaine n'est soustrait à l'investigation scientifique, du moment que celle-ci respecte l'être humain; ce sont plutôt les méthodologies qui contraignent les savants à certaines abstractions et délimitations.

5. On pourrait évoquer d'autres tensions très vives qui appartiennent, espérons-le, à un passé révolu. Au siècle dernier, au nom des nouvelles sciences et des nouvelles philosophies, le positivisme s'en prenait aux positions traditionnelles de l'Eglise, accusant celle-ci d'être opposée à la science et à la recherche. Léon XIII releva le défi, en montrant que l'Eglise accueille avec joie tout ce qui permet de mieux explorer la nature et d'améliorer la condition humaine. Il donna également une impulsion vigoureuse au renouveau des sciences ecclésiastiques.

De nos jours, *la distinction* et la complémentarité des ordres du savoir — l'ordre de la foi et l'ordre de la raison — ont été exprimées avec une clarté décisive dans l'enseignement du *Concile Vatican II*: «L'Eglise affirme l'autonomie légitime de la culture et particulièrement celle des sciences» (*Gaudium et spes*, n. 59, § 3). «C'est en vertu de la création même que toutes choses sont établies selon leur consistance, leur vérité et leur excellence propres, avec leur ordonnance et leurs lois spécifiques» (ibid. n. 36, § 2). On doit reconnaître les méthodes particulières à chacune des sciences. «C'est pourquoi la recherche méthodique, dans tous les domaines du savoir, si elle est menée d'une manière vraiment scientifique et si elle suit les normes de la morale, ne sera jamais réellement opposée à la foi: les réalités profanes et celles de la foi trouvent leur origine dans le même Dieu» (ibid., n. 36, § 2). Mais il serait faux de comprendre cette autonomie des réalités terrestres comme si elles ne dépendaient pas de Dieu et que l'homme pouvait en disposer sans référence au Créateur.

Si les principes sont clairs et devraient écarter désormais toute attitude de crainte ou de défiance, cela ne veut pas dire que toute difficulté soit aplanie: de nouvelles recherches et découvertes des sciences soulèvent de nouvelles questions qui seront autant d'exi-

gences pour les théologiens dans la façon de présenter les vérités de la foi, en sauvegardant toujours le sens et la signification (cf. ibid., n. 62, § 2). Mais les savants eux-mêmes procèdent, de leur côté, à une critique de leurs méthodes et de leurs objectifs.

Aujourd'hui, l'Eglise, loin de se cantonner dans une visée apologétique ou défensive, se fait plutôt l'avocate de la science, de la raison, de la liberté de recherche, pour légitimer la science authentique. Votre Académie peut en témoigner. Et au-delà de vos personnes, je m'adresse ici à la communauté scientifique mondiale.

6. Il importe en effet de situer l'effort scientifique *dans le contexte général de la culture*. L'homme ne saurait négliger de s'interroger sur la signification profonde de la culture et de la science pour la personne humaine (cf. ibid., n. 61, § 4).

L'homme vit d'une vie vraiment humaine, grâce à la culture, c'est-à-dire en cultivant les biens et les valeurs de la nature, en affirmant et en développant les multiples capacités de son esprit et de son corps. Se soumettre l'univers par la connaissance est un aspect capital de la culture (cf. ibid., n. 53). L'élargissement et l'approfondissement du savoir scientifique constituent donc un progrès indéniable pour l'homme, parce qu'il s'agit d'une approche toujours plus précise de la vérité.

Cette recherche libre de la vérité pour elle-même, est une des plus nobles prérogatives de l'homme. La science dévie si elle cesse de suivre sa finalité ultime, qui est le service de la culture et donc de l'homme; elle entre en crise lorsqu'on la réduit à un modèle purement utilitaire; elle se corrompt lorsqu'elle devient un instrument technique de domination ou de manipulation à des fins économiques ou politiques. Il existe alors ce que l'on peut appeler une crise de légitimation de la science. Il y a donc urgence à défendre une science authentique, ouverte à la question du sens de l'homme et à la recherche de la vérité intégrale, une science libre, et dépendant uniquement de la vérité. Du point de vue de l'Eglise, science et culture ne sauraient être dissociées.

De même, en considérant que l'homme n'est pas seulement l'objet, mais le sujet de la culture, l'Eglise encourage le travail de l'homme de science: elle apprécie chez les savants, non seulement l'exploit de l'intelligence, mais le mérite professionnel et moral, leur honnêteté intellectuelle, leur objectivité, leur recherche du vrai, leur autodiscipline, leur coopération en équipe, leur engagement à servir

l'homme, leur respect devant les mystères de l'univers. Ce sont là des valeurs humaines qui manifestent la vocation spirituelle de l'homme.

7. Par ailleurs, l'homme de science est appelé d'une manière nouvelle à une *ouverture*. Tout en respectant les exigences méthodologiques de l'abstraction et de l'analyse spécialisée, il ne faut jamais négliger l'orientation unitaire du savoir. Les conditions modernes ont fait apparaître *un risque* d'émiettement et le risque de se limiter à l'objet immédiat de la recherche. La science ne peut négliger les questions fondamentales sur son rôle et sa finalité; elle ne peut se fermer à l'universel ni à la connaissance des ensembles, ni à l'Absolu, même si, à elle seule, elle n'est pas en mesure de répondre à la question du sens.

Il me semble aujourd'hui que la communauté scientifique, après une période d'extrême spécialisation nécessaire sur le plan expérimental, est en train de retrouver l'intérêt des ensembles, la question du sens de l'univers, le mystère merveilleux de la nature et de l'être humain. Beaucoup de savants s'y aventurent; ils le font peut-être timidement à cause d'un certain agnosticisme ou par crainte de dépasser ce que leur propre recherche leur permet de dire. Mais le fait qu'un certain nombre soit plus sensible aux valeurs de l'esprit et de la morale, apporte à leurs disciplines une dimension nouvelle. Le savant ne reste-t-il pas un homme, ouvert à toutes les questions humaines, à tout ce qui doit servir l'homme, à la quête de la Vérité dans toute sa profondeur?

Peut-être est-il difficile de demander à tous les spécialistes d'aujourd'hui de se faire philosophes, mais les besoins de la culture contemporaine vous incitent fortement à apporter une indispensable participation aux *recherches interdisciplinaires, où savants, penseurs et théologiens ont à collaborer*. Les études philosophiques et théologiques sur l'homme et la nature ont besoin de votre contribution pour faire avancer notre commune connaissance du monde inanimé, de l'univers vivant, de l'être humain.

8. Si l'on considère maintenant, au-delà du progrès de la connaissance pure, les applications techniques multiformes des recherches et découvertes de la science, on peut dire que la communauté scientifique mondiale a des responsabilités morales considérables dont elle prend plus vivement conscience.

Devant cette Académie, en 1983, j'avais souligné combien la collaboration des savants du monde entier avait permis des décou-

vertes grandement bénéfiques pour les progrès de toute l'humanité. C'est manifeste.

Mais comment ne pas être lucide aussi sur les dangers que l'humanité encourt si elle emploie inconsidérément la puissance qui lui vient de la science? Et, bien que cela dépasse la compétence du chercheur, celui-ci ne peut rester indifférent: on se tourne de plus en plus vers la communauté des savants pour les questions d'éthique collective. Comme je le disais le 3 novembre 1982 aux universitaires à Madrid: «Hommes et femmes, qui représentez la science et la culture, votre pouvoir moral est considérable. Vous pouvez ensemble, et grâce à votre prestige, obtenir que le secteur scientifique serve d'abord la culture de l'homme et qu'il ne soit jamais utilisé pour sa destruction».

On pense spontanément aux dangers de l'énergie nucléaire. En déchaînant la puissance atomique, les chercheurs ont été, pour leur part, à l'origine d'une crise morale à nulle autre pareille dans l'histoire, comme je l'ai souligné à Hiroshima. A l'Unesco, j'ai insisté sur le fait que l'avenir de l'homme et du monde demeurait radicalement menacé, en dépit des intentions des hommes de science, si l'on utilisait leurs découvertes à des fins destructives. De ce haut lieu de la culture, j'ai lancé aussi un appel solennel aux savants pour qu'ils aident l'humanité, en alliant la conscience à la science, en faisant respecter le primat de l'éthique, en veillant à ce que la science soit au service de la vie et de l'homme (cf. Discours à l'Unesco, 2 juin 1980, nn. 20-22).

Le maintien de la *paix* entre les peuples est primordial, et nous espérons que le témoignage de nombreux chefs religieux, priant hier, à Assise, pour la paix, contribuera pour sa part à instaurer cette paix, qui est aussi un don de Dieu.

Le rapport harmonieux entre l'homme et la nature est un élément fondamental de la civilisation, et l'on devine aisément toute la contribution que la science peut apporter dans ce domaine de l'écologie, pour la défense contre les altérations violentes de l'environnement et pour l'accroissement de la qualité de la vie par l'humanisation de la nature.

Mais comment ne pas penser surtout au champ désormais immense de la *génétique*? La tentation d'y manipuler radicalement l'homme, en disposant des conditions de son engendrement, en risquant de porter atteinte à la vie de l'être humain, même à l'état d'embryon ou de foetus, à son intégrité, à son équilibre, pose des

questions si graves que des savants eux-mêmes s'interrogent sur la poursuite de leurs expériences.

En somme, on demande aux savants d'avoir devant les yeux toutes les exigences de l'éthique qui assurent la dignité transcendante de l'être humain. La question décisive est bien celle-ci: comment la science peut-elle servir l'homme? Comment peut-elle respecter, assurer, les droits objectifs fondamentaux de la personne?

9. *La contribution spécifique de l'Académie Pontificale des Sciences* est l'objectivité des données scientifiques recueillies de la part de savants qui excellent dans les domaines hautement spécialisés qui sont les leurs, par la rigueur de leur analyse des faits, la profondeur de leurs intuitions scientifiques, par leur désintéressement au service de la vérité, l'importance qu'ils donnent aussi aux valeurs morales. C'est de ces analyses et synthèses objectives que pourront tirer profit les hommes politiques — pour mesurer, par exemple, les risques d'utilisation de certaines sources d'énergie ou de certaines armes, ou les conséquences écologiques de certaines initiatives. Pourront également en tirer profit les sociologues et les économistes; les praticiens de la médecine et de la chirurgie, pour valuer le sens et les effets de leurs expérimentations et interventions; les moralistes, qui ont besoin de connaître avec précision les lois de la nature; les philosophes, qui recherchent le sens de l'être et la vérité transcendante; les théologiens, spécialement intéressés par les rapports entre la foi et la science. Votre contribution scientifique est donc capitale pour tous ces domaines, même si elle n'est directement ni politique ni théologique; elle constitue une base indispensable pour le travail des responsables et des spécialistes que je viens de nommer. Pour sa part, le Saint-Siège a reçu en diverses occasions le service apprécié de la compétence scientifique de cette Académie, pour des questions qui touchaient immédiatement la morale naturelle et évangélique, et il continue à compter sur vous.

En tant que Corps, constitué auprès du Saint-Siège, l'Académie Pontificale des Sciences porte le témoignage de l'harmonie entre l'Eglise et les hommes de science, de leur soutien réciproque, et elle est un appel aux valeurs de la conscience dans le monde scientifique.

10. Il est à *souhaiter* que vos travaux soient mieux connus dans l'Eglise et dans le monde. Il semble opportun que votre recherche intellectuelle, vos études, vos publications continuent à aider toujours davantage *l'oeuvre universitaire et culturelle du Saint-Siège* et de l'Eglise, en lien par exemple avec la Congrégation pour l'Educa-

tion catholique, le Conseil Pontifical pour la Culture, la Commission Théologique Internationale, avec les autres Académies et avec les Universités. N'y a-t-il pas lieu d'explorer quelques projets communs, où apparaîtrait visiblement le lien entre science et culture? L'Académie, qui regroupe diverses disciplines, a aussi une vocation interdisciplinaire pour réaliser cet «oecuménisme culturel», dont j'ai déjà parlé.

J'avais pensé, au début de mon pontificat, à une Académie des Sciences humaines et de la culture. J'ai opté, après consultations, pour un Conseil Pontifical pour la Culture. C'est vous dire le souci qui est le mien de promouvoir et de défendre la culture de l'homme, sur laquelle repose sa dignité. Je suis convaincu que l'Académie Pontificale des Sciences participe efficacement à cet objectif, et je vous encourage vivement à souligner toujours davantage la visée culturelle de vos travaux, dont la valeur intrinsèque est déjà un apport précieux au progrès du savoir.

11. Messieurs les Cardinaux, Excellences, Mesdames et Messieurs, durant ce demi-siècle, l'Académie Pontificale des Sciences a accompli une tâche d'une importance historique, car elle a situé les fruits objectifs de la recherche scientifique dans la perspective de la vérité, de la liberté, de la morale, du service de l'humanité et de la paix, de l'élévation vers la Vérité première, qui seule peut répondre aux questions fondamentales sur le pourquoi de l'existence, sur le sens de la vie humaine et du monde. Je remercie, autour de son Président, tous et chacun de ses membres, qui y ont apporté leur collaboration avec une grande compétence et un dévouement méritant.

Pour ma part, je n'ai cessé d'accorder un grand intérêt au maintien et au développement de cette Académie, dans la ligne de l'intuition remarquable de mon vénéré prédécesseur Pie XI, qui l'a fondée, mais avec une insistance accrue au regard des problèmes humains, moraux et spirituels de notre temps. En cette année jubilaire, je forme donc des voeux fervents pour son avenir: pour la valeur de ses travaux; pour l'enrichissement que ses membres, si divers par leur origine et leurs convictions personnelles, peuvent s'apporter entre eux et apporter ensemble à l'humanité; pour le service hors pair que l'Académie peut rendre à ceux qui assument une lourde charge dans la communauté mondiale ou dans l'Eglise et notamment au Saint-Siège, offrant à leurs réflexions et à leurs décisions des données de valeur, éclairant l'objet de leur responsabi-

lité morale. Et par-dessus tout, puisse ce sénat de savants — qui ont été appelés à faire partie de l'Académie Pontificale et qui ont accepté loyalement cet honneur et cette charge — apporter toujours davantage au monde le témoignage de l'estime, dans laquelle l'Eglise tient la science digne de ce nom, de la confiance qu'elle fait à ceux qui s'y adonnent avec compétence et honnêteté, de l'invitation qu'elle leur offre à dialoguer et à coopérer par-dessus toutes les frontières, de la responsabilité qu'elle leur reconnaît pour le bien de l'humanité!

Je suis touché de voir que beaucoup d'Académies des Sciences, de par le monde entier, ont accepté l'invitation qui leur était faite de venir s'associer à cette célébration jubilaire. Je salue et je remercie chaleureusement leurs délégations. A ces Académies aussi, j'adresse mes meilleurs voeux pour qu'elles encouragent leurs membres à faire progresser en toute liberté la connaissance scientifique, dans une ouverture à la vérité fondamentale sur l'homme et sur le cosmos, pour qu'elles puissent entretenir librement entre elles des relations fructueuses, et qu'elles forment un ensemble, comme une instance significative de la communauté mondiale, qui utilise le prestige de son autorité morale, afin que la science demeure toujours, dans toutes ses applications, au service de l'homme, au service de sa vie, de sa culture, de son élévation morale et spirituelle.

A tous les hommes de science ici présents, j'ai été très heureux de pouvoir rendre hommage, en présence des Cardinaux et du Corps diplomatique, et j'invoque sur vous, comme sur vos familles et vos collaborateurs, les Bénédictions du Seigneur «en qui nous avons la vie, le mouvement et l'être» (*Ac* 17,28).

DISCOURS DU PRÉSIDENT

Au début de l'audience, le prof. Carlos Chagas avait adressé au Saint Père l'hommage de l'Académie Pontificale des Sciences:

Très Saint-Père,

Nous nous réjouissons tous d'être ici présents pour Vous entendre parler à l'occasion commémorative du Cinquantenaire de la restauration de l'ancienne Académie des «Nuovi Lincei» en Académie Pontificale des Sciences, par Pie XI.

Je désire d'abord, au nom de Votre Académie et de tous les invités qui participent à nos célébrations, Vous féliciter pour le succès de Votre initiative de réunir à Assise les chefs religieux du monde entier pour une journée de prière.

Au cours des années passées, depuis 1936, l'Académie Pontificale des Sciences a accompli les tâches pour lesquelles Pie XI l'avait organisée. Elle a pu promouvoir la science et informer le Saint-Siège des progrès que celle-ci faisait, ainsi que la technologie. Pendant ce demi-siècle, la science et ses applications ont progressé d'une façon unique. Des développements extraordinaires se sont produits et, en conséquence, de nouvelles voies se sont ouvertes pour la connaissance scientifique. En plus, des nouveaux champs d'action pour l'application de la technologie se sont créés.

Le fait qu'une profonde modification sociale s'est produite, a occasionné des défis que l'humanité doit vaincre pour les dominer ou même les éliminer. Ce sont des défis de tout ordre, mais quelques-uns s'originent de la mauvaise application de la science et de la technologie.

Toutefois, comme Vous l'avez proclamé, Sainteté, la science et la technologie, conduites par la sagesse et l'inspiration divine, sont indispensables à la réalisation du développement de l'être humain et à l'amélioration de la condition de vie.

Le respect pour les données expérimentales, la participation dans les entreprises communes, l'acceptation de l'opinion d'autrui,

Le Prof. Carlos Chagas prononce son discours à

le désir d'aider, la compréhension de la position des autres sont quelques-unes des caractéristiques de l'éthique scientifique. Elles sont aussi à la base des éléments qui doivent s'établir entre les peuples pour la réalisation d'une paix durable. Ainsi, le vrai scientifique se place a côté de tous ceux qui désirent la paix, qui est faite de participation et de compréhension. Celle-ci se réfère à l'entente et la déférence que chaque peuple doit avoir pour la culture des autres, et la participation se réfère à la contribution que chaque nation doit donner au bien commun.

D'autre part, comme l'a bien dit Votre prédécesseur Paul VI de vénérable mémoire, le nom de la paix est le développement: développement intégral de l'homme et développement social. La contribution de la science et de la technologie devient ainsi positive: d'un côté, l'élargissement de la connaissance et la liberté de pensée, indispensables au progrès de l'être humain, et d'autre part, la contribution que les applications scientifiques peuvent donner à la situation existentielle de l'homme.

Sainteté, le 12 novembre 1983, en Vous adressant à l'Académie Pontificale des Sciences, Vous nous avez indiqué le bon chemin. «La vérité scientifique, qui ennoblit votre intelligence et élève votre recherche jusqu'à la contemplation du monde et de son Créateur, doit être transmise à l'humanité entière pour la promotion intégrale de l'homme et des nations, pour le service de la paix, qui est l'objet de vos réflexions et de vos projets».

Ces orientations ont été suivies par Votre Académie. Il m'incombe, Très Saint-Père, de Vous parler de certaines de nos préoccupations, qui correspondent en grande partie aux graves défis qui nous menacent dans la minute qui vient.

Le danger nucléaire est toujours présent et, certainement, les usines nucléaires méritent d'être rigoureusement surveillées, pour que des accidents ne se produisent pas. L'Académie Pontificale des Sciences prendra certainement à sa charge le rôle de Vous informer, comme elle l'a fait déjà, sur la sécurité des usines nucléaires. Elle se demande aussi comment elle peut agir davantage encore dans le domaine de la guerre nucléaire.

Parmi d'autres problèmes qu'elle désire étudier, il y a celui de l'utilisation des techniques modernes de la recombination de l'ADN pour la production de vaccins plus efficaces et plus économiques, pas encore obtenus par les méthodes classiques.

Cette technologie, appartenant au domaine de la biologie

moléculaire, a suscité, d'autre part, la préoccupation de nombreux groupes de scientifiques, voire le grand public, alerté maintes fois par des informations pseudo-scientifiques. Il incombe à l'Académie Pontificale des Sciences de Vous donner un compte-rendu scientifique des avantages et des dangers que les manipulations génétiques et ses techniques comportent, étude sur laquelle un jugement éthique doit être formulé.

Parmi les défis dont je Vous ai parlé et auxquels la science et les technologies modernes peuvent faire face, il y a ceux du Tiers Monde. S'il est vrai qu'une partie de ces problèmes est due à leur instabilité politique ou à l'avidité géopolitique, ou à l'enjeu des financiers internationaux, science et technologie, sagement utilisées, peuvent combattre la faim, les maladies, augmenter la production alimentaire, assainir les villes et les champs, et montrer ainsi que l'ingéniosité de l'homme doit surtout servir à l'humanité. L'Académie Pontificale des Sciences, suivant Vos désirs, s'est penchée et se penchera encore sur les maux qui atteignent deux tiers de la population humaine.

Permettez moi, Très Saint-Père, de Vous signaler encore un des problèmes qui inquiète vivement Votre Académie. Je me réfère à l'action prédatrice que l'humanité, soit pour des raisons d'ignorance, soit par cupidité industrielle, exerce sur l'environnement. Est-ce l'effet des mauvaises conditions dans lesquelles une grande partie des êtres humains vit, dans les bidonvilles et les «favelas», conséquences de la mauvaise répartition des biens matériaux, qui aura fait que l'humanité a perdu le respect pour la nature, avec laquelle Dieu veut qu'elle établisse une parfaite relation d'intéraction et de protection.

L'homme et l'ambience sont arrivés à un état qui nécessite notre cri d'allarme. Partout des ravages: la pollution des rivières fait disparaître les poissons, l'eau des océans aux bords des plages est insalubre, les races d'animaux qui faisaient, par leur grouillement ou leurs agiles courses, les beautés des champs et des forêts, commencent à disparaître, la déforestation a fait de nos terres des déserts arides, et davantage encore.

Je crois, et permettez-moi de Vous le dire, Très Saint-Père, que seulement Votre voix pourra amoindrir, sinon paralyser cette destruction de l'environnement qui cause la guerre et la faim et menace le futur de l'humanité, ainsi que la dignité humaine.

Très Saint-Père, permettez-moi maintenant, avec honneur et

joie, de Vous présenter les nouveaux Académiciens Pontificaux: Prof. Sune Bergström, Prof. Nicola Cabibbo, Prof. Albert Eschenmoser, Prof. Kenichi Fukui, Prof. Paul Germain, Prof. Stephen Hawking, Prof. Beatrice Mintz, Prof. Marcos Moshinsky, Prof. Czeslaw Olech, Prof. John Polanyi, Prof. Vladimir Prelog, Prof. Carlo Rubbia, Prof. Kai Siegbahn, Prof. Maxine Singer, Prof. Walter Thirring.

Ensuite, après avoir présenté les nouveaux Académiciens nommés depuis la dernière Session Plénière de l'Académie, qui a eu lieu en 1983, le Président Carlos Chagas a demandé au Saint Père de consigner la «Medaille d'Or Pie XI» au chercheur australien, docteur Elizabeth Anna Bernays.

La «Medaille d'Or Pie XI» fut instituée par le Souverain Pontife Jean XXIII, le 28 octobre 1961 à l'occasion du XXVème anniversaire de la fondation de l'Académie Pontificale des Sciences, pour honorer le fondateur de l'Académie, le Pape Pie XI; cette distinction récompense les mérites de jeunes chercheurs dans le domaine scientifique international.

TROISIÈME JOURNÉE

29 octobre 1986

SESSION PLÉNIÈRE

LE PROGRÈS DE LA SCIENCE ET L'AVENIR DE L'HUMANITÉ

Pendant toute la journée, ont succédé d'autres interventions des Académiciens sur le thème de la Session Plénière, «Le Progrès de la science et l'avenir de l'humanité».

Ont pris la parole les Académiciens Pontificaux: les professeurs Alexander Rich, Béatrice Mintz, Manfred Eigen, Christian de Duve, Michael Sela, John C. Eccles et Albert Eschenmoser.

En conclusion des travaux de la journée, les salles de l'Académie ont accueilli une réception officielle à laquelle ont participé, entre autres, les cardinaux: Agostino Casaroli, Secrétaire d'Etat de Sa Sainteté, Sebastiano Baggio, Camerlingue de la Sainte Eglise Romaine et Président de la Commission Pontificale des Cardinaux pour l'Etat de la Cité du Vatican, Roger Etchegaray, Président de la Commission Pontificale "Iustitia et Pax" et Gabriel-Marie Garrone, Président du Conseil Pontifical pour la Culture.

Alexander Rich

A BRIEF OUTLINE OF MOLECULAR BIOLOGY

I have been given the virtually impossible job of summarizing molecular biology in thirty minutes. Thus my colleagues should excuse me for simplifying the work excessively.

In his survey of physics, Prof. Abragam started his story with the situation in physics at the end of World War II. This is very easy

for molecular biology, as it did not exist at the end of World War II. What existed, of course, was an older discipline, biochemistry. However, molecular biology is a subject that has at its source the study of both the three-dimensional structure of biological molecules, especially large macromolecules, and attention to the molecular mechanisms for the transfer of information within living systems. In essence, that subject started with the work of Avery and his colleagues in 1944. They discovered that DNA, a polymer of nucleotides, was the transforming principle, that is, the molecule that could carry the inheritance information in microbial organisms.

Information flow in biological systems

In the early 1950s, the subject began to be pulled together with the recognition that DNA rather than proteins contains genetic information. The subject was given an enormous stimulus by the development of the double helical model for DNA by Watson and Crick. In that model the two strands are complementary to each other; if you know the sequence of nucleotide bases in one strand you can produce the other one. The nucleotide bases were held together by a system of detailed hydrogen bonds, a fitting together of the typical "lock and key" type that had been thought of many years earlier. Very soon the idea developed that the informational flow embodied in the sequence of bases goes from DNA to a similar molecule, RNA (with a slightly different sugar in the backbone), and then to proteins. Up until the early 1960s this was taken as a matter of faith rather than as a matter of fact.

The discipline began to develop considerable momentum in the early 1960s with the development of the genetic code, that is, the understanding of triplets of nucleotides. Thus the protein, a polymeric chain of amino acids, is specified ultimately by the polymers of nucleotides in DNA. Several members of this Academy played a central role in developing the genetic code. By the end of the 1960s most of the basic plan was understood. We understood how the sequence of nucleotides in DNA was transcribed by a system of enzymes that essentially copied one strand of DNA to make a complementary strand of RNA that then became the coding strand for the protein. This was called messenger RNA.

The messenger RNA is "read" in an elaborate apparatus called the "translation" machine system. It consists of a very large machine

called the ribosome that itself is made up of proteins and nucleic acids. The ribosome becomes attached at one end of the message together with amino acids that have themselves become attached to small nucleic acid molecules called transfer RNA. These molecules are key intermediates in protein synthesis because each of them becomes bound to an enzyme with great specificity that then causes them to be bound to a particular amino acid. There are twenty amino acids in biological systems; there are twenty different groups of transfer RNA molecules, each of which codes for a particular amino acid. This system is complex, and indeed we are still continuing to learn a great deal about this process. However, the essential step in information transfer is the manner in which the amino acid and the transfer RNA become attached and then fed into the ribosome in a particular sequence that then yields a polypeptide chain with a specific sequence.

The transfer RNA molecule contains 60-70 nucleotides folded up in an elaborate and interesting way to make an L-shaped molecule. At one end there are three nucleotides that interact with the messenger RNA and at the other end the amino acid is attached. This goes into the ribosome in an ordered array. The machinery of the ribosome then transfers a polypeptide chain from one transfer RNA to the other and the chain gets longer as the ribosome moves along the messenger RNA with the gradual accumulation of amino acids. Finally, at a certain point the messenger RNA contains a stop signal, a detachment site. These are a group of three nucleotides. The growing polypeptide chain then falls off, and the protein chain has been synthetized. This picture developed in the 1960s provided the basic outline of the flow of information. However, the system is not simple, and a great many details remain to be uncovered.

The recent explosion in molecular biology

In the late 1970s and 1980s, mostly during the last ten years, a remarkable series of tools have developed in this discipline that have led to a rapid and almost explosive growth. The first of these is the development of what is termed recombinant DNA technology. This development was dependent upon the discovery of a class of important enzymes called restriction endonucleases. These are enzymes of procaryotic or bacterial cells that have the ability to cut DNA at a specific sequence of nucleotides, often four or six in

number. These enzymes have enormous utility because they allow us to take a piece of DNA and cut it wherever the particular sequence appears. The pieces can be separated and can then be moved elsewhere. They can be reattached at other places, using other enzymes called ligases that will seal the break point. Thus, it is possible to take a piece of DNA from one organism and place it into the DNA of another organism. This is called recombination. Usually these transfers are carried out using small circles of DNA, called plasmids, that may have one to a few thousand nucleotides in a circle. Once the DNA has been redesigned with new elements in it, it can also be grown in large amounts and then used in other biological systems.

A second important event was the development of a technique for sequencing the nucleotides in DNA. DNA is a very long molecule that has thousands of nucleotides in a linear array. We have been able to uncover these sequences so that our current data bank contains approximately 10 million nucleotides sequenced from many different biological systems. The development of these techniques depended on several key developments. First, the discovery that a polymeric gel through which a liquid can flow can serve as a filter that is capable of separating linear DNA molecules according to length. The DNA migrates in an electric field through the gel, and it is possible to separate pieces that have very small differences in length. For example, it can nicely separate a piece of DNA with 87 nucleotides from one with 88, and so on, up to several hundred.

Another development was the ability to cleave DNA chains at a particular residue, i.e., at one of the four nucleotides. Thus DNA can be cleaved at guanine residues, for example, in a random manner. This cleavage can be carried out either chemically or by using various modified nucleotides in the synthesis. Using radioactive nucleotides, one can develop a ladder or a series of segments that may differ in length by one nucleotide. One ladder may terminate only at adenine residues, another at guanine, cytosine or thymine. By running these reactions side by side, and developing the radioactive steps of the ladder using film, we can read off the sequence directly. This enables us to simply have a piece of DNA labelled at one end with a radioactive phosphate molecule, and cleave it by methods specific for each residue. By seeing where these pieces migrate on the gel, we can then determine the sequence.

This methodology is very powerful and it suddenly allowed us

to read the "code", as it were. By reading the sequence of nucleotides in DNA, we can in turn uncover the sequence of nucleotides in RNA and, in turn, uncover the sequence of amino acids in proteins. This technique has now been automated; machines are available that produce sequences from DNA. It is likely that this will be intensified in the near future, as the sequence information has a great many applications in the fields of medicine, agriculture and industry.

A third major tool was associated with developments in chemistry that allow us to synthetize segments of DNA at will. This has also been developed into the form of machines, where you simply type in a particular sequence of nucleotides, the machine then carries out a sequence of operations in which nucleotides are added one by one to a chain that is attached to a polymeric matrix. After the long chain is assembled, the end of it is detached and the material is then purified. This synthetic DNA can then be put into another DNA fragment to make recombinant DNA. Thus we now have the ability to create at will a sequence of DNA and place it into a biological system.

The developments all together have led to explosive development in this field. For example, any biological function for which there is an assay and for which you can purify a protein using conventional methods can immediately be analyzed at the level of the gene. One can sequence a fragment of this protein. From the amino acid sequence, a segment of DNA can be synthetized that codes for that sequence. With that probe one can go into the cell and pull out the segment of messenger RNA that is actually synthetizing the protein. The messenger RNA can be sequenced by making a DNA copy of that message using the enzyme called "reverse transcriptase", which makes a DNA copy from an RNA strand. It is called reverse transcriptase because instead of going from DNA to RNA, it goes from RNA to DNA. With that one can create the piece of DNA that codes for the protein that has been isolated. Furthermore, one can take that piece of DNA, put it into a bacterial cell in a plasmid, for example, and with the appropriate instructions that cell can begin making this protein, wherever it is.

Suddenly we have the ability to make very large amounts of substances that may be present in the cell in very small amounts. We can test these substances in biological systems to really understand how they work. This has led to the development of a large

biotechnology industry dealing with important molecules that have medical, agricultural and industrial applications.

The organization of DNA

Because of this methodology, a number of discoveries have emerged. One of the most interesting and surprising discoveries was that DNA really has two different kinds of information. Part of the DNA codes for the amino acid sequence of proteins, but it is interrupted by other sequences, intervening sequences, that do not code for amino acids. The DNA produces an RNA copy called messenger RNA that is initially much longer than the part that codes for the protein. Parts of the messenger RNA are eliminated or "spliced out". These are called the intervening sequences. The DNA as well as its RNA copy contain both the intervening sequences and the coding segments. Originally we thought that the genes were unitary segments, but instead the coding segments are in pieces with other segments in between. It turns out that the intervening sequences make up 90 percent of the total gene, and the coding pieces only 10 percent. What has happened within the last 10 years is the DNA that is encompassed by the gene has suddenly and remarkably grown tenfold in size.

There may be a kind of crude analogy with what is going on in astrophysics. Recent discoveries of dark matter have led to estimates that our universe is ten times larger than we had thought. Suddenly we discover that we have a much larger universe: in molecular biology we thought our genes were of a certain size and suddenly they are ten times larger due to these intervening sequences.

This is an exciting and unanticipated development. Many people believe that these coding units represent functional subunits of proteins. The splicing system may be one that allows these subunits to be moved around into different arrangements to create new proteins. However, there is more to the story and much of it is still mysterious. The intervening sequences are different in character from the coding sequences. For example, they evolve much more rapidly and are far less stable than the sequences that code for the proteins. It is possible that they may be doing something else. For example, they may be doing something important in evolution, such as representing segments where old genes are reworked so that they may eventually lead to the formation of new genes.

It is also interesting that this process of splicing, which generally takes place with a complex system of enzymes, can actually occur in some cases at the level of the RNA molecules themselves. This is a very recent discovery that RNA itself has enzymatic properties and is able to self-splice. The chemistry of that process is quite interesting. Its implication is profound as it suggests that RNA may have played an especially important role in the early evolution of life. All of this points to the fact that the RNA molecule is of special interest in terms of understanding the origin of biological systems.

The number of nucleotides in the genomes of organisms varies considerably. The common colon bacteria, *E. coli*, has a genome of 4 million nucleotides. This DNA contains mostly coding sequences, without intervening sequences. At present almost half the *E. coli* genome is sequenced and it is likely that most of the sequence will be completed in five years or so. However, with a higher organism such as the human, the genome is one thousand times larger, but we do not have a thousand times more proteins. We may have a few more, maybe five, maybe ten times, but not a thousand times more than *E. coli*. There is a great deal of mystery about what the remainder of the DNA is doing. Some of this is called repetitive DNA, DNA that occurs in multiple repeats. We do not understand what this DNA is doing in our genome. Many people are working to try to understand this and other mysteries associated with the organization of the genome in higher organisms.

Three-dimensional structure and biological function

Another important aspect of molecular biology is study of the three-dimensional structure of macromolecules, principally proteins and nucleic acids. This subject is growing rapidly at present through the development of newer technology for X-ray diffraction analysis-synchrotrons, area detectors, automatic diffractometers and sophisticated computer programs for structure solution and analysis. In addition, the recombinant DNA technology makes it possible to produce large amounts of scarce materials, and this makes it possible to obtain crystals.

Proteins are complex structures and our growing knowledge of their three-dimensional structure makes it possible to understand the molecular consequences of mutations that produce changes in

amino acid sequence. These structures reveal the rather intricate patterns in which amino acid chains are folded together to create units that have striking chemical characteristics. Some proteins act as catalysts, i.e., they are enzymes. Now we can use recombinant DNA methodology to change specific amino acids in a given protein. By applying this methodology to study amino acids that act during enzyme catalysis, one potentially can discover what particular amino acids are doing in a catalytic reaction, and this is a rather exciting prospect. In principle it gives us the methodology that may ultimately allow us to understand how these large molecules act at a fundamental level. It will provide us with further information that eventually leads to a substantial challenge. If we have a string of amino acids in a particular sequence, what determines the three-dimensional conformation that the protein adopts? What determines the stable folding?

The picture we obtain from X-ray crystallography is a static picture, but the molecule itself is dynamic: it moves. How can we develop an understanding of both the movement of the molecule and the manner in which it folds together? These are the important questions that it is now possible to address because we have an enormous number of tools.

We can also determine the structure of proteins when they are bound to the DNA molecule. Work has already been done on the structure of proteins called repressors that modify the way in which DNA is transcribed into RNA. The protein seems to embrace the double helix, with protein helices intruding into the grooves of DNA. The structure of a restriction enzyme attached to DNA is also known. The protein has a remarkable organization: it contains a pleated sheet, a flat structure that itself has a twist that is left-handed. This left-handed protein twisted sheet is inserted into the right-handed groove of the DNA double helix and in this way determines the specificity of its binding and of its cleavage.

Understanding structure often leads to an understanding of function. This is seen in DNA where it appears that transcription to make RNA seems to involve conformational changes. It now seems that DNA actually loops or bends almost into a circle, so that proteins attached to it can touch each other. We are just beginning to understand the structural events that appear to be important in regulating the activity of DNA.

In this regard, we now know that DNA can itself undergo

conformational changes. Although the stable ground state of DNA is that of a right-handed double helix, DNA can also form a left-handed double helix with the strands held together by the same set of complementary hydrogen bonds. The left-handed form is called Z-DNA because the backbone has a zig-zag organization. It takes energy to put the DNA into the left-handed form, and this energy is supplied by the twisting or supercoiling of the molecule. In addition, there is a class of Z-DNA binding proteins that holds it in the left-handed conformation. The biological role of left-handed Z-DNA is only partly understood. It may have a role in regulating gene expression, but the most definitive studies have been carried out on Z-DNA binding proteins that are enzymes active in genetic recombination. In that process, two DNA molecules with identical sequences meet and «cross over», i.e., they exchange segments. The exchange process seems to involve the formation of a paranemic joining, i.e., half right-handed and half left-handed turns. Using a paranemic joining makes it possible to identify identical sequences on the two strands in the absence of strand breakage.

Epilogue

Molecular biology has moved far in the 43 years since Avery identified DNA as the agent of heredity. The rate at which knowledge accumulates is very high so that it is difficult to extrapolate into the future. Molecular biology is now a fundamental discipline in science and it will completely transform our knowledge of biological systems.

Beatrice MINTZ

CHANGING THE MAMMALIAN GENOME

The feasibility of deliberately changing the genome — that is, the genetic composition — of organisms like ourselves, has burst upon the public consciousness and concern only in the last few years, particularly since the advent of recombinant DNA technology. Yet as scientists we are increasingly aware of the transfers of DNA that have apparently been going on quite spontaneously, presumably for eons, in organisms from the simplest to the most complex, between species as well as within species. These include such diverse phenomena as the transfer of antibiotic-resistance genes, carried on circular plasmids, between bacteria; the spontaneous excision and reinsertion, at a new location, of "wandering" genes in some flies and plants; the spontaneous insertion of a mouse virus into a color gene on a chromosome of the host, causing a heritable change in coat color; the production of a malignancy due to insertion of viral or certain other gene sequences into an otherwise innocuous host gene; and even the capture of some host genetic material by a resident virus, enabling it to utilize that material so as to produce a malignancy.

I will first briefly survey the kinds of approaches, some direct others indirect, that have been used to change experimentally the genomes of laboratory mammals. I will also indicate examples of scientific questions that can be examined with these approaches and some of the practical difficulties that have been encountered in realizing certain of the objectives. Many scientists have contributed to these investigations and although some of their names will be indicated, there will be no attempt to cite the literature in this rapidly expanding field. Moreover, while serious ethical questions do indeed arise in the possible application of these technical advances to man, they will not be addressed here.

Possible ways of changing the mammalian genome

Some of the methods indicated below have already been used successfully *in vivo*; others are still visionary.

Replacement of cells. In the broadest sense, an organism's genetic complement is partly changed if functional cells of another genotype are substituted for some of the cells of the host or added to them, even if no genetic manipulation has been carried out on any of the contributing cells. The individual then becomes a mosaic of two (or more) genetically distinct populations of cells. The change may involve only the *somatic* (or non-reproductive) body cells, as in the case of transplants of tissues or organs such as blood-forming cells, skin, kidney, heart, or liver. Hematopoietic cells in fact furnished the first detected example of spontaneous occurrence of mosaicism in mammals when Ray Owen, in 1945, found erythrocytes of two separate genotypes in non-identical cattle twins due to exhange of blood stem cells through placental vascular fusions. This was later found as a rare event in some human twins. When the association of genetically disparate cells precedes the development of immunological competence, the individuals are each tolerant of both genetic kinds of cells.

Cell replacement may also involve both *somatic and germinal* (or reproductive) cells. This is likely to result when cells from different embryos are brought together at an early developmentally totipotent stage, as experimentally demonstrated in mice, rats, rabbits, and goats. From the clinical literature, it appears likely that a few cases of spontaneously conjoined cells from co-existing human embryos have occurred. The contributing cells form one mosaic but otherwise normal individual with both cell strains in many, or all, tissues, as if both had originated in a single unitary embryo. As in normal development, the two cell strains retain their identities, only fusing (to form heterokaryons) in skeletal muscle. A strange modification of early-embryo associations, also leading to normal development, has been carried out in mice by substituting for one of the input strains the stem cells of teratocarcinomas — malignant tumors of developmentally primitive cells.

Changes in genes. More direct ways of changing an individual's genome depend on actual genetic manipulation. The target may be either certain somatic cells, such as the blood-forming tissue in bone marrow; or the fertilized egg, from which all tissues, including the

germ cells, will ultimately have the genetic change.

When the cure of a genetic disease is the objective, the ideal strategy would be *gene substitution* by introduction of a normal gene in place of the defective one. However, the genetic basis for disease is often complex. In the human population, for example, some defects are known to be due to a single gene, as in sickle cell anemia; but others, such as *diabetes mellitus*, are multifactorial. Still others are due to chromosomal abnormalities, as in Down's syndrome. Gene substitution requires efficient and accurate targeting-and-excision technical capabilities and these are not yet adequately developed.

An alternative strategy now commonly used in gene transfer is the simple *addition* of a cloned gene. There are now numerous methods whereby this can be achieved in cultured cells, including DNA administration in a calcium phosphate precipitate, electroporation, microinjection (preferably into the cell nucleus), and infection by recombinant DNA in a viral vector. The last two methods can also be used on early embryos. Most of these techniques result in integration of multiple tandem copies of the exogenous gene. The copy number of an endogenous gene may be independently increased, for example, by amplification of the dihydrofolate reductase gene in response to methotrexate treatment.

Modification of structure of a gene can be achieved by homologous recombination between an administered recombinant DNA sequence and a portion of the endogenous gene, either to correct a defect or to create a specific defect. At present, the highest frequency of success is one in 10^3 cells, achieved by Mario Capecchi, when the donor sequence is microinjected into the nucleus of cultured cells.

Modification of function of a gene has occurred by several routes, some unforeseen and others engineered. Striking examples of the former are due to insertional mutagenesis leading to activation of an otherwise silent host-cell gene, or inactivation of an otherwise expressed host-cell gene, either by proviral or plasmid DNA insertion. Examples are the activation of an avian cellular oncogene, leading to tumor formation, observed by Susan Astrin and William Hayward; and the inactivation of a mouse collagen gene, reported by Rudolf Jaenisch. By changing tissue-specific enhancer and promoter sequences associated with a recombinant gene, the tissue in which the gene is expressed can be modified, as

shown by Douglas Hanahan in directing the tumorigenic effect of transforming sequences to specific tissues. Anti-sense RNA is a means of blocking gene function, as shown by Harold Weintraub and Jonathan Izant. To all these must be added the phenomenon of position effect: the fact that the chromosomal location of a gene may affect its function.

Technology

Animals with two cellular genotypes in somatic and germinal tissues were first formed in our laboratory by aggregating the cells of two entire mouse embryos in culture after first enzymatically removing the acellular envelope. Despite their giant size and rearranged cells, these aggregates develop normally, thereby testifying to the flexibility of early mammalian development. After implantation in the uterus of a surrogate mother, embryo-size returns to normal. Genetic markers in the cells of these so-called *allophenic mice* have enabled the clonal origins and developmental histories of many specific cell types to be retrospectively revealed and cellular interactions to be analyzed. Allophenic mice have provided new models of clonal phenotypic heterogeneity within tissues, of complex gene structure, of preprogrammed death of clones in development, and of the origins of tumors.

One of the input strains in allophenic mice can be genetically manipulated and preselected for a specific change. This depends upon the use of the stem cells of malignant mouse *teratocarcinomas*. We found that these cells, which are the abnormal counterparts of normal early embryo cells, can develop normally and contribute stably to all somatic and germinal tissues if they are introduced into normal early embryos. The cells can be cultured prior to this association and can therefore be mutagenized and selected for a specific endogenous mutational change in culture. Thus they offer the unique possibility of generating germline progeny that are potential models of specific human diseases. Teratocarcinoma cells can also be used to introduce (ultimately into mice) plasmid DNA by transfection or electroporation, or recombinant retroviruses by infection. Nonselectable genes can be cotransferred with, or linked to, selectable genes.

A more direct route for genetic change of the entire individual is by microinjection of plasmid DNA into the pronucleus of the

fertilized egg, resulting in integration into a host chromosome. A striking example of successful expression of an introduced gene in such *transgenic mice* was the production of giant mice by Richard Palmiter and Ralph Brinster, after injection of plasmid DNA containing the human growth hormone gene accompanied by metallothionein promoter sequences that were activated by feeding heavy metals. Although gene expression was not limited to a given tissue, tissue-specific regulated expression of other genes of interest has since been obtained in many laboratories by including in the construct the relevant upstream enhancer and promoter sequences. Tissue-specific tumors have also been produced by Douglas Hanahan by linking such regulatory sequences to transforming genes (e.g., from SV40). An interesting complication in all these studies is the chance occurrence of developmental defects due to disruption of a host gene by the integrated sequences in approximately 15-20% of cases. This could enable developmentally significant host genes to be isolated and characterized.

It has long been known, through the work of Till and McCulloch, that foreign hematopoietic cells could become established in adult irradiated mice and their developmental potential assayed by colonies formed in the spleen. The cells responsible for these colonies appear not to be the stem cells capable of giving rise to all hematopoietic cell lineages in both myeloid and lymphoid specializations. Roger Fleischman and I subsequently showed that hematopoiesis does in fact proceed from *totipotent hematopoietic stem cells* originating in the fetal liver and progressing to the bone marrow. This was discovered by introducing genetically marked fetal liver cells into mouse fetuses by microinjection through a placental blood vessel. The use of *W*-mutant hosts, with an endogenous stem-cell defect, enables irradiation to be circumvented by providing a selective advantage to normal donor cells. These prenatal recipients are apparently often populated by only one donor stem cell, demonstrating that all blood derivatives are clonally derived from it. In hosts with clones of different genotypes, the phenomenon of clonal succession became apparent, that is, the serial usage of cells identified by separate genotypes.

The genotype of hematopoietic stem cells (and also of early embryos) can be changed through infection with recombinant retroviruses. Advantages are the relatively high efficiency of this process and the likelihood that only one copy of the proviral DNA

will be integrated at a given locus. Richard Mulligan demonstrated that murine retroviruses that are replication-defective can infect bone marrow cells while the cells are co-cultured with a helper cell line previously transfected with the recombinant viral sequences. The viral life cycle does not continue in the marrow cells and the DNA remains stably integrated in a chromosome of the target cells. After transfer to hosts, development *in vivo* allows lineages to be traced by means of the unique viral integration markers. Robert Hawley and I, and workers in other laboratories, have recently found that «handicapped» viruses could be constructed so as to remove viral control over expression of an introduced gene; tissue-specific regulatory sequences can then be placed near the gene of interest. All these studies are still in a relatively early phase; expression of genes has been achieved primarily in cultured hematopoietic cell lines.

Practical problems in changing the genome

Despite the progress already made in producing genetic changes in mammalian cells or embryos, many practical problems remain to be confronted and solved, especially with respect to the situation *in vivo*. If a gene change is made very early in development, particularly in the fertilized egg, it is likely to affect germinal as well as somatic cells. If it is made later, only some somatic cell lineage(s) will be affected. In either case, an obvious difficulty is *diagnosis of the genotype* in progeny from genetically segregating matings. The diagnosis may need to be made before birth; and even if it is to be made later, the phenotype may not yet be expressed. New metrods now enable prenatal diagnosis of some defects to be made at the DNA level, for example, in cell extracts from chorionic villus or amniocentesis samples. In the case of very early embryos, some cells may be removed with impunity and used for DNA tests while the remaining embryo is placed in temporary frozen storage. One of the limitations is that a substantial reduction in embryo viability is likely to occur after thawing.

Another difficulty, important in changing the genotype of any somatic tissue, is that the change must be made in target *stem cells*, cells capable of ongoing self-renewal as well as production of more differentiated mitotic lineages. The problem may be illustrated in the hematopoietic system: While bone marrow samples may be re-

moved from an individual, it is not yet possible to recognize or isolate the stem cells. Pretreatment of the donor may stimulate proliferation of stem cells. The host may also need to be pretreated (e.g., by irradiation) to reduce the marrow population, so as to "make space" for donor stem cells, and these treatments may themselves be mutagenic. The stem cells must have whatever specific receptors may be needed for gene transfer if retroviral vectors are used. However, a gene of interest transferred into hematopoietic stem cells is likely to be one whose expression is desired only in one derivative, such as in the erythroid lineage, to cure a genetic anemia. The gene should therefore remain unexpressed in the earlier blood-cell stages and in other derivatives. In most tissues, the stem-cell source is still unknown. Nor do stem cells persist throughout life in all tissues.

Another complication is due to *clonal succession*. We have observed this phenomenon in the hematopoietic system. Separate stem cells become successively amplified to produce large cell-clones and each may have a different chromosomal insertion, or their mitotic descendants may have different degrees of expression of an introduced recombinant gene. Moreover, a successfully genetically modified clone may be short-lived or followed by one that has remained genetically unchanged.

Another problem is that *most genes are unselectable*. Therefore, it is not possible to isolate those stem cells that have taken up a donor gene during a period in culture, unless the gene of interest is accompanied by a selectable gene, preferably linked to it. An example of a useful selectable gene is the bacterial neomycin phosphotransferase gene conferring resistance in mammalian cells to the analog G418. The selectable gene must then be separately driven by a regulatory sequence (such as the herpes viral thymidine kinase promoter) that is expressed in the stem cells, even if the gene of interest is not. The ultimate expression of the unselectable gene may be adversely affected (down-regulated) by function of the promoter associated with the selectable gene. And the product of the selectable gene must be innocuous *in vivo*. In addition, its expression in culture or in the organism may not predict expression of the unselectable gene (driven by tissue-specific regulatory sequences) in the organism.

As already indicated, the *chromosomal location* of a donor gene may influence its expression. Proximity to native genes acting

sequentially in development may be required. The donor gene in turn may disrupt a crucial host gene or its regulatory sequences and destroy or impair its function, or may activate or increase activity of a host oncogene and lead to tumorigenesis.

There are many other ways in which *regulated expression* of a donor gene may be impaired: The product may be synthesized by an inappropriate cell. A normally secreted product may fail to be exported from the cell. The amount of the product may be below or above normal — in the latter case, sometimes due to tandemized copies of the donor gene. The times of production and release of a product may be inappropriately regulated. The foreign gene may encode a monomer whose contribution to a polymeric structure may need to be coordinated with other contributions.

Despite all these difficulties and complexities, progress continues at an accelerated pace. Gene transfer into early mouse embryos is yielding new strains supplying basic knowledge concerning gene regulation and also malignancy. Gene therapy limited to specific somatic cells is not at present practicable but may become so before long.

Christian DE DUVE

THE BIOLOGICAL REVOLUTION AND MEDICAL RESEARCH

The main theme of my talk will be that the revolutionary advances of the last forty years in our understanding of the fundamental processes of life — often referred to as the "biological revolution" — have opened the way to an entirely new form of medical research. I will illustrate this point with some examples drawn from the work of my associates at the ICP in Brussels and at The Rockefeller University in New York. But first a word about the biological revolution itself. This is often equated with the progress of molecular biology and its biotechnological applications. But this is a restrictive view. It is really the whole of cellular life that we are now beginning to understand and learning to control, not just the mechanisms of biological information processing.

A VACCINE AGAINST MALARIA

Malaria is one of the great scourges of the Third World. It afflicts 150 million people. In Africa alone, it kills one million children a year. A cheap vaccine against this dreaded disease would be an enormous boon to humanity. But this has proved impossible so far. The first step in the preparation of any conventional vaccine consists in the large-scale cultivation of the microbe or virus responsible for the disease. The infectious agent is then treated in such a way that it loses the ability to cause a serious disease, but not that of stimulating a defensive immune response. Such an attenuated pathogen represents a vaccine. When inoculated to healthy individuals, it makes them resistant against the disease without causing them any harm. Note that only a few constituents of the vaccine — usually proteins located on the surface of the infectious agent — are responsible for immunization. The rest is just ballast, although it

may help to intensify the immune response by an adjuvant effect. In the case of malaria, which is caused by a small protozoan parasite of the genus *Plasmodium*, preparation of a vaccine could never be envisaged for the simple reason that the parasite could not be cultivated.

A few years ago, a partial solution to the problem was provided by William Trager, a professor at The Rockefeller University, who worked out a procedure for cultivating the malarial parasite in the laboratory. This development did not in itself allow the preparation of a vaccine, as the quantities that can be grown by the Trager procedure are much too small for this purpose. But they are sufficient to permit extensive biochemical and molecular biological studies of the parasite, and a way has thus been opened toward the production of a vaccine by genetic engineering. In principle, this implies isolating one or more parasite genes that code for immunogenically important proteins and cloning these genes in an expression vector, i.e., transferring them to an appropriate cultivatable microbial host using a procedure such that the proteins coded for by the genes are actually produced. Such engineered microbes can then be used as factories for the large-scale production of parasite-specific proteins suitable for vaccination. A number of laboratories all over the world are now pursuing this goal.

In my laboratory at The Rockefeller University, Margaret Perkins has approached the problem in a rational way, starting with a basic investigation of the mechanism whereby the parasite invades a red blood cell. This is an essential step in the development and maintenance of the disease; it depends on a specific binding between surface components of the two cells. Dr. Perkins was able to identify the erythrocyte receptor for the parasite as glycophorin, a well-known membrane glycoprotein. She then used this material to isolate by affinity chromatography those parasite proteins that have the ability to bind to glycophorin. Among these is a protein of 130 kDa molecular mass, which appeared of particular interest because it is antigenically conserved in widely separated strains of the parasite from Asia, Africa, and Central America. Dr. Perkins prepared an antibody against this protein and used it to track down the corresponding gene, for subsequent cloning and sequencing. This work, which relied on what are now standard techniques of molecular biology, was carried out in collaboration with Dr. Jeff Ravetch, of the Sloan-Kettering Institute. The structure of the gene

is quite interesting and includes 11 highly conserved repeats coding for 50 amino acids. My colleagues were able to clone a fragment of this gene extending over 4.5 repeats in an expression vector that causes the gene product to be made as part of a fusion protein of which the other part is a piece of the enzyme β-galactosidase. Injection of this fusion protein to animals was found to elicit the production of antibodies that bind to the plasmodium surface, react with the native 130 kDa protein, and inhibit erythrocyte invasion by the parasite. The fusion protein is thus a promising potential vaccine. Its suitability in this respect is being tested further.

Designing drugs against tropical parasites

Ten years ago, a young Dutch investigator, Fred Opperdoes, working in the laboratory of Piet Borst in Amsterdam, was investigating another pathogenic protozoan parasite, *Trypanosoma brucei*, which is responsible for nagana, or cattle sleeping sickness, a major cause of livestock losses in Africa. Opperdoes made the surprising observation that, in this organism, a number of enzymes of the glycolytic chain are located within special membrane-bounded cytoplasmic microbodies, which he called "glycosomes". This is a remarkable finding because, in every other cell type investigated, whether microbe, plant, or animal, the same enzymes are free in the cytosol, the soluble part of the cell. Shortly after he made this discovery, Opperdoes joined the ICP in Brussels, where he has continued to concentrate his efforts on the glycosome, partly because of the great interest of this organelle from the point of view of basic biology, and partly because a functionally important entity present in a pathogenic parasite, but not in the host that it infects, is a likely target for selective chemotherapy.

The results obtained so far by Opperdoes and his associates include the important observation that glycosomes exist not only in *T. brucei*, but in all the members of the protozoan group known as *Trypanosomatidae*, which includes also the agents of human sleeping sickness in Africa, the American *T. cruzi*, which is responsible for Chagas disease (discovered by the father of our president), and the *Leishmaniae*, which cause several widespread disabling tropical diseases, among them, kala azar. Thus a glycosome-specific drug could be of major interest, both medically and economically. In order to identify a possible molecular target for such a drug, the

workers have investigated the glycosomes of *T. brucei* with the best tools of biochemistry and molecular biology. They have purified nine glycosomal enzymes, crystallized several, and obtained at least one in a form suitable for high-resolution X-ray crystallography. In collaboration with a group of investigators at the University of Groeningen, they have established the three-dimensional structure of this enzyme, and are in the process of doing the same thing for others. They have also cloned and sequenced the genes of several of the enzymes, and thus, by application of the genetic code, determined the amino-acid sequences of the proteins themselves. Finally, they have found that glycosomal proteins are made in the cytosol and are subsequently transferred into the glycosomes by some unknown mechanism without undergoing any detectable change in their primary structure. All these investigations are now converging on the central question: what are the structural peculiarities of the glycosomal enzymes responsible for their remarkable homing ability? The answer to this question could lie in a special configuration of positive changes on the molecular surface, in which a distance of about 40 Å separates two pairs of basic residues 7 Å apart. This feature has been found so far on three glycosomal enzymes and is lacking on the homologous cytosolic enzymes. It could serve as a plug for the attachment of the enzymes to the glycosomal membrane, possibly on a corresponding negatively charged structure, prior to their incorporation inside the particles. Drugs designed to fit either the positive structure or its negative counterpart might be expected to interfere with this process, which is likely to be of vital importance to the parasite's organization. Interestingly, suramin, the best trypanocide presently known, happens to consist of two clusters of negative groups separated by a distance of about 40 Å. The detailed molecular information that is being made available by these studies could lead to the design of better, custom-made drugs against a group of crippling tropical diseases of humans and domestic animals.

Selective chemotherapy against cancer

The problem of chemotherapy is selectivity. Whether the body is invaded by endogenous anarchic cells, as in cancer, or by exogenous organisms, as in microbial or parasitic diseases, the drugs used must effectively kill the undesirable cells without causing

irreparable harm to the normal cells of the patient. This is particularly difficult to achieve in the case of cancer because of the close kinship between the cancer cells and the normal cells from which they derive. Of the few differences that exist between the two cell types, some are known to affect the cell surface, in the form of molecular groupings that are present on the cancer cells, but not on the normal cells. Many investigators are now trying to exploit these differences for the selective targeting of chemotherapeutic drugs. In principle, this involves linking the drugs chemically to carrier molecules that have the ability to bind to the cancer-specific surface groups and thereby can serve as homing devices for the drugs. A major problem in this kind of approach consists in the choice of an appropriate linkage between drug and carrier. This linkage must be stable in the body fluids, but must be broken after the drug-carrier complex has become attached to its target, so that the drug may be released to exert its effect.

At the ICP, Professor Andre Trouet and his collaborators have succeeded in designing such a linkage by taking advantage of our earlier studies on lysosomes, which are tiny intracellular pockets within which a collection of more than 50 distinct hydrolytic enzymes carry out important digestive processes. It is known that most molecules that bind to the cell surface are subsequently internalized by a process called receptor-mediated endocytosis and are then, with few exceptions, conveyed to the lysosomes, where they are broken down. On the basis of this knowledge, my colleagues have developed a tetrapeptide arm for linking drugs to their carriers. This arm is quite stable until the complex reaches the lysosomes, where it is then rapidly split by enzyme action. Complexes of this sort have given excellent results on animal models, to the point that preliminary clinical trials have been initiated.

Comments

Many other similar examples could be presented, not only from my own laboratories, but from many others in the world. The three that I have briefly described should suffice to illustrate two important characteristics common to all of them.

First, they are representative of an entirely new kind of medical research, which would have been impossible, even unthinkable, 20 years ago. A kind of medical research based on the deep understand-

ing of living processes provided by the biological revolution, using the sophisticated new tools and approaches developed through this revolution, and carried out by direct participants in this revolution — biochemists, molecular biologists, cell biologists, immunologists, and other basic biologists, most of whom would not have dreamed of doing medical research 20 years ago. This means that a powerful new army of investigators, superbly trained and equipped, has been added to the clinical investigators, the epidemiologists, the pathologists, the pharmaceutical chemists, the pharmacologists, and the other researchers who until now have been mainly concerned with the fight on behalf of human health.

A second characteristic common to the examples I have mentioned, and to many others that I could have mentioned, is that so far hardly a single patient has yet been saved thanks to this new kind of medical research. This is certainly no reason to give up the new approach. On the contrary. But it is a sobering fact, which reminds us that the major problems that have so far withstood the assaults of classical medical research — cancer, atherosclerosis, viral infections, tropical diseases, degenerative conditions of all kinds, senescence, neuropsychiatric disorders, to name only a few — are very complex indeed. Even for the new approach they may prove a hard nut to crack, as we are already beginning to find out in the field of cancer, for example, or in the recent AIDS epidemic.

I am mentioning this only as a warning to myself and to my fellow basic scientists, newly recruited into the ranks of the medical research army. In our enthusiasm and inexperience, not to say arrogance, we run the risk of being over-optimistic and of making rash promises, which can only do disservice to our cause when we fail to fulfil them. Another mistake we may make is to underestimate the effectiveness of classical medical and pharmaceutical research. We may do well to remember that it has succeeded in almost doubling the expectancy of life in the span of one century, and that it has done so without the benefit of the biological revolution. It is practiced and advocated today by scores of well-trained and experienced researchers from whom we have a great deal to learn and with whom it is in our interest to collaborate closely.

Finally, we must keep in mind that understanding the mechanism of a disease does not necessarily provide a cure or a means of prevention. We understand many genetic diseases, but we can

neither cure nor prevent them, except in some cases by the rather crude and, to some, morally objectionable method of prenatal diagnosis and abortion. There seems little doubt from what we read in the scientific literature that we are well on our way to the understanding of cancer, even if we are still very far from having reached this goal. But whether this knowledge will be easily translatable into effective preventive or curative measures remains to be seen.

Such uncertainties do not, of course, in any way detract from the value or validity of an approach exploiting the latest advances and the best tools of basic biology. Barring another gift from chance — miracle drugs do sometimes blow in through the window — our best hope of alleviating the many diseases that still assail mankind and thwart in so many ways the legitimate desire of men and women for health, happiness, and fulfilment, especially in the Third World, lies in trying to "translate the biological revolution into a second medical revolution".

Michael SELA

SOME HIGHLIGHTS OF CURRENT IMMUNOLOGY RESEARCH

My task is to try to explain some facets of immunology in a very short time, and I can say that at least one thing helps me: it is sometimes better to be later in the series of presentations because a few of my colleagues have already explained several aspects of immunology which will make it easier for me.

Immunology as a discipline is certainly not limited to the fighting of infectious diseases, viral, bacterial and parasitic. It is crucially involved in almost all aspects of medicine, including cancer, the autoimmune diseases (normally we do not react immunologically against ourselves, but there are many mistakes), transplantation (rejection of transplants because we are not identical), immunodeficiencies and many other areas. Any molecule, any substance that initiates, that triggers an immune response, we call antigen and the immunological responses to this challenge are either antibodies, which we find in the blood steam, and which belong to the various classes of immunoglobulin molecules, or specifically sensitized cells. I think the most important aspect of immunology is the specificity. We can react specifically to hundreds of thousands of different challenges and the answer is always specific. This is the reason why historically one assumed first that if there is such a variety of antibodies that are being made, so many different specificities, probably there must be one basic molecule which is being instructed how to change itself. But this is not correct. The whole antibody diversity, or the base of the diversity, is contained already either in the germ line or by somatic mutation but anyhow it is a selection process, the finding of these antibodies, and not instruction.

Now, whereas it is very easy to see an organ such as liver or heart, or kidney, I want to stress that there is also an immunologi-

cal organ. As a matter of fact, depending on our weight, I think, on the average, the organ of immunology in each one of us is approximately one to two kilograms, except that they are not located in one place. They are the lymph nodes and the spleen and the appendix and the bone marrow, but altogether there are something like 10^{12} cells which are involved (we call them with the general name of immunocytes) and 10^{20} antibody molecules.

There are different classes of antibodies, and a typical molecule of antibody has two combining sites, two areas of specificity and it is built of two kinds of chains — the light chain and the heavy chain. This is a pattern which you will see afterwards in a whole series of analogous molecules. Antibodies exist in various classes and the class is defined by the longer chain, the "heavy chain", but there are also two types of light chains and the various combinations of these chains give rise to a whole series of additional specificities.

Whereas antibodies are actually produced by the progeny of immunocytes which we call B cells, a most important factor in the ability of the immune system to react specifically against an antigen is a class of small cells called T lymphocytes, or T cells [1]. We distinguished several different types among these T cells, namely those involved directly in destroying cells, bacteria, etc. (called T killers or cytotoxic T cells), those that help an efficient antibody response (called T helper cells), and those involved in the suppression of an immune response (called suppressor T cells). The various types of T cells possess on their membranes characteristic markers (or antigens) that help to distinguish them. They also all possess the specific receptor for the antigen, which was expected to be somewhat analogous to the immunoglobulin which serves as a receptor on the B cell (the receptor on the B cell is an immunoglobulin which still has an "anchor" in the membrane). Actually, the antigen must be "processed" first and be presented to the T receptor by an "antigen-processing cell" (macrophage or, most often, B cell) in conjunction with a class II antigen. Class I and class II antigens are characteristic markers of the major histocompatibility complex (MHC). The class II antigens are crucially involved in the genetic control of immune response. What is of great interest is that the recently elucidated molecular structures of the T cell receptors, of

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[1] W.E. Paul, C.G. Fathman and H. Metzger, editors, Am. Rev. Immunol., *4* (1986).

the class I MHC-encoded protein and of the class II protein are all similar to the antibody (or immunoglobulin) molecule, and they even share similar sequences of amino acid residues. The molecules are characterized by loops made up of about 70 amino acid residues within each chain, with sulfur atoms at each end of the loop joined by covalent bonds. Class I proteins are expressed on the surface of every nucleated cell in higher vertebrates. Class II proteins are expressed only on the surface of selected cells, such as the B cells. Variable, joining and diversity regions have been identified in the T cell receptor and in the immunoglobulin. Each such region is encoded by a sequence of DNA selected at random from among a number of distinct sequences in the genome. Such regions give rise to substantial combinatorial variability in the molecules expressed by different cells in an animal [2].

Another most important group of molecules involved in the initiation and control of the immune response are a series of soluble factors present in various body fluids and made in various types of cells. I refer to the different lymphokines such as the interleukins, the interferons, as well as such recently investigated molecules as tumor necrosis factor, also called cachectin (activated macrophages destroy cancer cells more effectively than normal cells, and they do it through tumor necrosis factor), the vascularizing factor denoted angiogenin, and the various thymic hormonal factors, thymosin, thymodulin, etc.).

The interaction of an antigen with the macrophage induces interleukin 1, an important mediator of generalized host responses to tissue injury or infection [3]. Interleukin-1 in turn initiates the proliferation and expression of T cells. The T cells, triggered by interleukin-1 start synthesizing interleukin-2 which is expanding both T cells and B cells, and thus is crucially involved in the expression of the immune response.

The specificity of the interaction between antigens and antibodies or antigens and specifically sensitized target cells is followed by biochemical events at the cellular level which, in turn, define the biologic consequences. One example is the activation of the complement system, while another is the inflammatory reactions. The products of these biochemical events in cells are designated

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[2] P. Marrack and J. Kappler, Scientific American, *254*, 28 (1986).
[3] C.A. Dinarello, J. Clin. Immunol., *5*, 287 (1985).

mediators because they function within the tissue microenvironment and are not generally transported as would be the case with hormones. Mediators may be preformed and simply secreted as a result of specific immunologic cell activation or may be derived from biochemical events involving membrane associated fatty acids, as would be the case with the oxidative metabolites of arachidonic acid, such as prostaglandins, thromboxanes and leukotrienes. The leukotrienes are perhaps of particular interest because the cells expressing the 5 lipoxygenase pathway are of bone marrow origin, and are considered to be involved in host defense and inflammatory responses.

Ultimately, it is the interaction of the antigen with antibodies or specifically sensitized cells, which triggers the immune response, and I would like now to come back to the notion of antigen. In studies which we initiated some thirty years ago we could show that synthetic polypeptides can induce antibody formation and thus, we had available synthetic antigens [4]. These can be made in tens of different kinds; you can keep all the variables constant while changing only one at a time and you could thus define rather easily what is the molecular basis of antigenicity. This included the role of size, shape, composition, accessibility of various areas within the immunogenic molecule, not electrical charge, optical configuration of the building bricks as well as the steric conformation of the antigen.

Synthetic antigens were important also for the elucidation of other immunological phenomena, and I want to mention here only the genetic control of immune response [5]. Approximately twenty years ago we first showed that when you take the synthetic antigens, very simple chemically, and you inject them into inbred strains of mice which are very simple genetically, some strains are responders and others are non-responders. This response is under strict Mendelian genetic control and is determinant-specific. Changing the nature of the determinant could totally change the response. A short while later this response was shown to be linked to the main histocompatibility locus of the species and actually led to the discovery of the class 2 antigens.

A natural extension of our studies of synthetic antigens in a

[4] M. Sela, Science, *166*, 1365 (1969).
[5] R.H. Schwartz, Adv. Immunol., *38*, 31 (1986).

more practical direction was the development of the concept of synthetic vaccines [6]. Following a clear distinction between segmented and conformation-dependent ("conformational") antigenic determinants (epitopes), we showed that the attachment of the synthetic "loop" peptide of lysozyme to a multichain poly-DL-alanine carrier results in a conjugate provoking antibodies reacting with intact lysozyme [7]. The reaction occurs with a unique region within the native protein (the "loop" region) and it is conformation-dependent. The inevitable conclusion of these studies was that a new approach to vaccination is possible, for the simple reason that if this holds for one protein, it may hold for others, including, e.g., viral coat proteins and bacterial toxins. The synthetic vaccines of the future should include at least five ingredients: specificity, built-in adjuvanticity, the correct genetic background, the capacity of coping with antigenic competition and the correct "texture", i.e., form which will give persistent and long lasting immune protection.

We showed that it is possible to prepare a synthetic antigen provoking antibodies neutralizing viruses (MS2 bacterophage and influenza virus), bacterial toxins (diphtheria and cholera), and that it is possible to prepare molecules, in which a synthetic antigenic determinant and a synthetic adjuvant are attached to a synthetic carrier that — when administered in aqueous solution — will provoke immunity against both viral and bacterial infections [8-12].

For the past few years the whole area of synthetic vaccines has expanded enormously, and there is a fair chance that in the near future some cases, such as malaria, hepatitis B or foot-and-mouth disease, will reach the stage of clinical application. Of the early worries, it seems that competition between antigenic determinants

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[6] M. Sela, Bull. Inst. Pasteur, *72*, 73 (1974).

[7] R. Arnon, E. Maron, M. Sela and C.B. Anfinsen, Proc. Natl. Acad. Sci. USA, *68*, 1450 (1971).

[8] H. Langbeheim, R. Arnon and M. Sela, Proc. Natl. Acad. Sci., USA, *73*, 4636 (1976).

[9] G.M. Muller, M. Shapiro and R. Arnon, Proc. Natl. Acad. Sci., USA, *79*, 569 (1982).

[10] I.O. Jacob, M. Sela and J. Arnon, Proc. Natl. Acad. Sci., USA, *80*, 7611 (1983).

[11] R. Arnon, M. Sela, M. Parant and L. Chedid, Proc. Natl. Acad. Sci., USA, *77*, 6769 (1980).

[12] F. Audibert, M. Jolivet, L. Chedid, R. Arnon and M. Sela, Proc. Natl. Acad. Sci., USA, *79*, 5042 (1982).

may be avoided, and thus one molecule possessing specific epitopes for several different diseases may be envisaged.

In view of the linkage between the immune response and the main histocompatibility locus of each species, it is possible that the choice of the correct macromolecules carrier will depend on the genetic background of the individual to be immunized. How to make these synthetic vaccines of the future in such a way that they should lead to long-lasting immunity, whether by choosing the right carrier and/or epitope, wrapping the antigen in the right envelope or creating micelles or iscoms will now be a major challenge which I have no doubt will be successfully met.

Of course, the synthetic epitopes can be prepared either by chemical synthesis or by the introduction of the appropriate cDNA into bacteria such as *E. coli* or viruses such as vaccinia, and thus have a genetic synthesis.

I would like to mention here one other approach to the vaccines of the future, and I refer to the anti-idiotypes as vaccines [13]. Anti-idiotypic antibodies are against those areas of an antibody (in its role as an antigen) which are unique to that molecule and different from other immunoglobulins of the same class. Thus, they are against an area which corresponds to the variable part of the immunoglobulin chains, and which determines the specificity of the combining site of that antibody. When one makes, in turn, antibodies against the anti-idiotypic antibodies, some of these might confer immunity against a virus or a bacterial toxin, if the initial antibody, against which anti-idiotypic antibodies were made, had its specificity thus directed. In other words, if something (the combining site) in antibodies is the mirror image of something in the antigen (determinant), then the mirror image of the mirror image may resemble the original antigenic determinant. At least some of the anti-idiotypic antibodies will indeed contain areas resembling such determinants. This approach has shown some promise in the hepatitis B virus system (successful experiments in chimpanzees) and — as an anti-tumor vaccine — with a lymphoma subline [14].

Another example of possibly practical results is the immuno-

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[13] R.C. Kennedy, J.L. Melnick and G.R. Droesman, Scientific American, *255*, 48 (1986).

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targeting of drugs. Several laboratories have in recent years attached covalently either chemotherapeutic drugs or toxins to antibodies against antigens which are present either exclusively or preferentially in cancer areas. In my belief there are actually no totally antigen-specific anti-tumor antibodies, and I would prefer to call those that we and others have been using "antigen-selective". In our early work we have shown that it is possible to attach drugs like daunomycin and adriamycin, via a bridge (dextran, and more recently polyglutamic acid) to antibodies against antigens present on leukemia, lymphoma and plasmocytoma cells, and the resulting conjugates not only preserve their drug and antibody activities, but actually are quite effective in *in vivo* studies [15, 16]. In more recent studies we have shown that conjugates of daunomycin, via a dextran bridge, with monoclonal antibodies against a rat alpha-fetoprotein (a protein produced by most liver tumors, but otherwise almost undetected in blood, even though abundant at the fetal stage) will save 60% of tumor-bearing rats, when administered intravenously, for the whole period of experiment [17].

Studies in several laboratories, both with immunotoxins and with immunotargeted drugs have already reached the clinical stage in the cancer field. We are now trying to extend the immunotargeting approach to parasites and to viruses. An especially interesting use has been described recently: a specific fibrinolyic agent was synthesized by covalently coupling urokinase to a monoclonal antibody that was fibrin-specific and did not cross-react with fibrinogen [18].

I would like at the end to give also one example, which reached the stage of successful clinical trials, and I refer to a candidate drug against multiple sclerosis [19]. The story started twenty years ago

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when, knowing that the basic protein of the myelin sheath of the brain is capable, when administered in complete Freund's adjuvant, to provide experimental allergic encephalomyelitis in many animal species, I wondered whether a simple synthetic basic copolymer of amino acids might do the same thing. We failed to induce the disease with any of the copolymers we prepared but some of them, when administered in aqueous solution, efficiently suppressed the onset of the disease induced by the natural basic encephalitogen in guinea pigs and rabbits. The copolymer we mainly used, denoted Cop 1, is composed of a small amount of glutamic acid, a much bigger amount of lysine, some tyrosine and the bulk of the content was alanine [20].

In later studies we showed that Cop 1 is capable of suppressing the experimental disease in baboons and rhesus monkeys, and that there is a weak but significant immunological cross-reaction between Cop 1 and the basic protein of the myelin sheath of the brain. When an analogue of Cop 1 made from D-amino acids was tested, it had no suppressing capacity nor did it cross-react immunologically with the basic protein. We then found that Cop 1 is not generally immunosuppressive, and that the specific action occurs in experimental animals via suppressor T cells [21].

After toxicological studies in animals, and treatment of several cases of advanced multiple sclerosis in Jerusalem, showing that there are essentially no effects, we embarked on a collaborative clinical study with Murray Bornstein and his colleagues at the Albert Einstein College of Medicine in the Bronx, New York, who organized a two-year double blind trial with 50 patients suffering from the exacerbating-remitting form of the disease [18]. The results have only recently become available, and they are very encouraging. Average exacerbations over two years were 2.7 for placebo and 0.6 for Cop 1 patients. Disability changes also favored Cop 1. Differences were more pronounced in less advanced patients. Two double blind trials with patients suffering from the chronic-progressive form of the disease are now in progress. It is possible and hopeful that a similar approach might be contemplated for other autoimmune diseases.

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In conclusion, both our basic knowledge of the immune response and the possible applications of this knowledge have increased enormously in the last few years. This is becoming of great importance both for the treatment and prevention of many diseases, but also for a deeper understanding of the basic genetic mechanisms of the formation of proteins generally, as well as for a beginning of a better understanding of embryology, differentiation, regulation and control. The monoclonal antibodies produced by hybridoma cells first developed by Kohler and Milstein, have been of tremendous use, both in research and in their medical and industrial applications. Most recently, this has been extended to hybrid hybridoma cell lines, of great potential use in one-step immunocytochemistry and immunoassays [22]. Because of the great need for human hybridomas, mainly for therapeutic purposes, the complementarity-determining regions in antibodies of one species may be converted to those of another species by genetic engineering [23]. We have thus learned a lot but there is always much more to learn. In contrast to territorial conquests where when one side gains the other side loses, in science when the known increases the definable unknown also increases, and this is the challenge of the immunologist today.

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John Charles ECCLES

BRAIN SCIENCES

I have the task of talking on the brain sciences in this brief time. It is beyond imagination what I am asked to do. There may be 20,000 brain scientists in the world today and next week 9,000 will be meeting in Washington DC. That gives you some idea of the enormous pressure of the subject. I feel the only way I can do it is rather like somebody wanting to come and look at a great art gallery, say the Uffizi, in ten minutes and I can't show them all the pictures. I can just pick a few of the excellent ones, the Botticellis and show them those, with perhaps one or two others, and they have seen the Uffizi.

So what can I do? First of all, I want you to think of the brain as an immense communication system, beyond imagination. There are ten thousand million neurones in the cerebral cortex, each receiving from about ten thousand synapses on its surface and communicating likewise by its ten thousand synapses to other neurones. There are now excellent ways of recording from single cells and of recording also from the ensembles of neurones in different parts of the cerebral cortex. For example, there is recording of field potentials in the cerebral cortex, or there is PET scanning and so on. I don't want to minimize the great work on the sensory and motor systems. I'm not going to deal with it today. I'm going to adopt a diametrically opposite approach. Instead of talking about the holistic view of the brain, I am going to concentrate on fundamental microsites, which are involved in the synaptic operation in the brain.

Physicists made a great advance when, instead of talking about gases, the gas laws, they finally got down to the motion of molecules, and from electricity to electrons, light to photons, radioactivity to decay of radioactive atoms and so on. Likewise, in the CONS, apart altogether from the global view, there are new

important developments at microsites. The microsites may be the synapses whereby one neurone communicates with another, but of more significance now are special elements of synapses.

Fig. 1 is a drawing of a nerve cell on which there are shown two synapses (S), which are microsites. The nucleus and the axon and all the various organelles of the nerve cell can be seen. In the presynaptic boutons there are small round vesicles filled with the specific transmitter molecules. When a nerve impulse comes to the bouton (arrow), vesicles empty their contents into the synaptic cleft. The transmitter molecules then act on the postsynaptic membrane.

Fig. 2 shows a fragment of the surface membrane of a nerve cell. It is made up of a bimolecular leaflet of phospholipid molecules projecting from their round heads on the outside and inside. Across the membrane are large protein structures, which are channels for ions and molecules, three different kinds being shown. The phospholipid membrane is highly resistant to electrical transmission but the protein structures are channels for ions, particularly the one shown to the left in Fig. 2B. The ionic current through such a channel can be recorded (Neher and Sakmann, 1976) by using a fine glass micropipette with a polished tip that is about 1 μm across. When it makes a firm contact with the surface membrane, it can be used to record selectively from the patch of contact because it seals with a very high resistance of more than 109 Ω.

When the physiological solution in the micropipette contains an extremely dilute solution of ACh, the activation of the ACh receptor sites on the external surface of the patch on a muscle fibre opens ionic channels across the membrane. As shown in Fig. 3A, the channels opening by 100 nM ACh result in inward current pulses that are of widely different durations but of the same magnitude, there being a very small variance from the mean at 2.7 pA. When a long run of channel openings is analyzed, there is found to be an excess of brief openings of no more than 1 msec. These brief openings are interpreted as being effected by a single molecule of ACh, the longer being effected when two molecules of ACh become attached to the receptor of the channel.

The current flowing through the channel is due to ions diffusing down the electrochemical gradient across the membrane (cf. Fig. 2B to left). In Fig. 3B this gradient is varied from +20 mV to −60 mV by an applied current and the sizes of the current pulses vary according to the expected linear relationship.

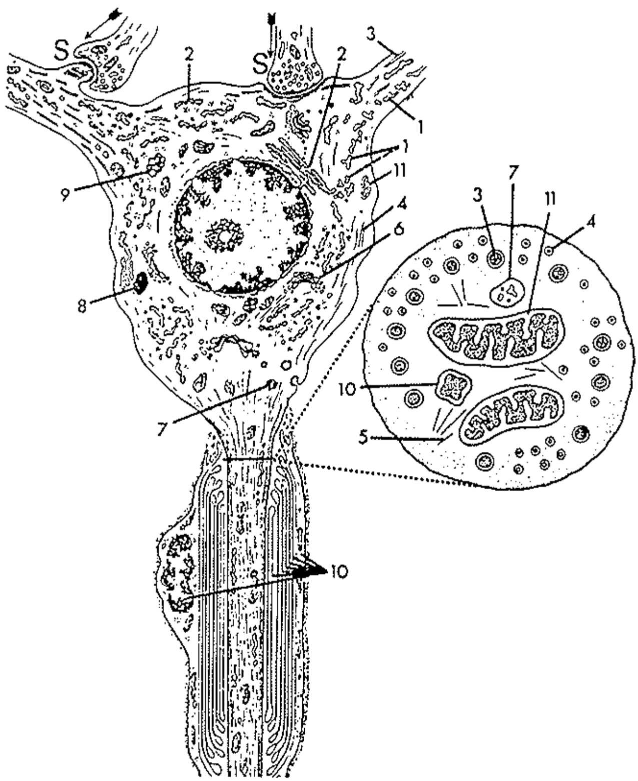

Fig. 1. Schematic diagram showing many features of a neuron as seen in electron micrographs. Two dendritic processes are shown and a myelinated axon wrapped by processes from an oligodendroglia cell. An exodendritic and an axosomatic synapse are shown. Within the neuron are shown the subcellular organelles discussed in the text. These include the rough and smooth endoplasmic reticulum, the Golgi apparatus with secretory vesicles, lysosomes, lypofuscin granules, multivesicular bodies, microtubules, neurofilaments, microfilaments and ribosomes (McGeer *et al.*, 1986).

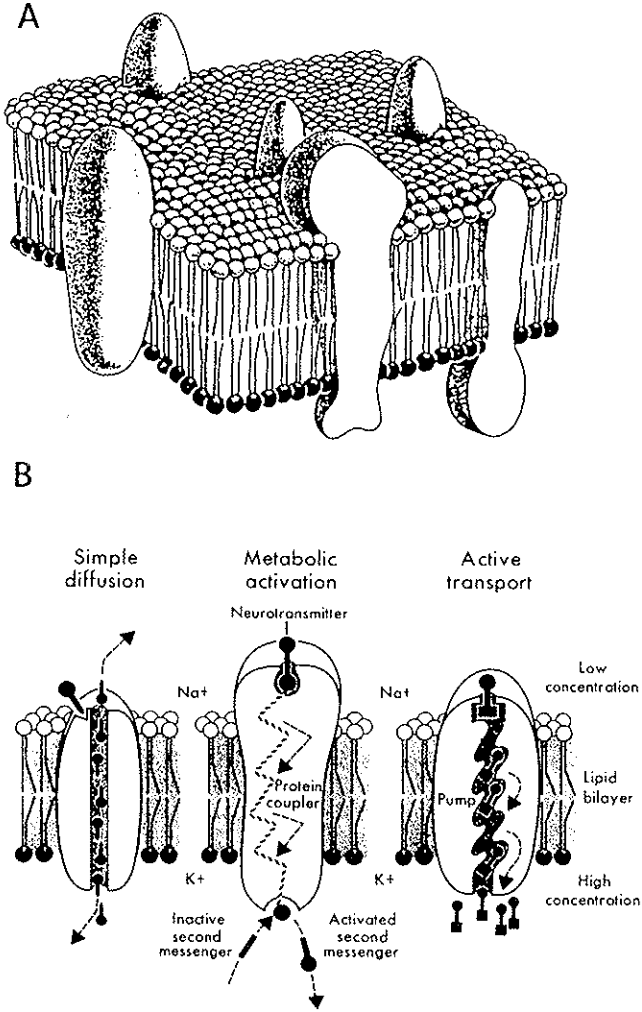

Fig. 2. Organization of the surface membrane. The basic structure is a biomolecular leaflet of phospholipid molecules with hydrophylic structures on the external surface. One set is oriented to the extracellular fluid (light colour) while the other is directed towards the intracellular fluid (dark colour). In freeze fracturing, the membrane parts in the middle, where its structural strength is least. In A six specific glycoprotein complexes are shown "dissolved" in the membrane. In B three of these are shown, representing three different types of receptors.
Many additional types of receptors exist in the membrane. In addition, structural proteins are applied to both surfaces to provide stability. The three types of receptors depicted are: 1) an ionotropic receptor which opens ionic channels upon activation by a neurotransmitter; 2) a metabotropic receptor which triggers a transmembrane reaction to a second messenger upon activation by a neurotransmitter; and 3) a high affinity neurotransmitter uptake system which "pumps" the neurotransmitter from a low concentration extracellularly to a high concentration in a nerve ending (McGeer *et al.*, 1986).

When there are several channels across the patch that is being recorded from, there is the expected summation of currents as illustrated in Fig. 3C for the current pulses of one, two or three channels, each of 3.9 pA.

The patch clamp technique has been applied to synapses on neurones of the central nervous system. For example, the inhibitory synapses have as transmitters, GABA or glycine. When the pipette was filled with either, the opened inhibitory channels passed small anions, Ce, NO_3, B, etc., as had been discovered earlier by cruder methods. Patch clamping enables very precise studies of these inhibitory ionic channels.

It can be concluded that the patch clamping technique is altering our whole understanding of chemical transmitting synapses both in the peripheral and the central nervous system.

It has long been known that the large afferent fibres (the Ia) from a muscle are selectively distributed in the spinal cord to make excitatory synapses on the motoneurones of their muscle. It is now possible to cut down this input to a single fibre. In Fig. 4C it was surprising to find that there was a wide fluctuation of the unitary EPSPs, but 800 added up gave an apparently normal EPSP (Fig. 4D). By horseradish peroxidase (HRP) injection it is revealed that a single Ia fibre gives several boutons to a motoneurone (Fig. 4B). Hence the fluctuation can be attributed to variations in the bouton contribution, each bouton giving a unitary vesicular output (exocytosis) every now and then. By a very sophisticated technique of fluctuation analysis, Redman and associates have been able to determine the contribution of individual boutons, there being in the illustrated case 4 such quantal emitters, with probabilities shown in Fig. 4E to H, together with the averaged EPSPs of each. It turns out that the probability of vesicular exocytosis is less than one for a bouton, with usual values of about 0.3. A similar range of probabilities has been found in other species of synapses. So here we have an important new and completely unexpected synaptic property.

In attempting to understand the synaptic mechanism underlying this probability, we turn to the idealized bouton drawn by Akert as a result of electromicroscopic and freeze fracture techniques (Fig. 5). Each bouton confronts the synaptic cleft by a paracrystalline structure composed of presynaptic dense projections and synaptic vesicles in hexagonal array in close contact with the presynaptic membrane fronting the synaptic cleft. Evidently the

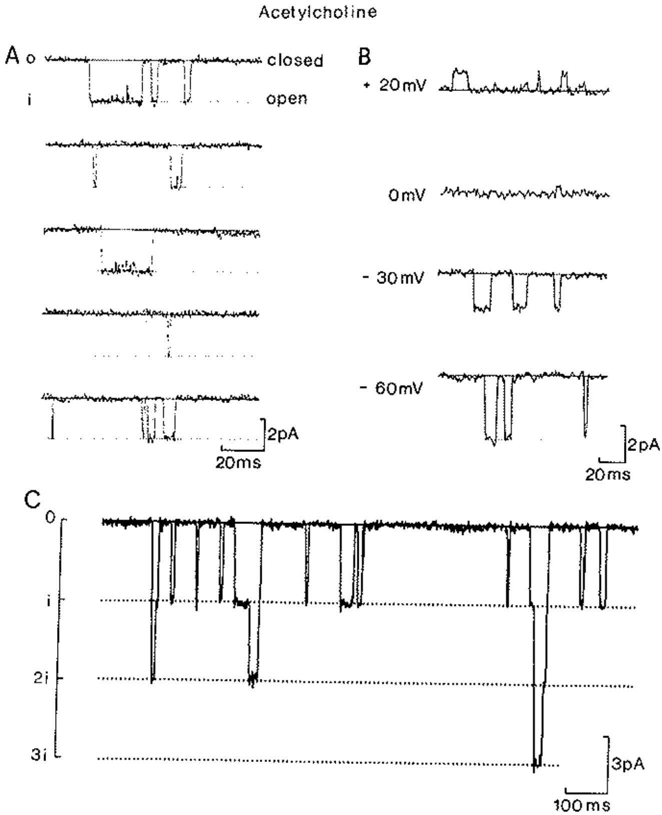

Fig. 3. A: Single channel currents recorded in the presence of 100nM acetylcholine from a frog muscle fibre at the resting membrane potential of −92mV. Temperature was 10 degrees C. Downward deflection indicates inward current. The distribution of current pulse amplitudes has a peak at 27 pA. B: Voltage dependence of single channel currents activated by 2 micro M acetylcholine in rat embryonic muscle. Temperature was 23 degrees C. Downward deflection indicates inward, upward deflection outward current. C: Single channel currents recorded in the presence of 100 nM acetylcholine from a frog muscle fibre at −130 mV membrane potential. Temperature was 10 degrees C. Currents of three individual channels superimpose to form regularly spaced amplitude levels of −3.9 pA (Colquhoun and Sakmann, 1981).

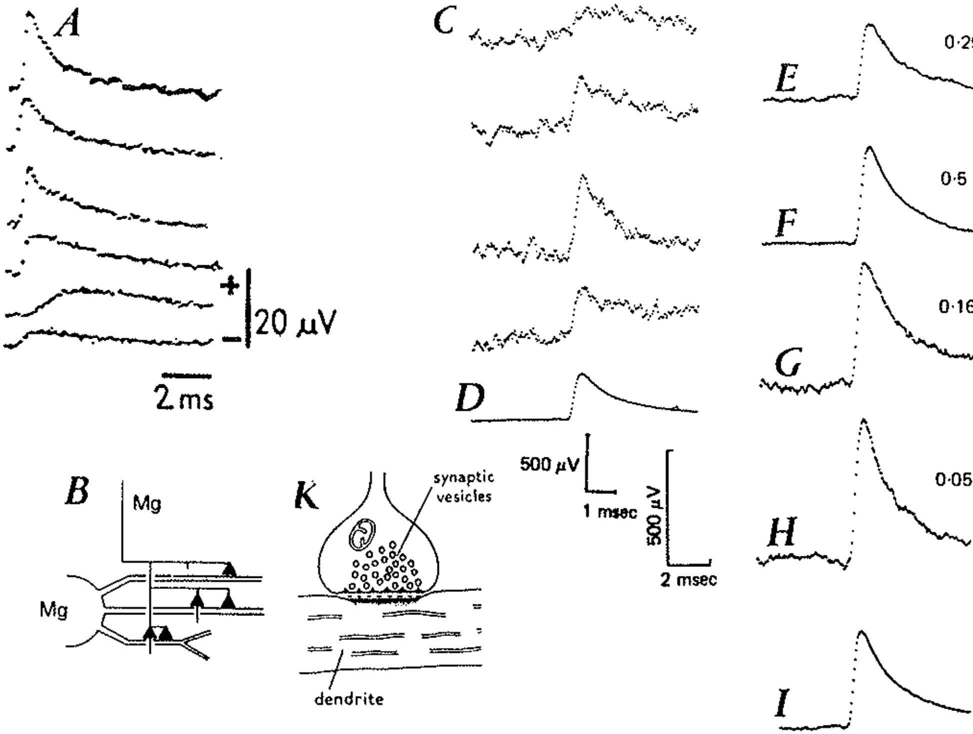

Fig. 4. A: Averaged recordings of EPSPs produced by impulses in the same Ia fibre terminating on six different motoneurones. B: Summary diagram of the location of Ia synapses from a single medial gastrocnemius Ia fibre on to a medial gastrocnemius motoneurone at five sites on three different dendrites as indicated. C: Four individual EPSPs selected from a population of 800 responses. D: is the average of all the 800 responses. E: is component (1) of the EPSP derived from fluctuation analysis. F, G, and H: are components 2, 3 and 4 of this same fluctuation analysis. The probabilities of the occurrence of these components are indicated to the right of each. I is the reconstructed EPSP obtained by adding the weighted sum of E, F, G, H; 0.29 E + 0.5 F + 0.16 G + 0.05 H (Jack *et al.*, 1981). K: Drawing of a synapse on a dendrite to show the bouton with vesicle and the synaptic cleft.

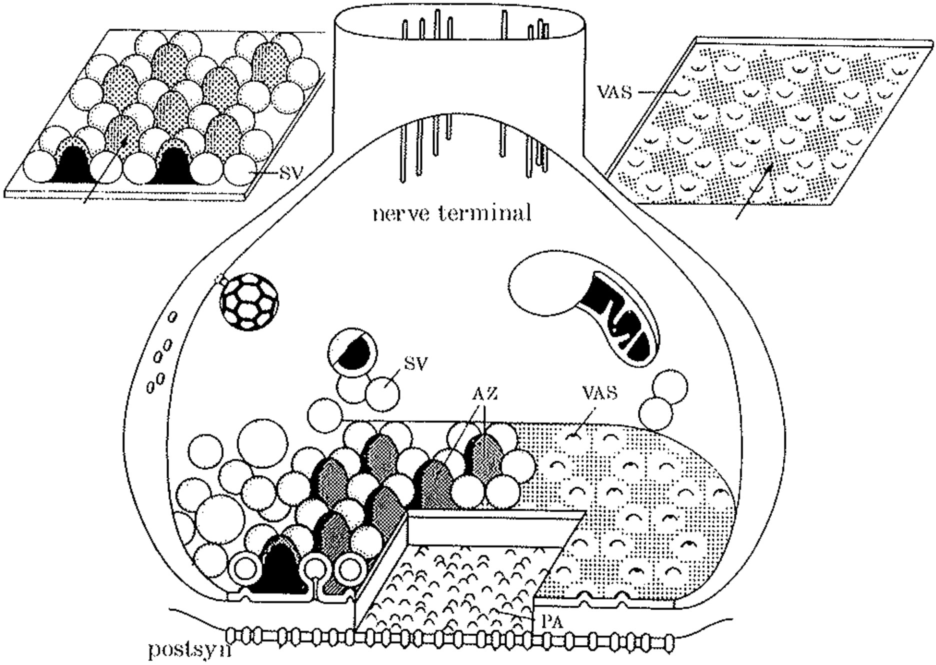

Fig. 5. Idealized synaptic bouton showing in partial perspective the presynaptic vesicular grid confronting the synaptic cleft with synaptic vesicles (SV) in hexagonal array between the presynaptic dense projections (AZ). The bouton is partly cut away to show the subsynaptic membrane, and to the right only the base plate (VAS) of the presynaptic vesicular grid is shown (Akert *et al.*, 1975).

presynaptic vesicular grid must work in a global manner conserving vesicles so that an impulse causes a single exocytosis with a low probability in accord with the fluctuation analysis of the unitary ESPSs in Fig. 4.

In his book the quantum physicist Margenau (1984) suggested that a non-material mental event such as an intention or thought could influence neural events at microsites without violating the conservation laws of physics. In a recent article (Eccles, 1986), it has been proposed that because of the probability of vesicular emission, the presynaptic vesicular grids are ideally fitted to be the targets for non-material mental events such as an intention for some movement. There need only be a change in probability of vesicular emission. Fig. 6 illustrates the movement of a synaptic vesicle up to the presynaptic membrane and its emission of transmitter (exocytosis). The structural change in opening the gate requires a gap of about one millionth of a centimeter in the double membrane about one millionth of a centimeter thick, so that the mass involved in exocytosis is about 10^{-18}g, which is of the order of magnitude for the effect of a quantal probability field as suggested by Margenau for the operation of a non-material event without breaking the conservation laws of physics.

It is of the greatest importance that the synaptic design allows this microsite operation for the explanation of the hitherto intractable mind-brain problem. The effect of a probability variance of one vesicular emission is many orders of magnitude too small for an explanation of neuronal discharges that would have an effective action in the cerebral cortex. However, there are about 10,000 spine synapses on one pyramidal cell and the apical dendrites of many pyramidal cells are assembled in bundles, so great amplification is available if the mental influence is concentrated on a local site of the cerebral cortex. This hypothesis that mental events act on probabilistic synaptic events in a manner analogous to the probability fields of quantum mechanics seems to open up an immense field of scientific investigation both in quantum physics and in neuroscience.

However, it is important to recognize that this hypothesis does not solve the ontological question: what is the mind? The whole subjective world is another existence. As Popper and I believe, it is distinct from the world of matter-energy. The whole mental world is the World 2 of Popper. It is of the greatest importance that we

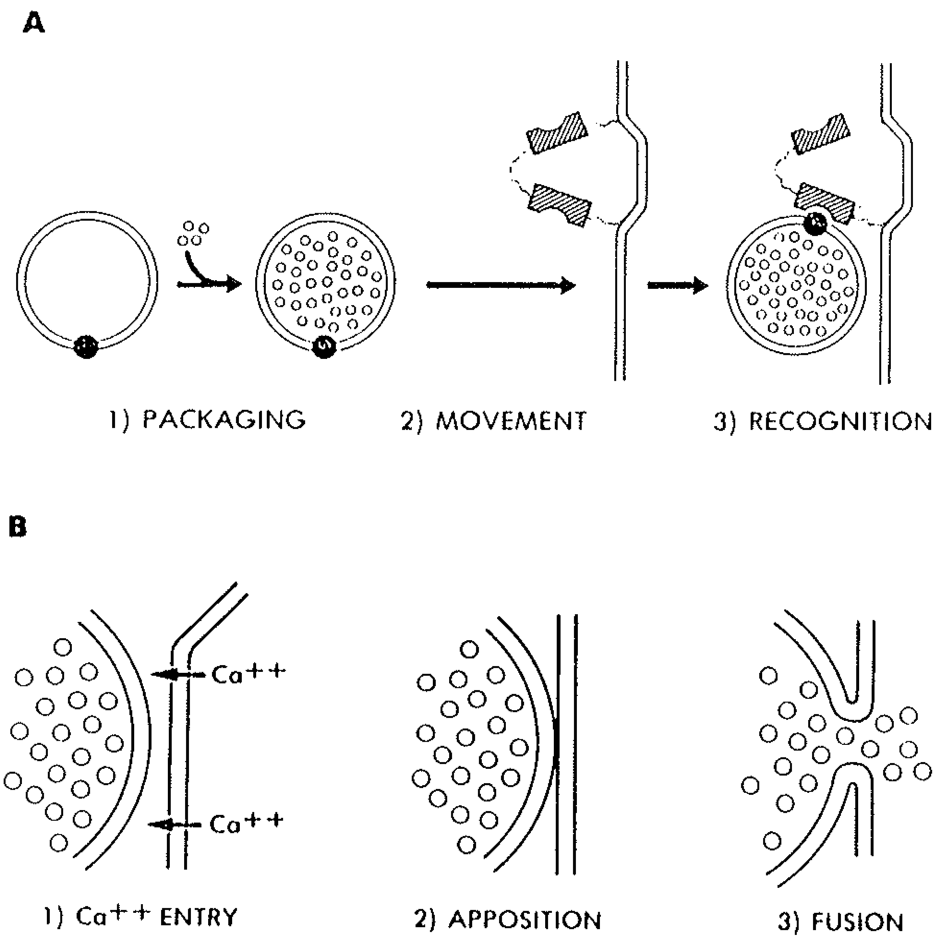

Fig. 6. Stages of synaptic vesicle development, movement and exocytosis. (A) The three steps involved in filling a vesicle with transmitter and bringing it to attachment to a presynaptic dense projection of triangular shape. (B) Stages of exocytosis with release of transmitter into the synaptic cleft, depicting the essential role of Ca^{2+} input from the synaptic cleft (Kelly *et al.*, 1979).

now have an hypothesis in which non-material mental events could act at neural microsites and effectively change the neural events without violating the conservation laws of physics.

In 1973, Bliss and Lomo published their most convincing demonstration of a model for memory. After moderate stimuli of a few hundred stimuli, EPSPs extracellularly recorded were potentiated for hours, days or weeks. This long term potentiation (LTP) was recognized immediately as the basis for a model of memory. There is much evidence that this prolonged potentiation is due to Ca^{2+} influx postsynaptically. Fig. 7A illustrates a transformation of our concepts on the nature of the LTP (Gustafsson and Wigström, 1986; Eccles, 1987). The hypothesis is that the postsynaptic receptor of the spine synapse is a double receptor structure. There is much recent evidence that a single synaptic bouton of a spine synapse has two distinct receptor sites for the transmitter, glutamate. One is the conventional quisqualate receptor that when activated opens channels to Na^{+} and K^{+} ions, so producing the large depolarization of the EPSP. The other is specially excited by N methyl-d-Aspartate (NMDA) and blocked by 2 amino-5-phosphonovalerate (APV). Activation of this NMDA receptor by glutamate gives normally a negligible depolarization. However, when the extracellular Mg^{2+} concentration is greatly reduced or when the receptor is subjected to a steady large depolarization, glutamate activated NMDA receptors give a large slow depolarization of the spine lasting for about 60 msec with a large influx of Ca^{2+} ions through the opened Ca^{2+} channels (Gustafsson and Wigström, 1986). APV prevents this depolarization of NMDA receptors and the opening of the Ca^{2+} channels. As would be expected, LTP is also blocked by APV.

In the normal operation of a cortical neurone such as that partly shown in Fig. 7B, there would be activation of hundreds of synapses with the current passing through the QQ receptors to give a large EPSP. Furthermore, this cooperativity would produce sufficient depolarization for opening the Ca^{2+} channels of those NMDA receptors activated by glutamate at that time. This correlates with the finding that only those previously activated synapses exhibit LTP. These synapses with double receptor sites provide an effective model for memory and a great challenge for further study. Especially notable are the precise analytical studies by Gustafsson and Wigström on NMDA receptors for glutamate which may well be the key structures in the laying down of memories in the cerebral cortex.

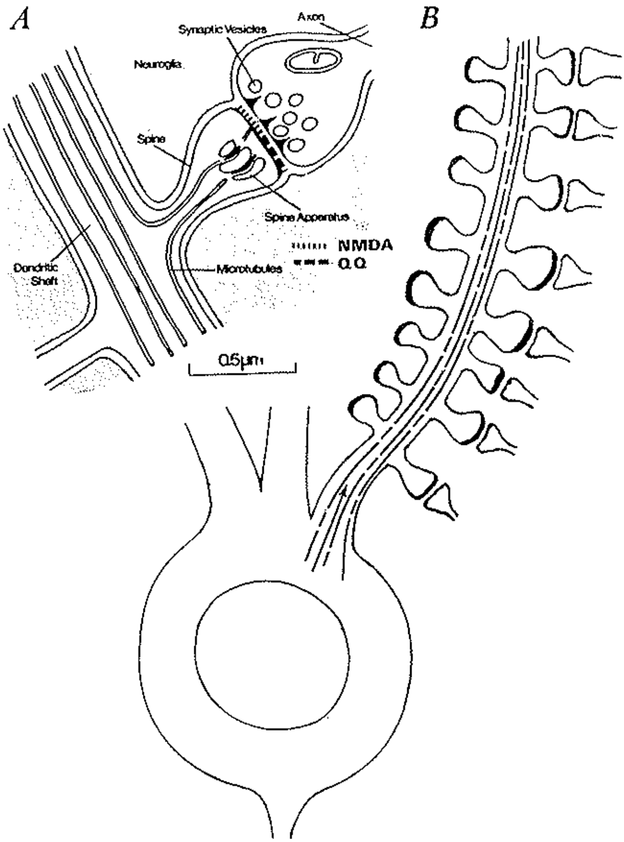

Fig. 7. A shows a spine synapse on the dendrite of a hippocampal neuron. The postsynaptic glutamate receptor is shown with a double composition. One part is the normal depolarizing synapse, that is depolarized by the transmitter, glutamate, acting on receptors that are probably those specially receptive to quisqualate, hence labelled QQ, and the other part is specially receptive to N-methyl-D-Aspartate (NMDA) (Eccles, 1987).

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Albert ESCHENMOSER

CHEMISTRY

The two fields which happen to be presented here in sequence, neurophysiology followed by chemistry, seem extraneous indeed and it would appear that a juxtaposition could hardly be a more drastic one than this. On the other hand, the situation reminds me of what I often feel when I find myself confronted with progress reports on research in biology: perhaps from all the disciplines of science, it might well be the chemist who is best able to apprehend and judge the immensity, the sheer miraculousness of certain molecular phenomena displayed by organic matter at the biological level of organization. By saying the chemist, I really mean the synthetic chemist. His criterion for judging complexity is accessibility by (*de novo*) synthesis; to him, molecular systems that have been reached by chemical synthesis are, in a way, conquered territory, they are susceptible to intimate experimental study and eventual understanding, not only with respect to their final functional form, but also along the dimension of their chemical genesis on the level of precursor systems of lower complexity. The human mind reacts differently towards objects that have been (or can be) fabricated as compared to those which cannot; chemical syntheses of complex molecules of natural origin are, so to say, tiny steps forward in the process of demythologizing living matter. To chemists, accessibility by so-called total synthesis represents a final goal in chemical reductionism. With such a reference point, the chemist can only shudder at the immensity of the gap between what to him appears possible and what exists.

Today, a substantial if not the major part of the most fascinating and most important chemistry that is being done is happening outside chemical laboratories; some of the reports which we have heard today in this session exemplify this statement.

What then is what one calls chemistry today? Or asked more pragmatically: what are chemists doing today?

To comment on these questions I have chosen to make use of the fortunate fact that, about a year ago, an important document appeared which amounts to a competent and comprehensive analysis of the present state of chemistry in the USA. I refer to the so-called *Pimentel Report* [1] "Opportunities in Chemistry", written by a committee of academic and industrial chemists and chemical engineers under the chairmanship of *George Pimentel* (University of California, Berkeley) and the auspices of the National Academy of Sciences, Washington. This document, in describing the face of chemistry of a major chemical nation, represents in my opinion a valid survey of what is in the foreground of interest today in chemical research as a whole. Here, I shall make use of parts of the report's Executive Summary as a frame for my comments; I apologize to those of you who are members of the National Academy and may be already familiar with the report's content.

"Priority should be given to the following research frontiers:

A. Understanding Chemical Reactivity
B. Chemical Catalysis
C. Chemistry of Life Processes
D. Chemistry around us
E. Chemical Behaviour under Extreme Conditions".

"*Understanding Chemical Reactivity*" is at the very center of the aims of research in chemistry. It remains, perhaps beside chemical synthesis, the principal task of chemists at a time when much of the isolation of new natural substances comes out of biological research, when the determination of new and complex molecular structures, natural as well as unnatural, has become mostly the task of crystallographers and spectroscopists and, perhaps most importantly, at a time when the study of the structure and function of molecular constituents in the living cell, in fact the chemistry of the living cell, have long become established as the natural research territories of biochemistry and molecular biology. "Understanding molecular reactivity" will be the essence of what

[1] G.C. Pimentel *et al.* (Committee to Survey Opportunities in the Chemical Sciences), "Opportunities in Chemistry", National Academy Press, Washington, D.C. 1985, 344 pages.

chemistry will infuse into these sciences when they move more and more from discovery to rationalization, when they continue to become more and more molecular.

Within chemistry, "understanding chemical reactivity" refers to a multitude of levels differing in the degree of conceptual as well as experimental quantification; communication between these levels is one of the important and never ceasing challenges within the field. Chemistry stretches from chemical physics and quantum chemistry on the one side to the art of making molecules and the empirically founded (yet extremely heuristic) language of structural formulas on the other. "Understanding chemical reactivity" on the last mentioned level is a *conditio sine qua non* for expanding the field of chemical synthesis, for the development as well as discovery of new pathways of structural change.

"*Chemical Catalysis*", the next item in the priority list of the Academy's report, is wisely chosen indeed, for the importance of the chemical phenomenon of catalysis can hardly be exaggerated; it touches on the fundaments of our very existence in being one of the prerequisites of life itself. In contemporary chemical research it is perhaps the hottest topic of all; it promises a new type of chemical synthesis in the future, one that will possess the virtue of enantioselectivity, an aspect of longstanding preponderance of synthesis performed by living Nature. Research on chemical catalysis today comprises the compartments of heterogeneous and homogeneous catalyses, of photo- and electrocatalysis as well as of catalysis by artificial enzymes. In petrochemical technology, advances in the field of heterogeneous catalysis always had and are still to have great economic impact.

Proposition C of the Academy's reports refers to *Chemistry of Life Processes* and reads: "We propose an initiative to develop and apply the techniques of chemistry to the solution of molecular- level problems in life processes and to develop young research scientists broadly competent in both chemistry and the biological sciences".

What causes a branch of science to come of age is connected with the switch from discovery to rationalization. There was a time when fundamental discoveries dominated the face of chemistry, a time which, so it seems, is long over. Within what is meant by "chemistry" today, the problems of rationalization and the challenges for creative design have come to replace the opportunities to discover; exceptions notwithstanding, so at least it appears to many

of us. Yet, so I think, the opinion is misleading, because the El Dorado for chemical discoveries today is the chemistry of the living cell, a field which belongs to "chemistry" in its comprehensive sense, a field that (adequately) is called biochemistry and (more often than seems adequate) molecular biology. The endeavour to comprehend the living cell on the molecular level is vehemently doing away with our classical compartmentalizations of chemical and biological sciences, and attempts to reorient or redefine them are of little relevance. Physics, chemistry and biology differ in their way of studying life-related problems primarily methodologically and so the report's recommendation is an appeal to chemists for bringing their methods and techniques into play in this interdisciplinary field, to participate in large numbers in the adventure of studying life, to grasp their chance at a time when biology as a whole moves, because it's bound to become more and more molecular, towards chemistry.

I think recommendation D, *Chemistry around us*, speaks well for itself: "We propose an initiative to understand the chemical make-up of our environment and the complex chemical processes that couple the atmosphere, oceans, earth and biosphere with special reference to man's conscious and inadvertent disturbance of this global reactor. Analytical chemistry and reaction dynamics define the core of this initiative".

Finally, *Chemical Behaviour under Extreme Conditions* is a proposition which expects from experiments in this direction "critical tests of our basic understandings of chemical reactions and new routes towards discovery of new materials and new devices".

In trying now to go beyond this survey of chemistry by describing in some detail a few examples of ongoing research, I have selected, being myself an organic natural product chemist, examples from the fields of organic and biological chemistry; furthermore, I will allow myself to tell you a little about research from my own laboratory.

In organic chemistry of today, an enormous amount of work is going on in what previously was called "asymmetric" and today is referred to as "diastereoselective and enantioselective synthesis". Most of the molecules of interest to chemistry and biology are chiral, chirality (handedness) being defined as the property of an object (e.g., a molecule) to be non-superimposable with its mirror image. The prototype of two chiral objects are our own two hands;

they are like mirror images, but the left hand is not superimposable with the right hand. Classical chemical synthesis of compounds that consist of chiral molecules (as most naturally occurring compounds do) produced these compounds uniformly as binary mixtures composed of equal amounts of the right- and left-handed variety of molecules. In order to produce the natural (optically active) form of compounds, such so-called racemic mixtures had to be separated by special techniques to provide the two constituents (the so-called enantiomers) in pure form.

In living cells, molecular synthesis proceeds under the control of enzymes, catalysis being the control tool. Enzymic synthesis does not produce racemic mixtures, it forms only one of the two possible enantiomers of a given cell constituent; the chemist says, enzymic synthesis proceeds with high enantioselection.

Figure 1 [2]

[2] Photograph by Fritz Kreppelt, ETH.

The phenomenon of enantioselection in biological synthesis is fundamental. With Fig. 1 I try to remind you of its basis, using the photograph of a model which is part of ourselves and, therefore, apt to provide intuitive insight. The top of the photograph shows a right hand shaking a right hand, this being our natural way of shaking hands. At the bottom, a right hand tries to shake another person's left hand, a situation which all of us have experienced to be an unnatural and a structurally very different contact between two hands of two persons. In the chemist's language, these are two diastereomorphic handshakes. Chiral molecules experience the same thing. The two types of molecular contacts (right + right versus right + left, or mirror images) lead to two clearly different (diastereomorphic) contact structures which have different energy contents and which, in structural communication between chiral molecules in a biological process, transmit different messages. Enzyme catalysis implies molecular contacts between proteins and reaction substrates at such a level of molecular intimacy, that it easily differentiates between (and, therefore, selects one of) the two diastereomorphic reaction pathways ("diastereomorphic handshakes"); in doing so, it produces selectively one of two possible enantiomorphic reaction products.

To emulate Nature by developing the methodology that renders chemical synthesis enantioselective whenever needed is now a central research goal in synthetic organic chemistry. A multitude of approaches are under investigation, but there is agreement about what type of solution eventually has to emerge: the approach by catalysis, the design and synthesis of reaction-specific, chiral catalysts which in non-racemic form enantioselectively catalyze the conversion of achiral starting materials to chiral and non-racemic reaction products with high efficiency.

Fig. 2 provides an example of what is meant; it illustrates the *Sharpless* reaction, an important and extremely useful discovery made in 1980 by Katsuki and Sharpless [3], providing a near-perfect solution to the problem of enantioselective epoxidation of allylic alcohols by chiral catalysis.

Achiral allylic alcohols produce chiral epoxy alcohols in racemic form when treated with a hydroperoxide reagent in the presence of titanium (IV) tetraisopropoxide as catalyst in solvents such as

[3] T. Katsuki and K.B. Sharpless, J. Am. Chem. Soc., *102*, 5974 (1980).

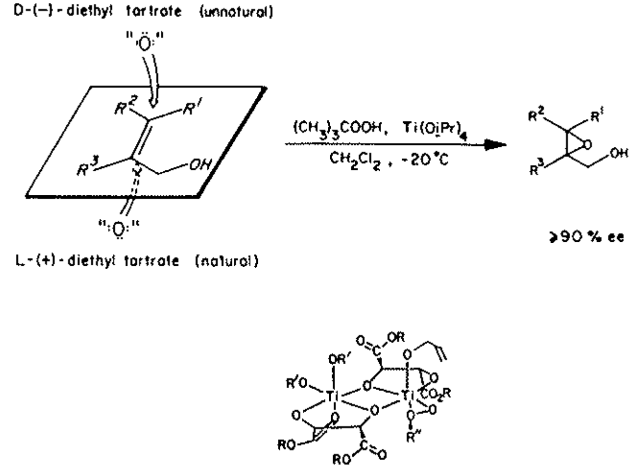
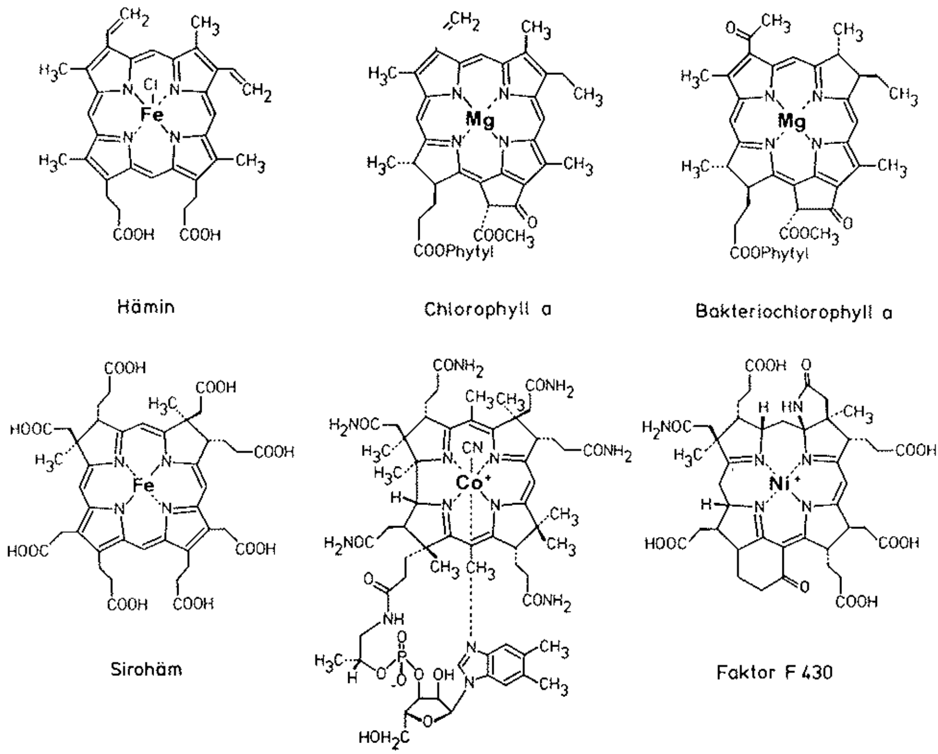


Figure 2 [4]

dichloromethane. The discovery was the observation that addition of a pure enantiomer of diethyl tartrate makes the system produce almost exclusively one of the two possible product enantiomers. The non-racemic, chiral additive converts the achiral titanium(IV) alkoxide by ligand exchange to a chiral, non-racemic catalyst (see Figure 2), which, in principle by "handshake-selection" of the type illustrated in Fig. 1, catalyzes the epoxidation process to one of the two enantiomeric reaction products more efficiently than to the other. The phenomenon has been found to be remarkably general in the sense that its enantioselection operates almost independently of the constitution of the allylic alcohol. The process has become an exemplary model of achievement in the long march of organic chemistry towards the ambitious goal of comprehensive enantioselection in chemical synthesis.

Let us switch from synthetic methodology to the field of natural products chemistry, specifically to the chemistry of coenzymes. Coenzymes (or cofactors) are low molecular weight molecules of a chemically quite often intriguing structure, selected and used by Nature to perform specific catalytic tasks in metabolism in conjunction with substrate specific proteins.

[4] Parts of the Figure are taken from M.G. FINN and K.B. SHARPLESS, in J.D. MORRISON (Ed.) "Asymmetric Catalysis" Vol. 5, p. 247, Academic Press (1985).



Vitamin B12

Figure 3

Fig. 3 presents a gallery of structural formulas which stand for a special group of cofactors, the family of the uroporphinoids. They all are biosynthetically closely related since they are derived from one single precursor (uroporphyrinogen). They all have closely related, yet in detail distinctly different structures, and they all fulfill fundamental biological functions which, however, are of very different nature. There is in the upper left the ubiquitous iron protoporphyrin structure which deals with the biochemistry of molecular oxygen. There are the chlorophylls, the hearts of the photosynthetic apparatus in green plants and photosynthetic bacteria. There is vitamin B_{12}, the structurally most complex member of the family, generated exclusively by microorganisms, but absolutely indispensable in daily microgram quantities for humans. Finally, there is the newcomer in the family, coenzyme F 430, a nickel hydroporphinoid which participates in the conversion of carbon

dioxide and hydrogen to methane in methanogenic bacteria, an exergonic process, on which the energetics of the life of these microorganisms is based. The rich palette of fundamental biological functions as well as of complex molecular structures has kept the uroporphinoid family of cofactors over the last hundred years in the limelight of research in biological chemistry, as well as in pure chemistry, not to ignore the role that vitamin B_{12} has played for crystallography and, conversely, crystallography has played for vitamin B_{12}. In fact, it is crystallography again that very recently has induced in biological chemistry a major step forward towards the understanding of the biological function of the chlorophylls, namely, the structure of the photosynthetic reaction center of the photosynthetic bacteria Rhodopseudomonas viridis by *J. Deisenhofer, R. Huber, H. Michel et al.* [5]. Since this work represents one of the most significant contributions to biological chemistry in recent years, I have chosen to mention it here in some detail.

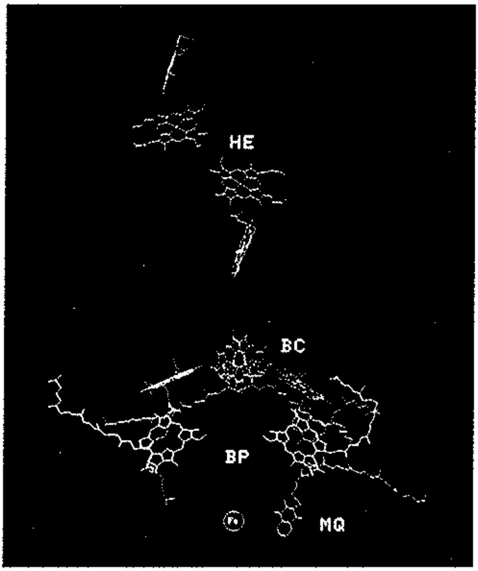


Figure 4 [6]

[5] J. DEISENHOFER, O. EPP, K. MIKI, R. HUBER, and H. MICHEL, J. Mol. Biol., *80*, 385 (1984).

[6] Original slide of Professor R. HUBER (see acknowledgement) and J. DEISENHOFER, O. EPP, K. MIKI, R. HUBER, and H. MICHEL, Nature *318*, 618-623 (1985).

Fig. 4 reproduces an original slide from Professor Huber which he kindly made available to me with the authorization to make use of it in this presentation.

The outstanding feature of this x-ray analysis is that it encompasses an entire aggregate of proteins and cofactors in (presumably) their functional "constellation" implying not less than four protein and ten porphinoid cofactor molecules (4 magnesium-containing bacteriochlorophylls, 2 magnesium-less bacteriopheophytins and 4 iron-containing hemes). The mere fact that this aggregate could be induced to crystallize should be hailed as a major achievement; the information which its x-ray analysis has uncovered provides new and drastic support for the view that in chemistry and biology most if not all truly major steps forward in our understanding of natural phenomena were steps that have expanded our knowledge of structure.

The essence of the functional achievement of the membrane-bound molecular machine is that it allows an electron to jump from a photoactive center after light excitation (within less than a picosecond) to a nearby acceptor from where it moves, instead of returning, forward along a chain of electron-transfer stations in order to eventually contribute to the formation of NADH, the cells' major reductant. Meanwhile, the electron-deficient (positively charged) center of the machine re-accepts an electron from a nearby electron donor and, thereby, becomes photoactive and functional again; the energy generated by the intermediate charge separation is used for the making of ATP, the cells' major energy storage molecule.

The x-ray analysis of the aggregate shows a dimerized pair of bacteriochlorophyll molecules (the "special pair") as the photoactive center; nearby, at a (Mg → Mg) distance of 13 Å and with an interplane angle of 70°, there are two monomeric bacteriochlorophylls, one at each side, both followed at a distance of 11 Å by a bacteriopheophytin molecule. Then, the apparent symmetry ends; only one of the pheophytins is neighboured by an electrophilic naphthoquinone nucleus and then an iron center as next stations of what apparently represents the electron transfer path along which the reducing electron leaves the machine.

On the opposite side, the "special pair" faces at a (Mg → Fe) distance of 21 Å the nearest member of a straight chain of four porphyrin nuclei, the heme parts of a C-type cytochrome protein; it

is *via* this chain of electron-transferring porphyrins that reduction of the oxidized form of the photoactive center takes place.

In the operating photosynthetic unit, the forward step of electron transfer from the primary to the secondary electron acceptor is known to be eight orders of magnitude faster than the (thermodynamically more favourable, but kinetically blocked) electron drop from the primary acceptor back to the electron hole of the oxidized special pair. This is the basis of the notoriously high quantum yield of the primary photosynthetic process and is presumably the focal achievement of the specific supermolecular structure of the photosynthetic reaction center.

We recognize how in bacterial photosynthesis two members of the porphinoid family are functionally collaborating, chlorophylls and hemes, magnesium chlorophylls and metal-free chlorophylls, as well as iron complexes of the protoporphyrin ligand. Let us have a glimpse at the chemistry of the biological function of other members of the family, primarily of the structurally most interesting of all, the cobalt complex co-enzyme B_{12}.

"COENZYME B_{12} FULFILLS ITS BIOCHEMICAL ROLE
BY SERVING AS A FREE RADICAL RESERVOIR
FROM WHICH 5'-DEOXYADENOSYL RADICALS ARE
REVERSIBLY RELEASED; JUST AS OXYHEMOGLOBIN
SERVES AS A RESERVOIR FOR THE STORAGE AND
REVERSIBLE RELEASE OF OXYGEN"

(J. HALPERN, 1985)

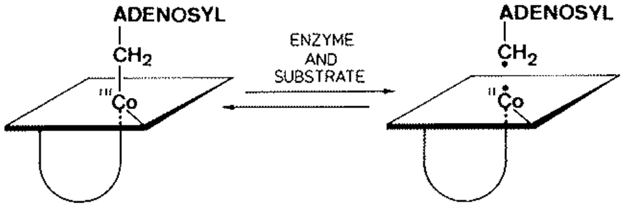


Figure 5

Coenzyme B_{12} differs structurally from vitamin B_{12}; instead of a cyanide group, it has an adenosyl moiety bound by a carbon-cobalt bond on the top side of the molecule. As a result of comprehensive studies in biochemical, organic as well as inorganic laboratories, this metallo-organic bond is now known to be the heart of the

coenzyme; there is (almost) general agreement that in all enzymic reactions where coenzyme B_{12} is participating, this carbon-cobalt bond breaks homolytically to form an adenosyl radical which then induces the structural changes (mostly rearrangements) of the substrate molecules. It was *J. Halpern* [7], an inorganic chemist, who has summarized the essence of the biochemical role of coenzyme B_{12} most articulately (see Fig. 5). Therein, the strength, or better the optimal weakness of the cobalt-carbon bond appears as a critical property of the coenzyme molecule. In Nature's evolving the vitamin B_{12} structure, the aim must have been to modify the ligand structure of porphinoids in such a way that the optimal strength of the critical bond ensued. Such tuning a structural theme to a specific coenzymic task is, to a chemist, a fascinating aspect in Nature's creation of the structures of biocatalysts; to seek a structural and functional understanding of such molecules is a major challenge for contemporary and future research in organic coenzyme chemistry. The porphinoid family presents an exceptional opportunity for such studies; Fig. 6 illustrates the challenge.

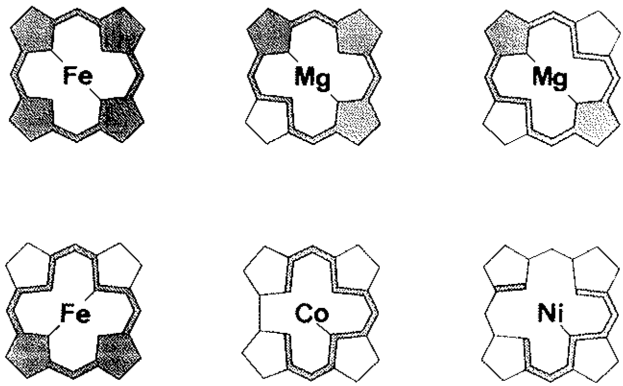


Figure 6

The three major structural parameters of Nature's tuning the porphinoid complexes to their special functions are the nature of the coordination metal ion, the structure and coordination valency of the ligand chromophore and the size of the ligand's central coordination hole. The coordination center is iron in all those cofactors

[7] J. HALPERN, Science, *227*, 869 (1985).

which have either to deal with molecular oxygen, or to perform redox biochemistry (hemes and siroheme). There is magnesium in the chlorophylls, a metal ion with a closed electron shell and a stable valency, therefore photo-inert and suitable to serve as the coordination center when the ligand has to do photochemistry. Finally, there is cobalt and nickel in coenzyme B_{12} and F430 respectively, whose biochemical functions imply metallo-organic reactions. The chromophor structure varies between the extremes of the maximal degree of unsaturation of the ligand in the hemes to the highly reduced state of the chromophore in coenzyme F430. The inconspicuous looking difference in the size of the inner macrocyclic rings in the ligand systems of the coenzymes B_{12} and F430 has recently been studied in synthetic model systems in our laboratory; such a variation of ring size has been found to be a subtle, but marvellously effective tool for tuning the chemical properties of correspondingly coordinated cobalt and nickel ions.

When we are speaking of Nature's varying a structural theme and of tuning a biomolecule's structure to its functional task, then we are speaking of evolution. If we are prone to extrapolate, we find ourselves confronted with a basic enigma in biological chemistry, the puzzle of the origin of biosyntheses. A biologist may perhaps allow himself to take it for granted that biosynthetic pathways simply evolve; not so the chemist, or again more specifically, the synthetic chemist; to him the origin of biosyntheses is an incessant provocation. By this very reason, the question how biosynthetic pathways can and may have originated will eventually become a field of chemical inquiry, one which quite naturally will lead to what is one of the basic challenges to the chemical sciences: the task of delineating the chemical pathways of life's origin. Let me touch upon some aspects of this challenge.

If I happened to be asked about what might be missing in the aforementioned report "Opportunities in Chemistry" I would probably point to the concept of "molecular and supermolecular self-assembly" [8]. Work along such lines, so it seems to me, is an urgent necessity as well as an opportunity of great promise for chemistry, and more specifically, for chemical synthesis.

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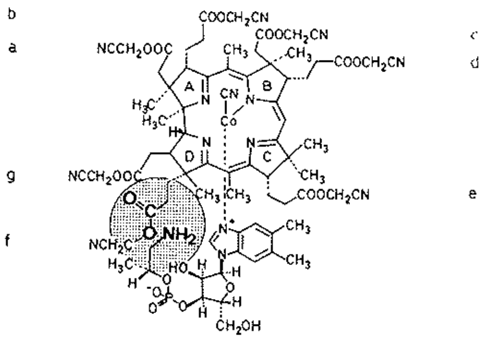
[8] See, however, the PIMENTEL-Report (page 52-53) on "self-organized solids".

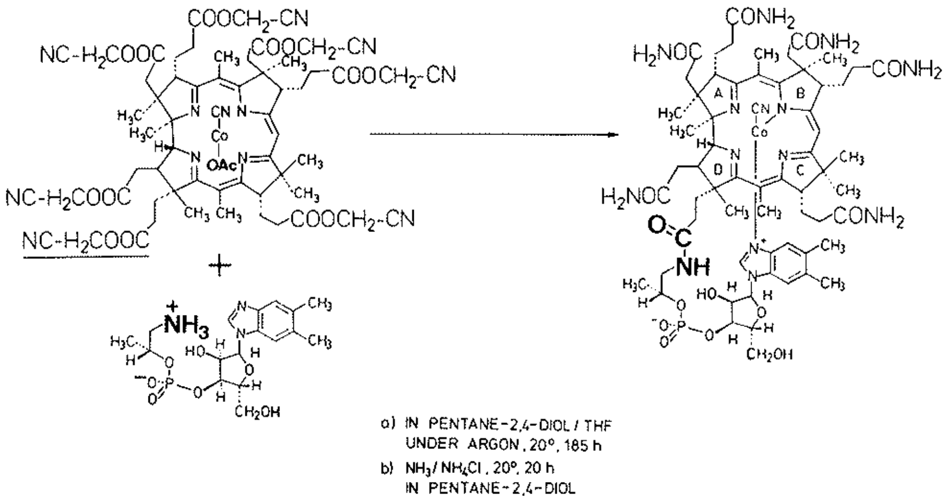
Self-assembly means the formation of molecules or molecular aggregates from their precursors proceeding without external instruction under a given set of conditions. The self-assembling molecule (or molecular aggregate) is supposed to have the code for its formation within its own structure. In a multistep chemical synthesis of a complex molecule, the chemist starts from small molecules and moves forward step by step by constructing one covalent bond after the other; each step requires a great deal of external instruction such as the choice of starting materials, reagents, solvents, catalysts and physical conditions. It is only after the chemist has set the stage for each step that a reaction proceeds; to be sure, however, once the stage has been set, then the reaction product forms by what is, in fact, a self-assembly. A *better* synthesis is one which requires *less* external instruction by proceeding via intermediates which have a *higher* potential for self-assembly. The work on vitamin B_{12} and especially the recently studied synthetic analysis of this vitamin's structure provide illuminating examples of self-assembly; one of the perhaps most revealing is illustrated in Fig. 7 and 8.



THE INTRODUCTION OF THE NUCLEOTIDE INTO HEPTA-CYANOMETHYL-COBYRINATE PROCEEDS VIA PRE-COMPLEXATION AND OCCURS WITH HIGH REGIO-SELECTIVITY (AT LEAST 30 TO 1) INTRAMOLECULARLY AT THE f-CARBOXYL FUNCTION

Figure 7

The vitamin-B_{12} molecule bears a nucleotide loop at the bottom side of the ligand plane, a 19-membered ring spanning from the cobalt center *via* a dimethylbenzimidazole nucleus, a ribose moiety, a phosphate ester group and a hydroxy-propyl-amide link to the carboxyl function of the propionate side chain of ring D. Both the



G Bartels
R.Nussberger

SELECTIVE FORMATION OF VITAMIN B_{12}

Figure 8

Harvard — and the ETH — synthesis of the vitamin followed the concept that this specific carboxyl function is to be introduced and to be kept in a chemically differentiated form, distinguished from all other six peripheral carboxyl functions in order to be able to eventually attach the nucleotide loop unambiguously at the carboxyl function of ring D. Recent experiments, carried out in our laboratory as part of a systematic probing of the vitamin-B_{12} structure for its potential for self-assembly, showed that the chemical differentiation referred to above, a specific example of applying a classical concept of chemical synthesis, is in fact superfluous. Reaction of the nucleotide component with a mildly activated, *but undifferentiated* cobyrinic acid heptaester derivative followed by an ammonolysis step leads exclusively to vitamin B_{12} and *not* to a mixture of isomeric B_{12}-derivatives with nucleotide loops linked to other carboxylic functions. The link between the nucleotide chain and the propionate carboxyl function at ring D proceeds *selectively* without any further external instruction; we might say the code for the *selective assembly* of the nucleotide loop is located in the B_{12}-structure itself. The mechanism of how this remarkable selectivity comes about is fairly well understood, but not to be discussed here.

Self-assembly is of course the domain of biology. The probably most renowned recently uncovered type of *constitutional* self-assembly (clearly reminiscent of the modest B_{12} example described above) is the self-splicing of RNA. *Conformational* self-assembly of the molecular and supramolecular variety is commonplace in biology, and it is clear that the ubiquity of the phenomenon among molecules acting in biological systems is very much at the roots of the sometimes miraculous success which experimenters in molecular biology and biotechnology are used to enjoy.

If chemistry is to move forward in the design and construction of complex molecular and supramolecular structures, it must intensify its interest in the phenomenon of self-assembly and, in choosing and designing targets, make systematic use of the enormous potential of these phenomena for chemical synthesis.

A field of chemistry in which the problems of forming molecules with a minimum of external instruction become dominant is, of course, the field of (potentially) prebiotic chemistry. Here the word "self-assembly" assumes its basic meaning. The field had started with *Stanley Miller's* famous experiments in 1953 on the formation of proteinogenic amino acids under (so-called plausible) prebiotic conditions; and later it reached some further highlights, such as *Juan Oro's* discovery of the formation of adenine from HCN and the discovery of what I would like to call the *Ferris-Orgel* reaction, which is, besides its prebiotic relevance, also an important contribution to the field of organic synthesis. The spontaneous formation of adenine from HCN is the prototype of a potentially prebiological, constitutional self-assembly of a relatively complex biomolecule, the code for adenine's formation from HCN resides in the molecule's structure itself. Similar relationships hold for all four elementary nucleic acid bases; how close their constitutional distance to HCN and some of its derivatives (all of them observable in interstellar space) actually is, can be recognized from Fig. 9, which summarizes what is an extract of perhaps the essence of our present knowledge on these constitutional relationships.

How close is the constitutional distance between coenzymes and α-aminonitriles, the presumed prebiotic precursors of α-amino acids? Is a postulate, according to which not only amino acids and, e.g., nucleic acid bases, but also coenzyme catalysts are of prebiotic origin, chemically justifiable? This question has recently been the subject of extensive experimental studies in our laboratory; Fig. 10

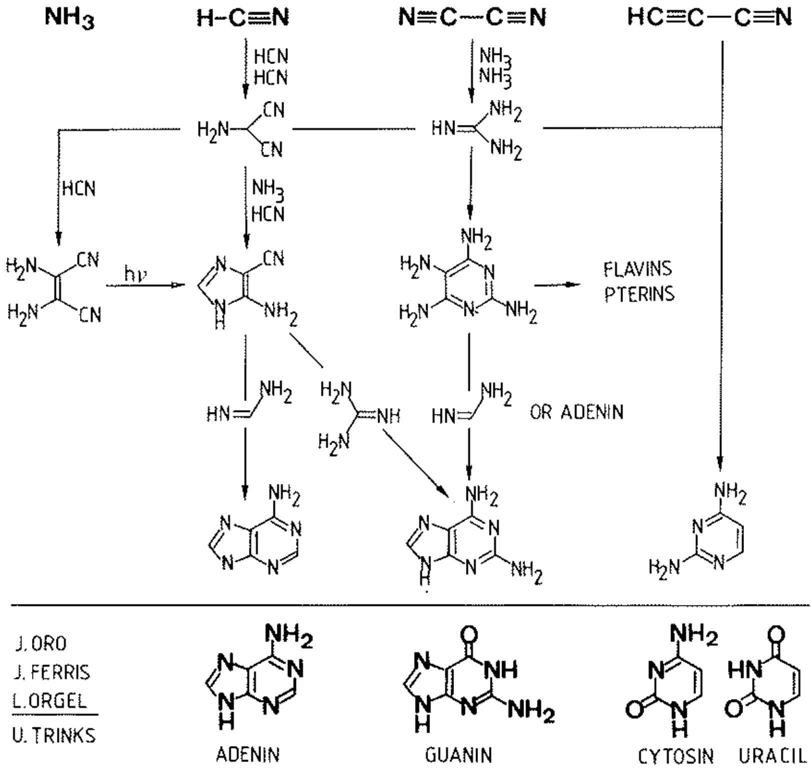


Figure 9

shows some of the results, summarizing experimentally established pathways between α-aminonitriles and uroporphyrinogen octanitrile, the cyanide form of uroporphyrinogen which happens to be the common precursor in the contemporary biosynthesis of all biologically relevant porphinoid cofactors. Such and other experimental results support the contention that at least some of the catalytic coenzyme structures had not, so to say, been invented by biological synthesis but, much more probably, had played the role of environmental vitamins to emerging primitive organisms.

The low molecular weight pieces are only the preliminaries of what is assumed to be the focus of the origin-of-life problem, namely, the constitutional and conformational self-assembly of the pieces to self-reproducing and evolving biomacromolecules. This center of the problem rests on two solid pillars of physico-chemical theory: on one side, *Ilya Prigogine's* theory on dissipative structures

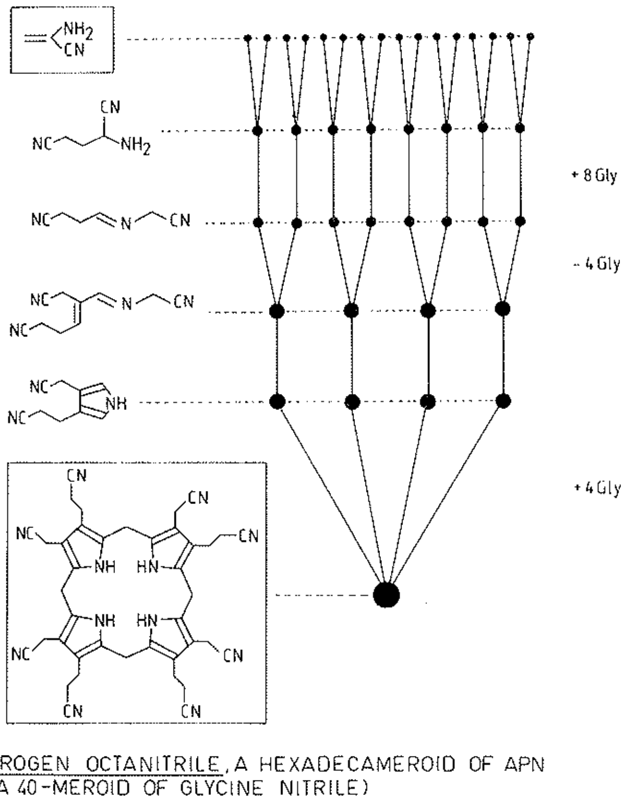


Figure 10

showing that there is indeed nothing wrong thermodynamically with order growing out of chaos in a state of non-equilibrium, and, on the other side, *Manfred Eigen's* theory of molecular evolution which demonstrates that Darwinistic selection is inescapable once a primitive self-reproducing RNA molecule and a coded protein synthesis have come into existence. The task of chemistry now and in the future is to close what I tend to call the "*Prigogine-Eigen gap*", the realm of uncertainty and even sheer ignorance spreading between the two pillars, uncertainty and ignorance, when it comes to define the molecular structures and chemical pathways available to Nature in the critical phase of molecular and supramolecular self-assembly that, perhaps after many "genetic takeovers" (*Cairns-Smith*), eventually led to the symbiosis of informational and func-

tional biopolymers which we are familiar with today. It is true, however, in the minds of most theoreticians as well as practitioners in the field, a sort of optimisms prevails which sees the solution just behind the corner, an optimism referring to the belief that "a first RNA molecule" three billion years ago had somehow managed to assemble itself from mononucleotides and, furthermore, had succeeded to survive and to reproduce in a medium that has been referred to as the "prebiotic soup". *Leslie Orgel's* recent success in demonstrating RNA-template control in experimental polycondensations of activated mononucleotides to RNA chains under the catalytic influence of zinc ions is considered by many to corroborate this "RNA-first optimism".

However, there is serious skepticism growing at the same time. It primarily refers to the usually tacit assumption that pieces like the mononucleotides have self-assembled under prebiotic conditions. *Orgel* himself wrote [9]: "The formation of sugars under plausible conditions and their incorporation into nucleotides have not been achieved. Until this problem is solved or bypassed, it remains a weakness in theories of abiotic nucleic acid synthesis". This quote is still fully valid as shown by a statement made in 1986 by *Robert Shapiro*, a carbohydrate and polynucleotide chemist who has critically analyzed the existing literature evidence on prebiotic ribose synthesis and who, as a result of it, came to the following opinion [10]: "Our present understanding of prebiotic ribose synthesis offers no support for the presumption that significant amounts of oligonucleotides, or even nucleotides, were present on the early earth". This year, the same *Robert Shapiro* published a remarkable book entitled "Origins, A Skeptic's Guide on the Creation of Life on Earth" (Summit Books, N.Y., 1986), a critical but essentially non-polemic, certainly very informative analysis and overview of the chemical aspects of the current paradigm on life's origin.

In my own view, the endeavour of analyzing the potential chemistry of life's origin has hardly been started. It seems to me that what has been done so far, was handicapped by having been dominated by ideas which, with a few exceptions, were hardly anything else than plain back extrapolations of known biochemical

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[9] L. ORGEL, Nature, *216*, 455 (1967).
[10] R. SHAPIRO, Abstracts ISSOL Meeting 1986.

pathways, mostly by arbitrarily depriving them of their enzymes. What the problem needs is a a complementary approach, a sharp *de-novo* synthetic analysis and a comprehensive experimental study of the self-assembly potential of a handful of elementary nitrogenous starting materials and their descendants. It may well turn out that the nearest candidacy for a first self-reproducing macromolecular system is not necessarily our familiar RNA, and there is little doubt that the amino acid code, as we know it today, is not going to be a candidate for the original coding system. The endeavour of exploring this essentially untouched territory of chemistry as well as the design of artificial self-reproducing macromolecular systems are part of the future of organic synthesis, of the future of chemistry.

Acknowledgement. I would like to thank Professor *Robert Huber* (Martinsried-München) for kindly allowing me to make use of one of his slides in this presentation (Fig. 5). I also thank *Fritz Kreppelt* for the photograph of Fig. 1 as well as Drs. *J. Hayes* and *E. Zass* for correcting the English of the manuscript.

QUATRIÈME JOURNÉE

30 octobre 1986

SESSION PLÉNIÈRE

LE PROGRÈS DE LA SCIENCE ET L'AVENIR DE L'HUMANITÉ

La dernière journée de la Session Plénière de l'Académie Pontificale des Sciences a été solennisée par la visite de Sa Sainteté Jean Paul II.

Arrivé en voiture à la Casina Pie IV en fin de matinée, le Saint Père a été accueilli par le Président prof. Carlos Chagas et Il s'est ensuite rendu dans l'Aula Magna où Il a rencontré les Académiciens Pontificaux, s'intéressant au sujet de leurs discussions scientifiques.

Après avoir adressé aux présents ses salutations et ses souhaits, le Saint Père a quitté la Casina Pie IV vers 13 heures, salué par le Président et les responsables de la Chancellerie de l'Académie.

Auparavant les Académiciens Pontificaux: les professeurs Stanley Runcorn, Giampietro Puppi, Stephen Hawking, Giovanni Battista Marini-Bettolo et Johanna Döbereiner étaient intervenus sur le sujet de la Session Plénière.

La discussion scientifique sur le sujet de la Session Plénière s'est conclue en début d'après-midi avec les trois dernières interventions prononcées par les Académiciens Pontificaux: les professeurs Sune Bergström, Govind Kumar Menon et Crodowaldo Pavan.

Stanley RUNCORN

EARTH SCIENCES

Had a geophysicist or geologist been asked to address this Academy 50 years ago at its re-foundation, one can be certain that he

would not have said that the next 50 years would be concerned primarily with the increasing debate about and final universal acceptance of Wegener's theory of continental drift. In fact, geoscientists of that time considered that their programme centred on the increasing use of the tools which the physicists and the chemists were making available to them, for example, x-ray crystallography. They would have said that the work of geologists and geophysicists would be concerned with powerful laboratory techniques applied to geological problems. They might even have said that the great global questions about the Earth had been settled. Firstly, they would have referred to the great debate about the age of the Earth. The controversy between Kelvin, who thought that the Earth was about 20 Myr old from his study of its thermal history, and the biologists and the geologists, who thought the age was much greater, was a famous one. The latter were finally justified by the discovery of radioactivity and its application to the dating of rocks. The age of the Earth is now known to be 4.55 Gyr. Secondly, they would have described the resolution of the great controversy about the nature of the ocean basins. Were they simply subsided continents, or were they different in their chemical composition? That, of course, was a controversy partly solved by the use of chemical analyses of rocks dredged from the ocean floor, which showed that below a thin layer of sediment the ocean floor consisted of the ferro-magnesium silicates, while the continent consisted of the much less dense silicates richer in calcium and aluminium, rafts of "granite" floating on the denser mantle. But it was also settled by observations of gravity over the oceans which showed no difference between the mean gravity field over the continents and oceans, when reduced to the same datum.

Paradoxically, it was this concentration of the geologists' attention on the most modern techniques which caused them to neglect Wegener's theory. As late as 1928, one of the greatest American geologists was asking the rhetorical question; "Can we call geology a science when there exists such difference of opinion on fundamental matters as to make it possible for such a theory as this to run wild"?

It is also worth reminding oneself that no geologist or geophysicist would at that time have looked forward to the possibility of comparing the Earth with the planets. Fig. 1 shows a typical astronomical photograph of the 1930s of Mars and Fig. 2 shows

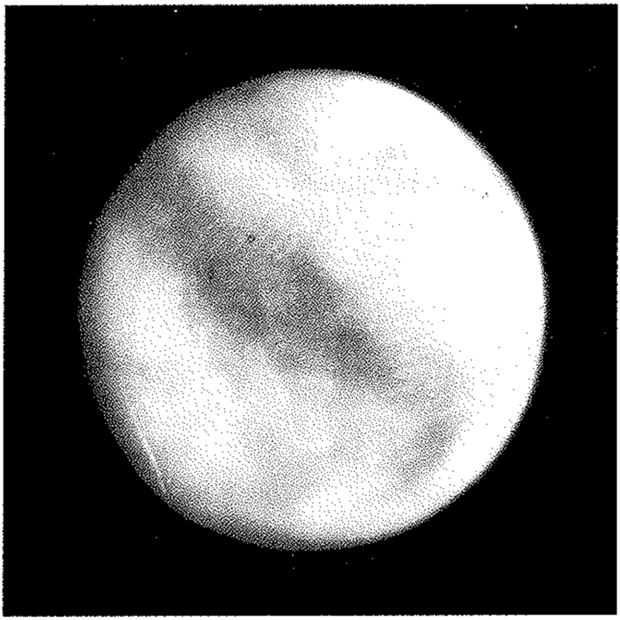


Figure 1 - Ground based telescopic photograph of Mars.

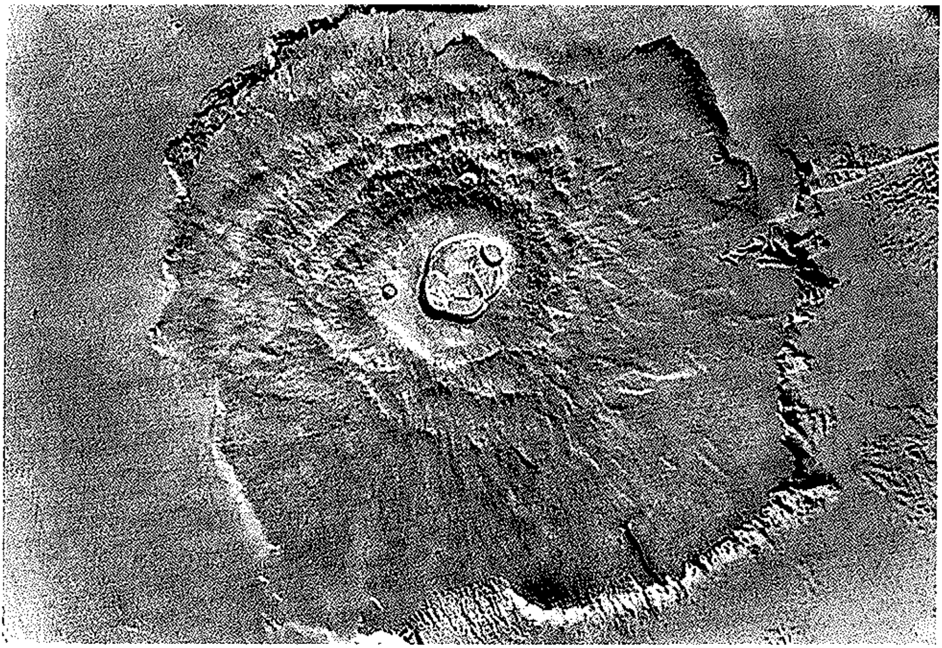


Figure 2 - Voyager photograph of Mons Olympus, Mars (courtesy NASA).

what space missions show us of the surface: the biggest volcano in the solar system. Fig. 3 was the best astronomical photograph of the Galilean satellite Io, with slightly different development times. Fig. 4 shows what we know about Io today. The great sulphur volcano is one of its fascinating features. Both these examples point to the fundamental importance of heat sources on the evolution of planetary surfaces: in many cases little is yet known about them. Fig. 5

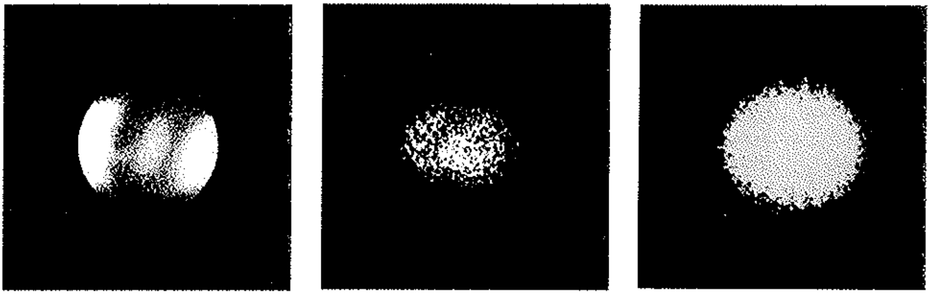


Figure 3 - Ground based telescopic protographs of inner Galilean satellite of Jupiter, Io.

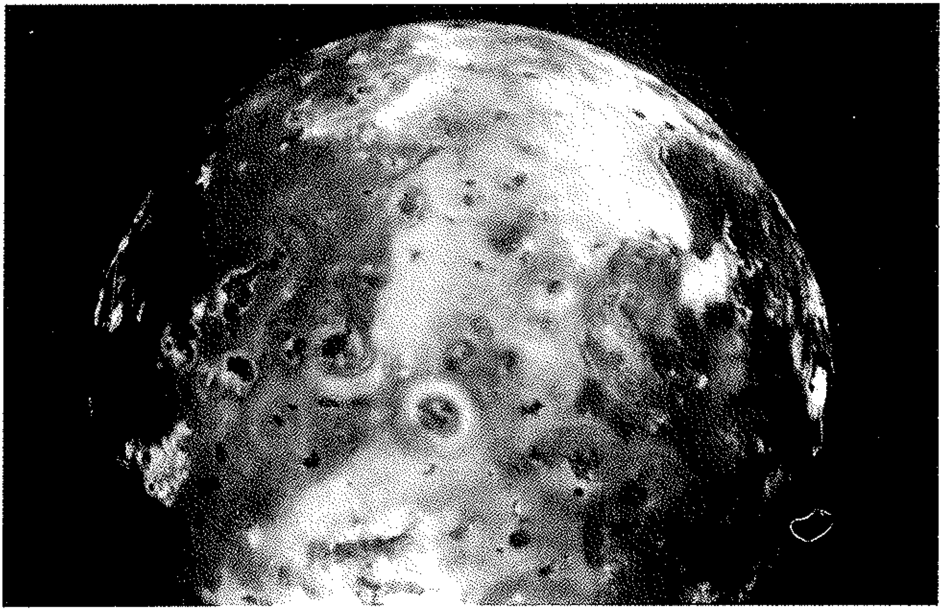


Figure 4 - Voyager photograph of Io (courtesy NASA).

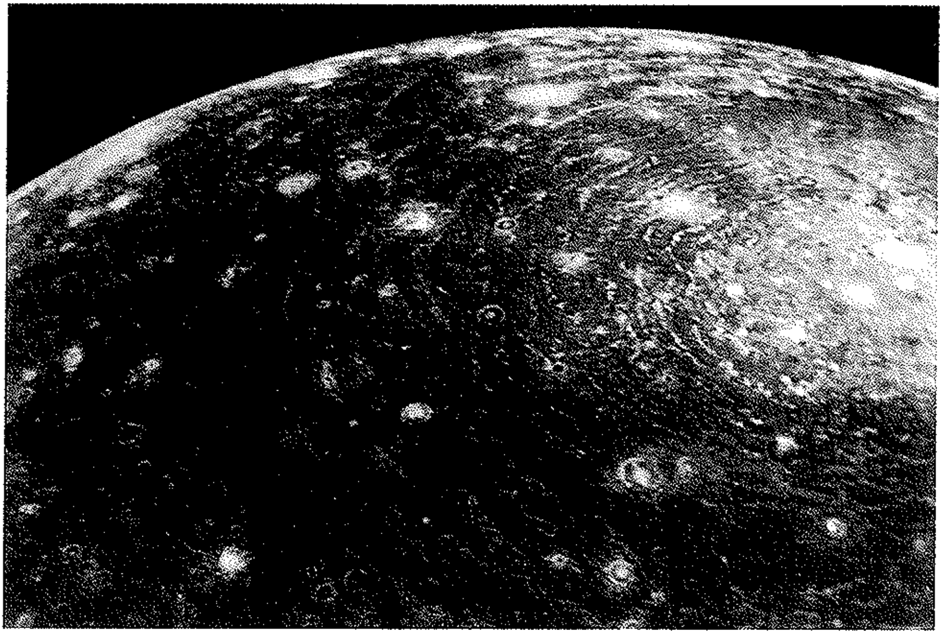


Figure 5 - Voyager photograph of outermost Galilean satellite of Jupiter, Callisto (Courtesy NASA).

shows that the Galilean satellite Callisto, which demonstrates the very great importance of impact phenomena in the solar system: the great impact on Callisto with its concentric rings, is one of the most interesting. It would have been inconceivable to the geologists of 50 years ago that impact phenomena played any important role in the solar system and particularly they would have rejected the idea that it played any role whatever in the history of the Earth. Yet hundreds of terrestrial impact craters have been identified and some impacts are thought to have decisively altered the course of evolution.

Wegener's theory (Fig. 6) of drift was based upon a comparison of the geological and palaeontological affinities of continents now separated by thousands of kilometres of ocean but once, according to his theory, in contact. One of his most interesting arguments was that from palaeoclimatology; Fig. 7 shows the evidence of the great Permo-Carboniferous glaciation in Australia. It also occurred in Africa, India and South America, as far as could be determined contemporaneously, 250 Myr ago. Recent glaciations occurred in high latitude in N. America and N. Europe in Quaternary times and had

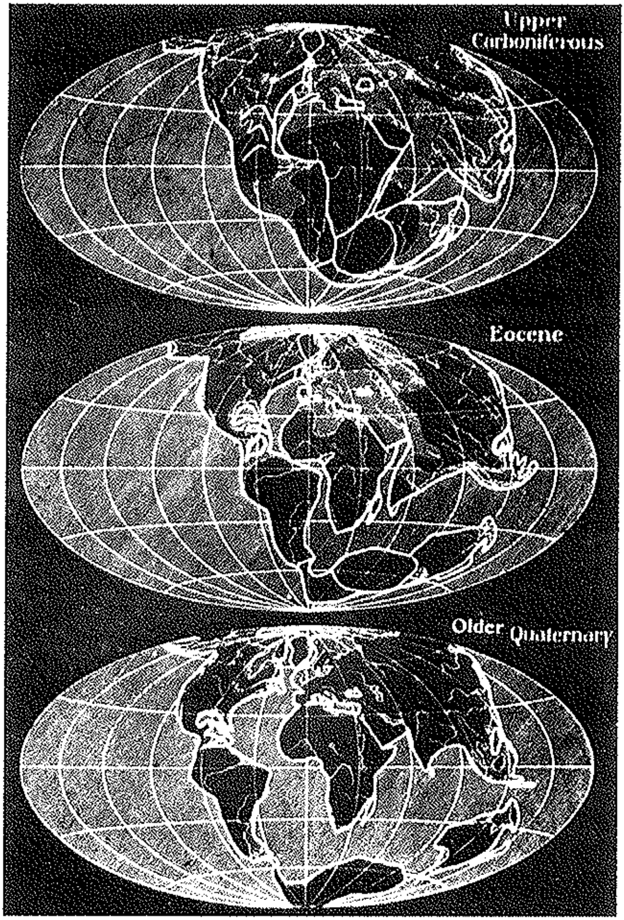


Figure 6 - Wegener's reconstruction of the continents. (from *Origin of continents and oceans*, A. Wegener).

been much studied. Wegener's argument was that it was very difficult to understand these very widespread glaciations of India and the southern continents unless these continents had been close together and near the pole in an original continent called Gondwanaland in Permo-Carboniferous times. Wegener's other numerous lines of argument were qualitative. I once summarized the position by saying that each of his lines of evidence could be explained by some other process, but taken as a whole his case was more convincing than was allowed by most geologists.

Figure 7 - Perno-Carboniferous glaciation of Australia: (a) glaciated pavement near Adelaide, Australia.

(b) tillite, Hunter River valley, New South Wales.

The advance of science takes place very often by the replacement of a qualitative argument by a quantitative one but not always by a direct route. 50 years or even 30 years ago, if geophysicists had been asked what particular field of geophysics ought to be developed in order to settle this controversy about continental drift, they would have said seismology or gravity, but they certainly would not have said geomagnetism. Fig. 8 shows the beginnings of our understanding of the Earth's magnetic field. The book by William Gilbert, from which this is taken, is perhaps the earliest treatise on experimental physics in which he demonstrates the properties of magnets. In the diagram he shows an experiment in which, near a sphere of lodestone magnetized along an axis, were suspended magnetized needles, which we would call dip needles. He demonstrated that the angle of magnetic dip, the angle the field direction makes with the surface, increases with latitude, as was already known on the Earth. Thus he concluded that the directional property of the compass needle was evidence of a global magnetic field. The present field is different from such a simple geocentric dipole field aligned along the Earth's axis of rotation, but it changes. When the mean field is determined over some thousands of years, it

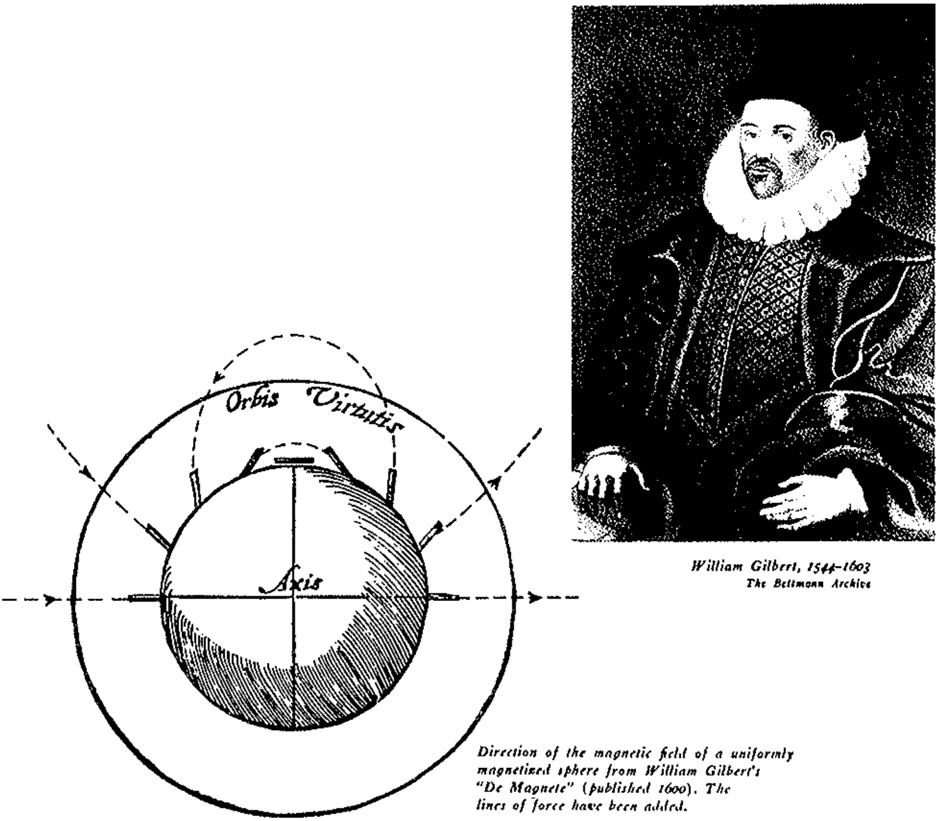


Figure 8 - Gilbert's terella experiment in "de Magnete" 1600.

is exactly a dipole along the axis of rotation, the angle of magnetic dip I depending on latitude λ by the equation: $\tan I = 2 \tan \lambda$, — it was an early discovery of paleomagnetism. The study of the mean Earth's field in the geological past turned out to be decisive in the controversy about continental drift.

The subject of palaeomagnetism has developed gradually over a hundred years with participation from scientists of many countries, e.g., Chevallier, Mercanton, Königsberger and more recently Nagata and Thellier. As rocks form, igneous rocks during cooling and sedimentary rocks in settling and consolidating, the iron oxide grains become magnetized along the direction of the Earth's magnetic field at that time. This magnetization is often preserved without its direction altering for hundreds or even thousands of millions of

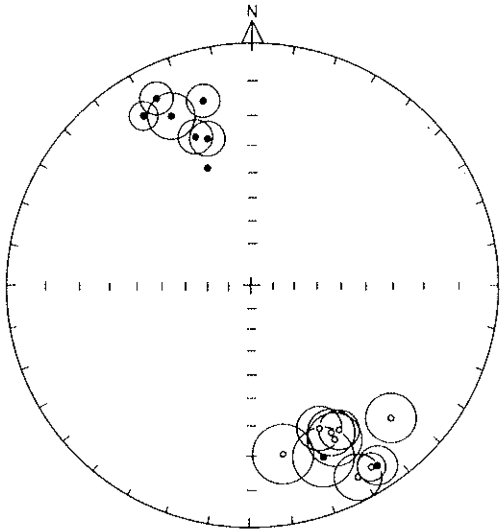


Figure 9 - Directions of magnetization of the Chugwater formation of Triassic age in Wyoming.
"●" positive angle of magnetic inclination or dip; "○" negative angle of magnetic inclination or dip circles are 95% circles of confidence.

years. Thus palaeomagnetism has enabled the record of the Earth's magnetic field to be studied over a large part of Earth history: ten million times the historical record. The basic discoveries of palaeomagnetism are shown by Fig. 9, the stereographic projection showing the directions of magnetization of the Chugwater formation in Wyoming, Triassic in age about 200 Myr old: the full dots are points on the lower hemisphere of this projection and the open circles on the upper hemisphere. Thus a north-seeking magnetic needle during this time would have sometimes pointed north-west and sometimes south-east with a low angle of magnetic dip. This arrangement of directions of magnetization at 180 degrees is proof that the Earth's magnetic field, while being a dipole along the axis of rotation, from time to time reverses its polarity. The most important feature of these palaeomagnetic results, from the point of view of continental drift, is that the angle of magnetic inclination or dip, 10-20°, is much smaller than would be found today in Wyoming and the magnetic meridian makes an angle to the present geographical meridian. This is an example of the quantitative evidence of palaeomagnetism that the continent had moved relative to the pole.

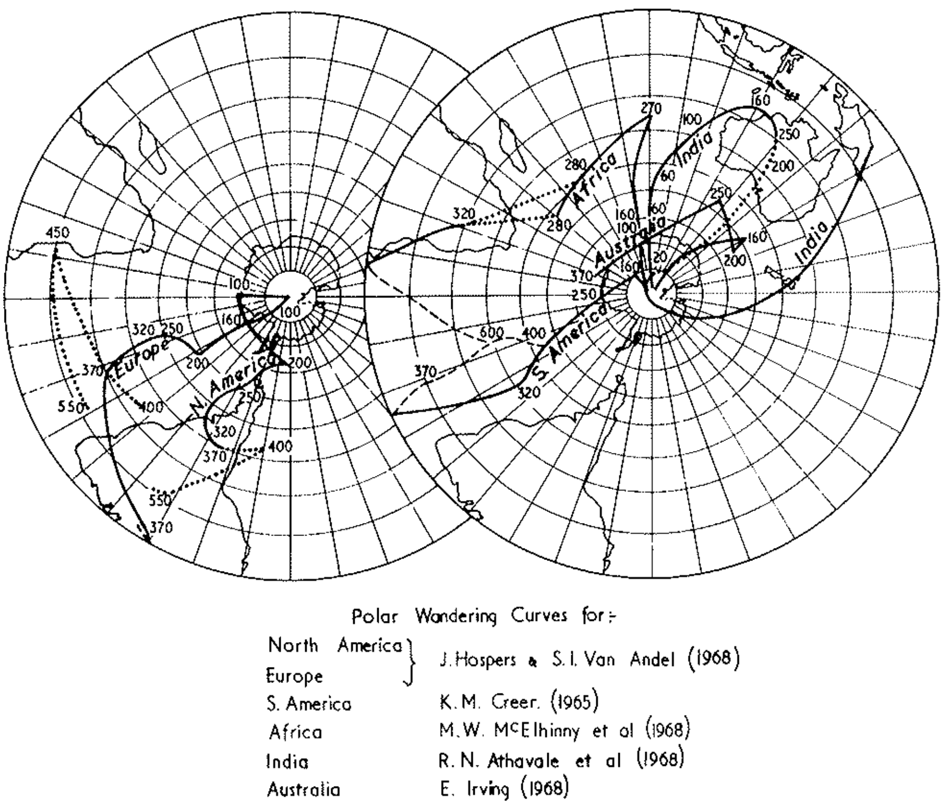
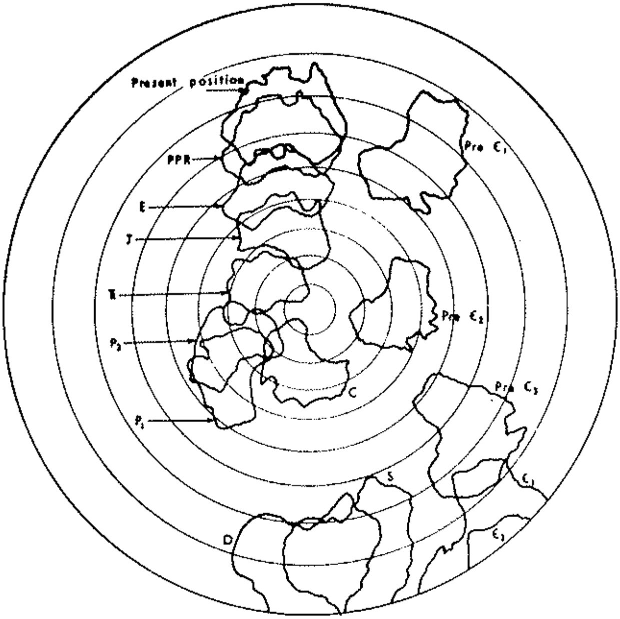


Figure 10 - Polar wandering curves for Europe, N. America, S. America, India and Australia (ages in millions of years); dotted lines are uncertain parts of paths.

In the early development of palaeomagnetism it became clear that the pole had moved gradually throughout geological time as seen from America and from Europe. Had the polar wandering paths, as we called them, coincided for all continents, we would have supposed that the Earth had gradually reorientated itself with respect to its axis of rotation. But because the polar wandering paths from different continents are separated and only converge on the present pole during the Tertiary — it became necessary to appeal to the theory of continental drift to explain the data. Fig. 10 shows that the paths for Europe, North America, South America, India and Australia are all different. Fig. 11 shows that another representation of the palaeomagnetic data is to place a continent in its original position on the globe. It shows the successive positions of Australia



T	Tertiary	D	Devonian
K	Cretaceous	S	Silurian
J	Jurassic	O	Ordovician
Tr	Triassic	€	Cambrian
P	Permian	Pre-€	Pre-Cambrian
C	Carboniferous		

Figure 11 - Positions of Australia throughout geological time from palaeomagnetic surveys by E. Irving and R. Green.

over about the last thousand million years relative to the pole from E. Irving & Green's data. In the Permian and Carboniferous, Australia was in a position, determined from palaeomagnetism, where extensive sea level glaciations would have been entirely understandable. One of Wegener's arguments was the good fit of the Americas to Europe and Africa, and Fig. 12 shows how good the fit is when the edge of the continental plate, taken to be the line of greatest slope of the continental shelf, is used rather than the variable coastlines. Fig. 13 is the less familiar fit of Europe and N. America. Curiously enough Wegener's argument on the good fit was treated with great scepticism until it was established in 1952 by Professor W. Carey fitting continental outlines on a globe. This was verified by Bullard and colleagues 20 years later, on a computer. Curiously, the computer demonstration was accepted by geoscien-

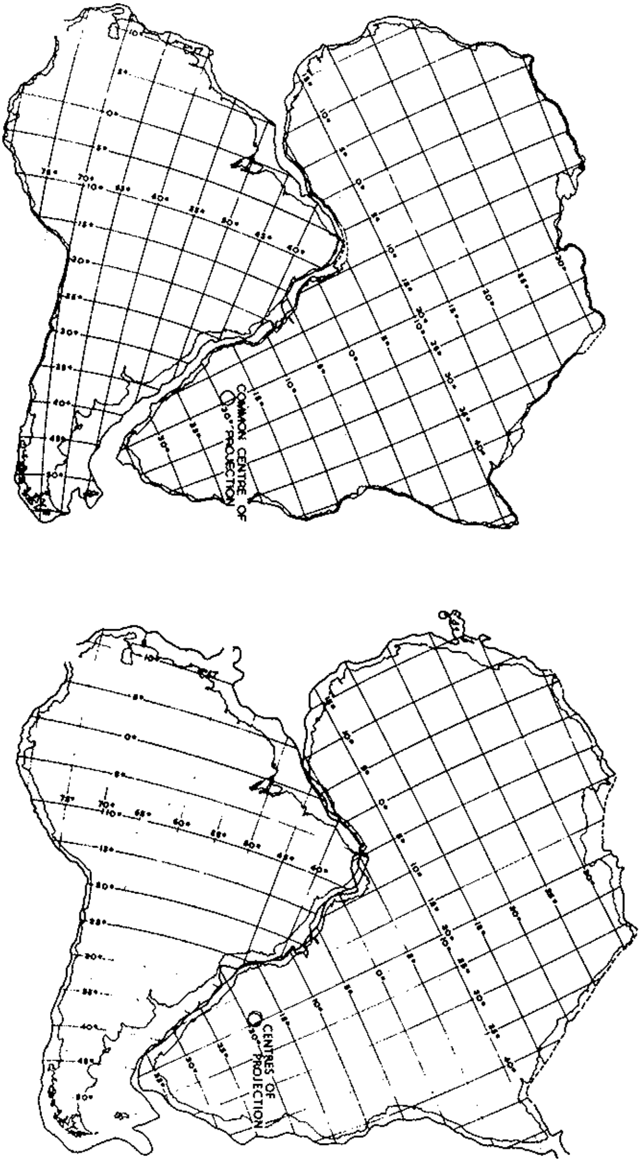


Figure 12 - Fit of S. America and Africa at continental shelf (W.S. Carey).

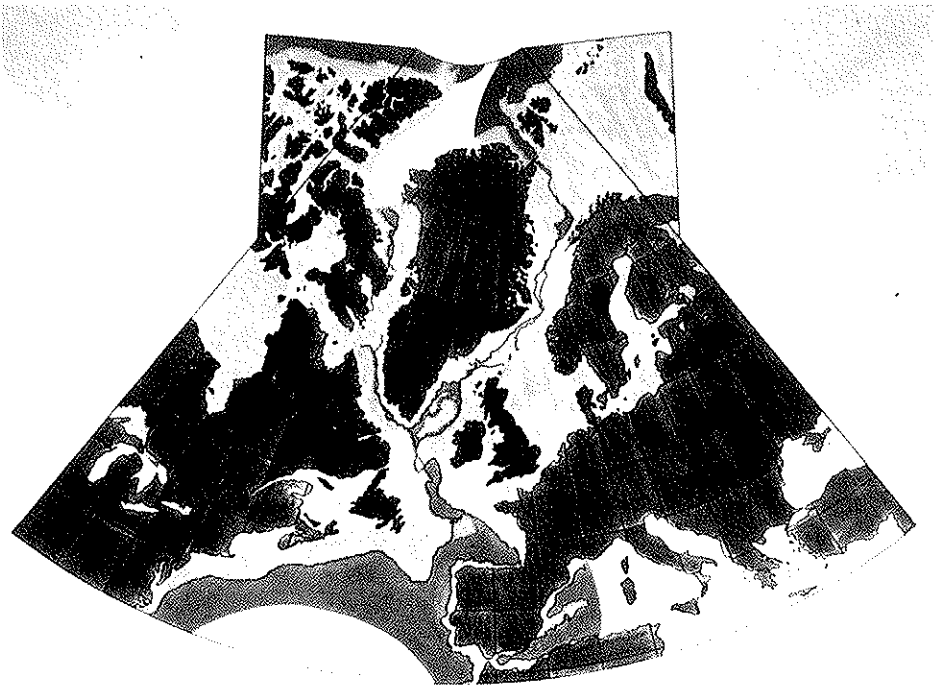


Figure 13 - Fit of N. America, Greenland and Europe at continental shelf edges. E.C. Bullard, Everett J.E. & Smith A.G., Phil. Trans. Roy. Soc. 1965.

tists whereas Carey's rather simpler demonstration seems not to have convinced!

The question of what processes took place in the ocean basins when the continents moved apart finally led to the theory of seafloor spreading; first by A. Holmes, then in a more complete form by H.H. Hess. Finally the two complementary theories of continental drift and seafloor spreading were integrated into plate tectonics. The plates are the outer layer of the Earth which have finite strength even over geological time. Below the plates in the mantle solid state creep makes flow possible. The plates, between 35 and 50 km thick, behave, even over geological times, as classical elastic solids because the temperature is below the critical temperature for creep. The distribution of shallow earthquakes delineates the ridges where tension is extending the ocean floor, for instance in the mid-Atlantic ridge as the Americas move westward relative to Europe and Africa. Through the rifts, e.g., in the centre of the mid-Atlantic ridge, lava from partial melting of the mantle creates

new ocean floor. The deep focus earthquakes occur beneath the Andes-Peru trench, the Japan trench, the Tonga trench and the Java trench, where the plate edge, cold and therefore rather rigid, is being pushed down into the mantle. Earthquakes occur down to 700 kilometres in these regions as the plate edges store energy which is released on rupture.

Scientific method requires us to test theories of the Earth by making comparisons with the planets. The Moon is of particular interest in the theory of plate tectonics because a moment's look at the Moon shows that there have been no such great horizontal displacements of the lunar lithosphere since the earliest impact basins that can be mapped, at least 4 Gyr ago.

It is a fascinating and important feature of this subject that, not only must new techniques be used to improve knowledge but the importance of old data must be recognized. The laws of rotation of the Moon were discovered by Cassini in 1700: from them Laplace deduced that the Earth must be exerting a torque on the Moon to produce the precession of its axis. This torque implied the existence of bulges on the Moon (or a 2nd harmonic in its figure). Laplace showed early last century that these "bulges" were twenty times greater than if the Moon were in hydrostatic equilibrium. Until very recently, it was taken for granted that Laplace's explanation was corrct; that the Moon had been distorted in its early history and had simply retained this distortion because of the finite strength of its solid interior. However, it is inconceivable that continental drift could be explained without invoking solid state creep, which, depending on the Boltzmann factor, is exponentially dependent on temperature. This explains why the rigid plates of the Earth can resist stress differences, e.g., to maintain high topography, whereas in the mantle below the plates the temperature has risen to that critical value at which the smallest stress differences produce flow.

The interpretation that I gave in 1962, which has now come to be rather generally accepted, is that these non-hydrostatic bulges on the Moon are not due to rigidity but to hydrodynamic motions in the interior. Thermal convection is a fundamental process in the planets, as D.C. Tozer has shown, in order to transport heat within them: conduction is a very ineffective process on the planetary scale. Convection distorts the Moon: the rising currents pushing the lithosphere outwards. A second harmonic pattern, i.e., one with two cells, is required to explain the 2nd harmonic in the gravitational

field which is inferred from Cassini's laws. As convection cells tend to be as wide as they are deep, I suggested that such a convection pattern would have developed only if there is a small iron core in the Moon. Hitherto unsuspected, the core is now required to explain why, although the Moon today has no magnetic field, it had one in its early history. The Apollo rocks returned to the Earth possess remnant magnetization and there is no explanation of planetary magnetic fields except that they are generated by convection in liquid conductors by a process analogous to a dynamo. In the terrestrial planets this occurs in their iron cores and in the major planets in their metallic hydrogen cores. The question of the existence of a lunar core illustrates a difficulty which does not arise in a laboratory science: the difficulty of settling an issue with finality. The lunar core, when its existence was first postulated, was in conflict with the then attractive theory that the Moon was cold and dead and had never differentiated, so that the iron could never have sunk to the centre. Moreover the moment of inertia of the Moon, divided by the product of its mass and radius squared, a very useful parameter called the moment of inertia factor, appeared then to exclude a core. Indeed its value in 1962 corresponded to an empty shell! A sphere of uniform density has a moment of inertia factor of 0.4 and in the 1970s, when satellites were placed around the Moon and tracked, this value was found: indicating that there was no core. However, if one has a good idea in geophysics, it is often worth waiting for the data to change! Today the value of this all-important factor is 0.3905, which is consistent with a core of radius 500 km. I discuss the Moon because it shows one way in which we are trying now to understand the flow patterns, which in the Earth's interior are the fundamental cause of continental drift. At present we are still in a very early stage in understanding the forces which are moving the plates and there is a rather vigorous debate going on as to whether the convection forms a single layer of cells between the core, which has a radius of 3,500 kms, and the base of the lithosphere, or whether there are two layers of cells separated by the known phase change which occurs at 650 km depth. From the Moon we have learned that the determination of the non-hydrostatic terms in the gravitational field are all-important in delineating the convection pattern. So it is today recognized that the convection pattern in the Earth's mantle will be discovered by understanding the geoid. Until satellites were placed in orbit around

the Earth, there was very little evidence that the Earth, like the Moon, has a non-hydrostatic figure over long wavelengths.

Recently, geophysicists have discovered a new method to probe the density variations in the Earth's mantle. It is a new technique called seismic tomography. It makes use of the very small differences in travel times of earthquake waves from epicentre to observatories. The anomalies of velocity of seismic waves through the mantle are interpreted as the variations of density. Fig. 14 shows sections through the Earth, the red areas being the hotter material with smaller seismic velocities, the blue being the cold material with higher seismic velocities. Perhaps this work with the geoid will

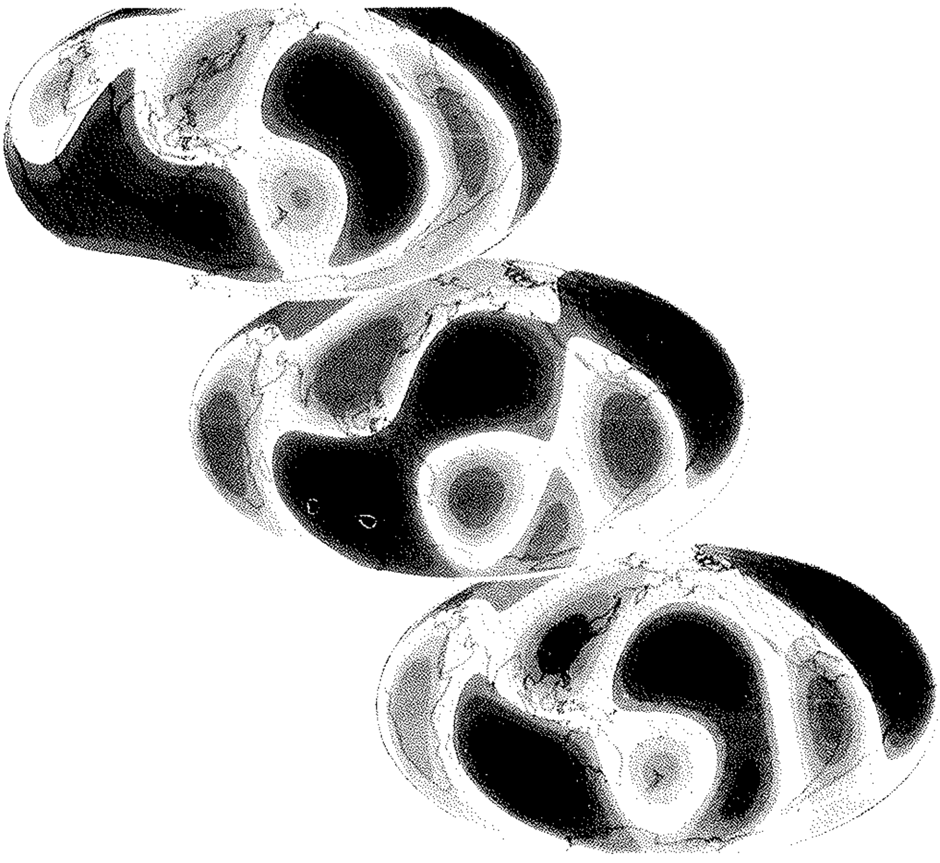


Figure 14 - Seismic tomography — one out of many maps of the mantle anomalies. A.M. Dziewonski and J.H. Woodhouse, Nature, 325, 1987.

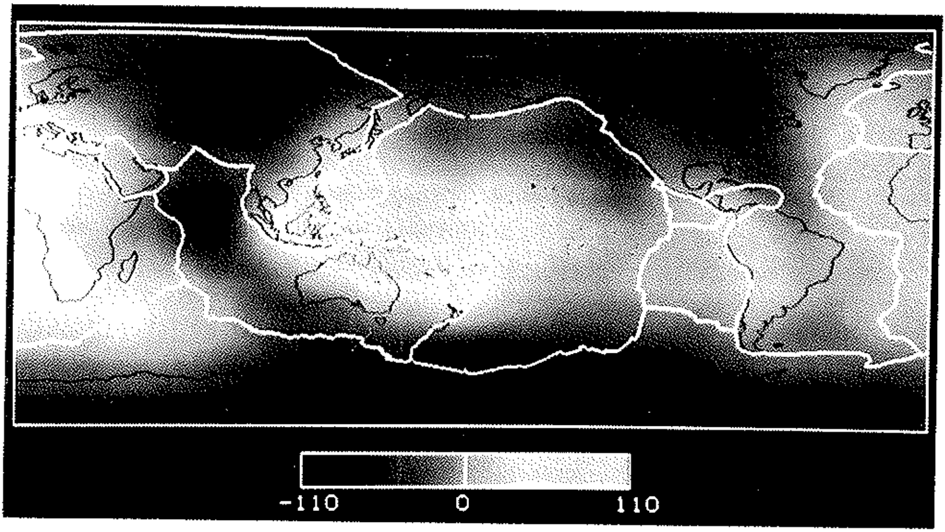


Figure 15 - The geoid — many geoids have been published: this is one.

determine the three-dimensional pattern of convection in the mantle. Fig. 15 shows the gravitational field, the highs and lows of the geoid, low over the Indian Ocean, the Caribbean, high over the W. Pacific and N. Atlantic, which imply variations in density deep in the mantle over horizontal surfaces. Thus the seismic and gravity data together reveal the variations of density on horizontal surfaces which provide the buoyancy forces which must be driving convection. Once the convection pattern is determined its relation to the plate motion can be studied and hopefully the problem of the forces which move the plates — the most profound in geoscience — can be solved.

Recently there has been a new development in the study of the Earth's gravitational field by measuring the height of the ocean surface by a radar altimeter from a satellite in orbit. It enables geoid variations with smaller horizontal scale to be mapped than those determined by satellite tracking. The maps show negative anomalies over the trenches due to the absence of mass in the ocean trenches. Small positive anomalies appear over the ocean ridges. As it is in isostatic equilibrium, the ridge has additional mass closer to the ocean surface compensated by hotter, less dense material below — a potential double layer. This is one of the most elegant new techniques.

Comparisons with the other planets are important. The Pioneer Venus data on the gravity field of Venus shows a good correlation between high gravity and high topography, which are rather analogous to our continents, whereas in the Earth there is only poor correlation between the surface features and the highs and lows of gravity. I think that it means that convection in Venus has gradually brought these floating continents to positions above the descending convection currents. The Soviet Venera project of radar studies of the surface of Venus has shown up very interesting tectonic features but the interpretation has only just begun. I conjecture that it reveals a phenomenon similar to continental drift, the response of the lithospere of Venus, very different from the Earth's, to the stresses set up by convection.

Come now to the dynamo theory of the generation of planetary magnetic fields. The observations which led to it were surveys of the Earth's magnetic field over the last four centuries, which revealed its complex secular variation. Fig. 16 shows the contours of equal difference between the angle of magnetic inclination or dip, calculated on the axial dipole field model, or Gilbert's uniformly magnetized sphere model, and the observed value of the angle of dip. The main feature is that the pattern is rather similar for the two epochs a century apart, but the lines of zero differences and the clusters of oval contours show a westward displacement of about 20°. Just as weather maps reflect the hydrodynamics of the atmosphere, so the geomagnetic secular variation charts tell us about the magneto-hydrodynamics of the core, where convection, perhaps ten million times faster than the convection in the mantle, generates a field by the dynamo process as the core, being iron, is a conductor.

The more detailed study of the secular variation possible from more complete modern surveys is leading to much more detailed understanding of the motions in the core. From the older maps revealing the westward drift, it can be inferred, by Alfven's principle, that the core is rotating more slowly than the mantle, i.e., to the west. The discoveries of the relative motion of the core and mantle, and of evidence that it varies, have solved a problem which baffled the astronomers since last century. It was known from astronomical observations of the motion of the Moon, Sun, Venus and Mercury that the Earth's rotation changes irregularly with a time scale of decades. In Fig. 17 the dotted line shows how this change has occurred since 1840. The full line shows how the westward drift of

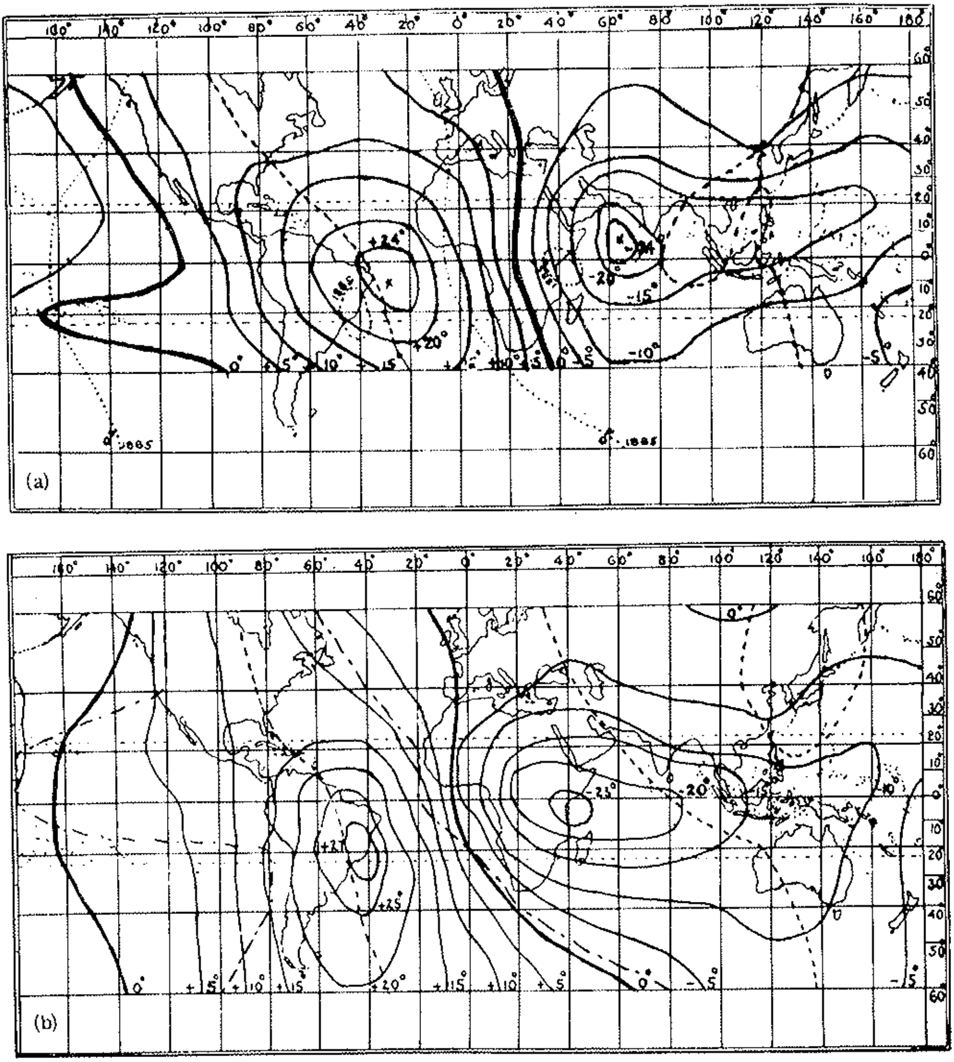


Figure 16 - Bauer's geomagnetic maps of the 18th and 19th centuries. Isapoclinic is a line of equal difference between the observed angle of magnetic inclination or dip and the dipole value.

the geomagnetic field and therefore the core has changed its relative rotation with respect to the mantle. The agency is electromagnetic coupling because the lower silicate mantle being at high temperature is a semiconductor. This record in the changes of the rotation of the Earth, which is another important proof of motions in the core, can

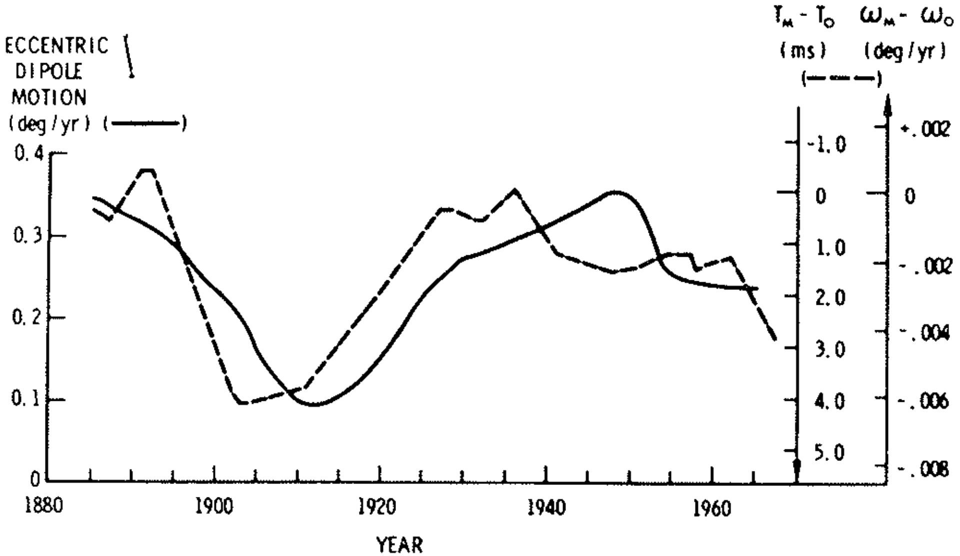


Figure 17 - Correlation between the irregular changes in the length of the day and the westward drift.

be extended back in time some thousands of years by the use of ancient astronomical observations. Fig. 18 shows a Babylonian tablet from the British Museum which describes an eclipse seen in Babylon. F.R. Stephenson from such data has demonstrated the steady deceleration of the Earth's rotation by lunar and solar tidal friction. This transfers the loss in spin angular momentum to the Moon and Earth's orbit so is different from the interchange of angular momentum between the core and mantle which I have just discussed. But Stephenson's data, Fig. 19, also shows a non-tidal long term change in the Earth's rotation rate which perhaps is due to a change in the Earth's moment of inertia over the last few thousand years. The interesting question is whether one can extend this data on the rotation of the Earth back to much earlier times. It seems possible because supposed daily, monthly and yearly growth increments in fossils have been identified. In corals, molluscs and stromatolites these growth lines and groups of lines show the influence of these astronomical cycles on the environment which affects the metabolism of marine life. Thus data on the length of the day and the length of the month in remote geological times has been

Figure 18 - Babylonian tablet describing the eclipse seen in Babylon in 136 BC.

determined, but the data is so far very fragmentary. This is a field which is only very slowly developing and it certainly needs to attract the interest of biologists because the mechanism by which these great astronomical cycles control the growth of marine life is not at all understood.

I end by going back to the Moon, especially the remnant magnetism discovered in the samples returned by the Apollo and Soviet Luna missions. The Moon's geological formations have also been found to be magnetized by magnetometer surveys from the sub-satellites launched in the Apollo 15 and 16 missions and by the astronauts' surveys. From the very small magnetic anomalies of the sub-satellites 100 km above the Moon, Coleman, Russell and Hood have calculated the directions of magnetization of different strata. From these I have calculated pole positions and shown that they group into 3 pairs of opposed poles defining 3 axes different from

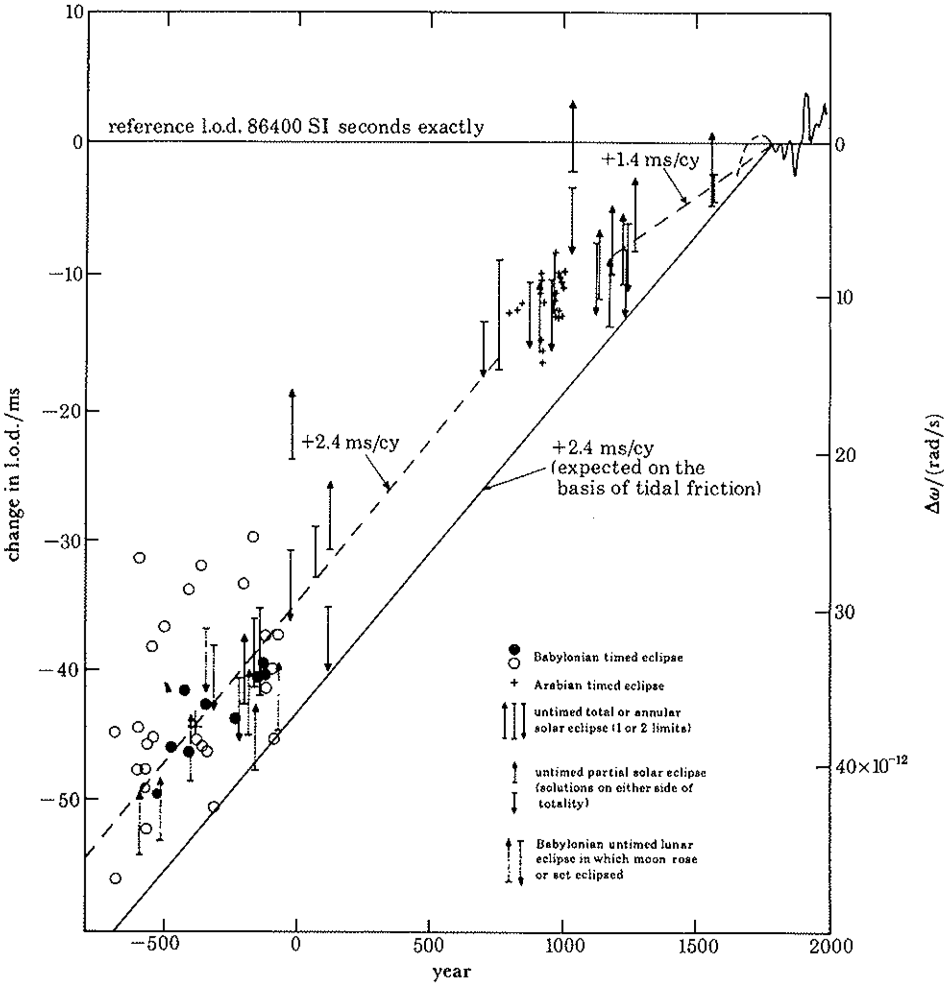


Figure 19 - F.R. Stephenson's use of ancient astronomical records to determine the change in the Earth's rotation rate.

the present axis of rotation. These 3 axes are dated from study of the geology of the magnetized regions as 4.2 Gyr, 4.0 Gyr and 3.85 Gyr, the last being the date of the impact which produced the Imbrian basin. The corresponding palaeoequators lie close to the multi-ring basin of corresponding age as shown in Fig. 20. From this association I have concluded that the Moon was reoriented at least 3 times relative to its axis of rotation from the disturbance to its

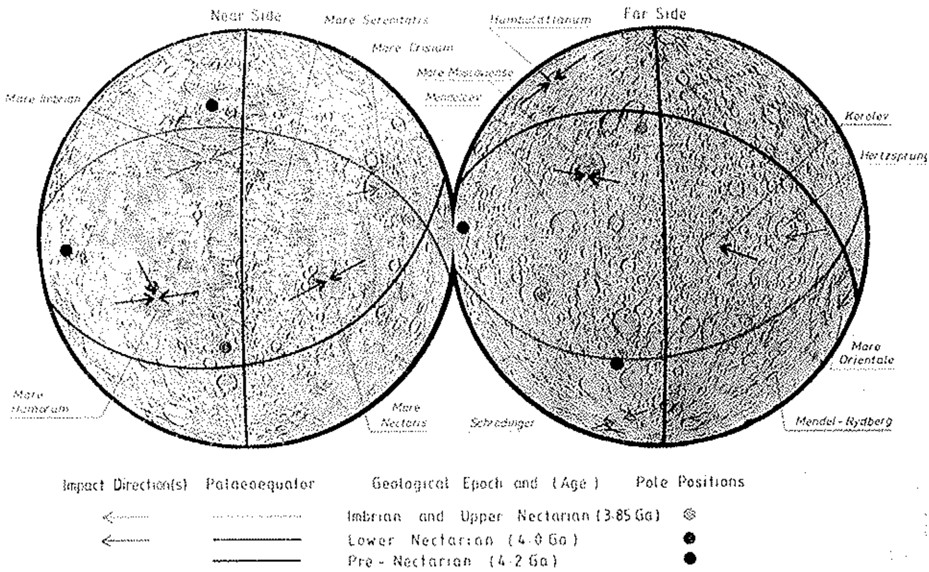


Figure 20 - Poles and palaeoequators on the Moon (calculated from analyses by P.J. Coleman, C.T. Russell & L.L. Hood of the Apollo 15 & 16 magnetometer survey.

moment of inertia produced by the excavation of the multi-ring basins. Because the impacts occurred near the equator of their times I have concluded that the Moon had a primeval satellite system, the orbits decaying by tidal friction so that each satellite breaks up just within the Roche limit, the resulting bodies cause a number of impacts along the palaeoequators. Thus from lunar palaeomagnetism evidence of other bodies in the primeval Earth-Moon system has been obtained and this may prove to be diagnostic evidence concerning the origin of the Earth-Moon system and indeed the origin of the solar system.

Giampietro Puppi

SPACE SCIENCE

My talk is on space science but I found it difficult not to consider technology too, science being to a large extent dependent on progress in technology, and on the other hand technology being fostered to a great extent by the demands of science.

One may say that this has always been so but in the past the liaison has not always been so tight as it is now. And not only in space but in almost all the human activities.

An example: The property of curved reflecting surfaces to concentrate solar light was known to Archimedes, the property of image magnification by a lens probably known since the XIII century, but the application of these properties to build microscopes and telescopes had to wait until the XVII century.

In recent times recognition of a new principle and the development of applications related to that principle, normally need a short time.

As an example one may quote some of the more recent discoveries like the principle of Maser and Laser or the properties of semiconductors. The step towards applications has been in this as in other fields almost immediate. In space science the needs of the scientists had for some time to wait for the improvement of technology and this can be easily understood if we think of the maturity already achieved in the experimentation in a laboratory with a technology at its beginning.

I remember the problem, for satellites in low earth orbit, of accumulating data and transmitting them to selected receiving stations on earth: the bottle-neck was the low or not reliable performance of tape recorders. I remember the difficult problem of passing from spinning satellites with contra-rotating antennas to a three axis stabilisation.

And I remember a number of cases, apparently regulated by the

law of chance, of satellites which lasted more than the expected time and satellites which became silent very soon.

Not speaking of partial or complete failures, which are always with us. But if you compare the state of the art today with that of 20 years ago you can perceive the great development, in particular in the importance and complexity of the results obtained.

Among these results I will discuss only a few of them following my personal interest and considering their relevance for the benefit of mankind.

— I will be very brief on the knowledge acquired in the general field of astronomy and on the exploration of the solar system, where the most spectacular goals have been achieved, because they are well known.

• In astronomy I believe that the major advances came from the possibility with space means to see the universe in new regions of the electromagnetic spectrum emitted by distant masses, besides visible and radio regions, characteristic of telescopes and radio-telescopes sitting on the ground. The information on the structure of the universe in the infrared region on one side and in the x-ray and y-ray region on the other side is filling two important gaps, the first situated in between short radio waves and visible light and the second beyond visible light. In particular, x-ray and y-ray are witnessing the existence of very energetic local phenomena previously unknown.

The achievements in the field of exploration of the solar system are better known to the general public.

A synthesis is quite difficult but I will try at least to call attention to a few items, as examples.

• We know now that rings around big planets are not a unique feature of Saturn but a common feature of other big planets too.

This fact can suggest that ring formation is most probably a process connected with the formation of the planet itself and not an accident, and what is seen today is mostly the result of the evolution in time.

• We know that major satellites of big planets show a variety of surface properties and sub-surface peculiarities; facts that demonstrate that the process of formation has been not uniform or the evolution in time of the interior different. By the way, also the existence or non-existence today of a magnetic field in the planets starts to be seen as a consequence of the time evolution of the internal structure.

• In general to disentangle what is due to the process of formation and what to subsequent evolution by dissipative actions is more and more the real goal.

Telecommunications: Telecommunications are a necessary subsystem for all space missions of course, but the most important impact on human society comes from space segments dedicated to the connection between local networks for telephone, television and data transmission.

This practice is today so integrated in our life that people pay no more attention to it.

But the progress has been very impressive: from few simultaneous channels to a very great number of channels, from a limited number of bandwidths to many bandwidths, from a limited number of bits of information per second to a great number of them, from poor angular definition to concentrated beams and so forth and so on.

Progress in this field is a continuous one; there are problems to be solved, like the crowding in the geostationary orbit of these telecommunication satellites, but solutions are possible. In conclusion we can consider this field as a "mature" field.

Earth resources: Remote sensing from satellites of the properties of earth surface for controlling vegetation, hydrology, features of the earth crust, etc., is technically in a very advanced stage. The game is for an increasing spatial resolution and for an increasing number of channels of information. A very recent study week at our Academy made a check of the utilization of this information worldwide, and particularly in the developing countries. The results show a very complex scenario; there are a few countries where a special effort is under way in order to use this information for practical purposes and many others, and not only the developing ones, where there is no practical use of this information, or insufficient utilization.

The problem is that in order to benefit from this information you must have a research activity, which connects the data provided by the satellites with observations on the ground, and can elaborate and interpret the results.

Meteorology from space: This kind of remote sensing has an interesting story, quite different from the one presented just now related to observation of earth surface.

Almost every country in the world has a meteorological service

which can make practical use of satellite data for weather forecasting.

As a matter of fact they did use at the beginning the pictures of the atmosphere as an integration of the information available with classical means, looking at the evolution in time of the most important feature of weather, with a real improvement of short-term forecast.

With the increase in quality and quantity of information they were unable to handle the increasing amount of data and for some time the enthusiasm of the Meteorological Community was somewhat limited.

On the other hand the Scientific Community was in general not very interested in helping to improve short-range predictions and instead interested to understand better the physics of the atmosphere, performing a series of field experiments. The most important of those has been the so-called Garp Programme (Global Atmospheric Research Programme) originated at MIT, started in the 60s by the World Meteorological Organisation, and aiming to understand Tropical Circulation, atmospheric predictability, mountain effect and so on.

The bottle-neck of handling a large number of data for weather forecast, on the other hand, has been removed more recently, since the advent of supercomputers.

Now satellite observation of various parameters of the atmosphere like cloud cover, temperature, etc., is currently incorporated in real time in very detailed models for operational weather forecasting by meteorological services or institutions dedicated to forecasting.

Today the divorce between scientists and forecasters is much less severe and collaboration is improving with mutual benefit.

Oceanography from space: perhaps the most recent development and one of the most promising. Here the transition from the traditional way of observation of properties of the sea from fixed stations along coasts and at islands, and from fixed buoys or mobile stations on ships or airplanes, to a simultaneous view of a whole ocean or of a particular basin, represents the transition from few scattered space-time local informations to a series of synoptic instantaneous measurements of the condition of the sea. A proper sequence of these synoptic observations is the neccessary basis for feeding models of the evolution of large scale phenomena.

This is not a minor point because more and more scientists are believing that in order to understand the regular behaviour as well as important meteo-oceanographic anomalies it is the whole coupled ocean-atmosphere system which has to be investigated.

During a very recent study week, here at the Academy, on the problem of "persistent meteo-oceanographic anomalies and teleconnections", tropical and sub-tropical great phenomena like El Niño, Monsoons and Droughts, as well as mid-high latitude anomalies in the atmospheric circulation and the reality of teleconnections among them, were deeply discussed. A major conclusion was that, in order to come to an understanding, it is the global planetary ocean-atmosphere coupled system which will be investigated.

Maps of sea surface temperatures, surface winds, ocean currents, wave spectra, precipitations and their time behaviour are the basic ingredients necessary to feed models able not only to represent the actual system but also to predict the future behaviour.

Large-scale persistent meteo-oceanographic anomalies have a strong impact on the economic and social conditions of many countries; an impact which in many cases develops toward major natural disasters.

The time scale for the full development of some of these major anomalies is long enough (months, years) to give a high value to an early forecast. The real problem is to distinguish the onset of a major anomaly from fluctuations which always exist in complex non-linear systems.

The role of oceans is fundamental for energetic reasons and for driving the coupled system with time constants much longer than that of the atmosphere. These kinds of phenomena are in between typical weather phenomena and typical climatic phenomena in view of the continuity of the spectral distribution of time fluctuations; in other words they can be seen either as long-lasting weather phenomena or short-lasting climatic changes, a very intriguing and interesting perspective.

Oceanography from space, which is the real new tool, started as a by-product of meteorology from space.

Scientific and social interest, as well as the development of suitable sensors for measuring the relevant parameters, suggested more recently the launching of dedicated satellites, the best known among them being the "SEASAT".

In this field it is not difficult to foresee in the near future a

major development in the performance of the sensors, in the precision of the measurement and in the quality of the models, fed by more and more extensive and reliable data.

Oceanography from space is not limited to strictly physical phenomena. To quote a couple of different applications let us mention the evaluation of the primary biological productivity through detection of phytoplancton concentration via interpretation of the colour of the sea.

Another more straightforward application is the monitoring of the presence and movement of sea-ice formations.

Manned versus unmanned space flights: This is a subject which has been always present since the beginning of space activities, and is still a matter of debate from many points of view, from the technical one to the political one.

Man in space is an element of prestige and of flexibility against the more rigid pre-determined conditions of a fully automated mission, but it is also a complication in terms of safety measures and living conditions for the crew, and for the imperative condition of re-entry.

Where these conditions are impossible to meet, as in the missions to very distant objects of the solar system (like the Voyager's missions) or to very hostile environment (like Venus atmosphere), the only possible choice is in terms of unmanned missions. Where conditions are not impossible, as in near earth orbits or exploration of the moon (and maybe tomorrow Mars), other elements of appreciation come into play, and the choice is more problematic.

The dialectic between the two fundamental options is also depending on the advances in technology mostly in the field of robotics, artificial intelligence, and sensors. With the progress of technology it seems to me that more and more the figures of merit of manned flight are superseded by those of the unmanned flight, except for a unique final perspective: the colonisation of space by man.

In the meantime both options are going to survive as in the past. The two major actors in space activity have, since the beginning, used both options. In fact the USSR has sent the first man in orbit around the earth but America has sent the first man on the moon. The first shuttle has been put into operation by America but the first example of space station was put permanently in orbit by the USSR.

Now the USSR is building a space shuttle, and America is planning for a space station.

For what concerns unmanned missions, both countries have been engaged in an almost similar effort for nearby bodies of the solar system, like Mars and Venus, and definitely America for very long-lasting missions toward the most distant component of the solar system: the major planets.

European and Asian countries, although on a minor scale, have also contributed to space activities, mostly interested in nearby earth orbits for science and applications to service to the earth.

In this last perspective no doubt space activities have reached a high degree of maturity in terms of telecommunication for commercial use, and surveillance of the condition of the atmosphere, the oceans and the land. The scenario that emerges for the future is two-fold:

Continuous improvement of what I call "mature" fields for the immediate benefit of mankind, and endeavours intended to prove the ability of mankind to enlarge his frontiers towards a real cosmic projection.

Stephen William HAWKING

RECENT PROGRESS IN COSMOLOGY

In the last 25 years, the hot big bang model of the universe has been found to be in good agreement with observations of optical and radio sources, of the microwave background, and of the abundances of the light elements, such as Helium.

In this model, the universe is supposed to have started off in a very hot and dense state about 15 thousand million years ago, and to have expanded in a smooth way until it reached the low density of about 10^{-29} grams per cc.

As I said, the predictions of this model seem to be in agreement with observation. However, uncertainty remains over two aspects. The first is the first second of the universe. How did the universe start out? And why did it start in the way it did? The second is, how did the galaxies and stars form? The universe appears to be homogeneous on a very large scale but on smaller scales there are large variations in the density. How did these structures form?

The most widely accepted theory is that the early universe was nearly uniform in density but that there were small variations in the density from one region to another.

In the regions with higher density, the gravitational attraction of the extra mass would slow down the expansion faster than in the rest of the universe. The density in these regions would therefore decrease slower than in the rest of the universe and the density contrast would increase.

Eventually the region would stop expanding, and would form a bound system, like a galaxy.

If this picture is correct, the density fluctuations should give small variations in the temperature of the microwave background from different directions. The present observational upper limit of about one part in 10^4 is just about compatible with this theory of galaxy formation. However, a fairly small increase in the sensitivity

of the observations should reveal variations in the temperature of the microwave background from different directions.

If it does not, we shall have to abandon this theory of galaxy formation in favour of another, maybe that galaxies form from the attraction of matter to some kind of "seeds", such as cosmic strings.

But where do these small variations in density come from? And why does the universe expand at just the critical rate to avoid recollapse? To answer these questions one has to look at the very early stages of the Universe.

In 1981 Alan Guth, at MIT, suggested that the universe might have had a period of exponential or "inflationary" expansion when it was only abous 10^{-35} seconds old. This rapid expansion by a factor of about 10^{30}, or more, would have led to the universe expanding at just the critical rate to avoid recollapse. It would also have flattened out any bumps in the density distribution.

However, quantum fluctuations in the scalar field that causes the inflation would have led to small variations in the density. These would have the right spectrum and can have the right amplitude to account for the formation of galaxies.

But where did the universe come from? How did it begin? Some people say that Science should not investigate the beginning of the universe, because that is the work of God.

But the whole universe is the work of God. It seems that He ordains that it should obey well defined Laws that we can discover. Is it unreasonable to hope that the same Laws should hold at the beginning of time?

In the classical theory of general relativity, the beginning of the universe is a singularity of infinite density and space-time curvature. At the singularity, all the Laws of Science would break down. Thus, one could not predict how the universe would begin.

However, in quantum theory, it is possible that the beginning of time is a perfectly regular point of space-time, at which the Laws of Science hold.

It is possible that space-time is finite in extent but without boundary, like the surface of the Earth, but with two more dimensions.

The surface of the Earth is finite in extent, but it doesn't have any boundary or edge. It doesn't have any beginning or end.

Time is like degrees of latitude on the Earth. One can think of the universe as starting as a single point at the north pole. As one

moves south, the circles of latitude get bigger, corresponding to the universe expanding with time.

The circles of latitude reach a maximum size at the equator, corresponding to the maximum size of the universe. The circles of latitude then contract down to a point at the south pole, corresponding to the recollapse of the universe.

The north and south poles are the beginning and end of the coordinate, latitude, on the Earth. Yet they are just ordinary points, and the Laws of Science hold at them, as they do at other points on the earth. Similarly, the Laws of Science can hold at the beginning and end of Time.

So where does all the matter in the universe come from? The answer is that by quantum theory, matter can be created from energy, in the form of particle anti-particle pairs.

So where did the energy come from? The answer is that the positive energy of the matter particle and anti-particles is exactly balanced by the potential energy of the gravitational field, which is negative. Thus, the total energy of the universe is exactly zero.

This means that the universe can expand and create new matter, without any barrier. In the words of Guth: It is said that there is no such thing as a "free lunch": but the universe is the ultimate free lunch.

I realize that the ideas I am suggesting go against previously accepted ideas of the origin of the universe, just as Galileo's idea that the Earth went round the Sun contradicted the accepted view. I was born exactly three hundred years after Galileo's death. I hope that I don't suffer the same fate.

Giovanni Battista MARINI-BETTÒLO

ECOLOGY

Introducing discussion on *Ecology* I should like to underline that the term Ecology proposed in 1870 by Haeckel has been misused in the last years and that it may even induce some confusion. Moreover the political use of this word has modified its real meaning, being adopted to indicate a part or some aspects of other disciplines related to ecology.

Therefore I should like first of all to make clear the present scientific meaning and objects of ecology.

According to the definition of Haeckel, "ecology is the study of the economy and of the habitat of the organisms. It includes the relationships of animals with the inorganic environment and also of plants with other animals" whether they are positive or negative, direct or indirect. At this point it is necessary to mention one of the main objects of Ecology, the *Environment*. The *environment*, at any level of life organization, is a system, active, complex but fragile — of interrelationships formed, in time, between its components and under the influence of the factors acting upon it. Every *level*, from the cell to the biosphere, presents an internal and external environment. An *ecosystem* (lake, forest, ocean or town) represents the level of the organization of life where the dynamic of the interrelations between physical and chemical factors and the living component is more evident. The cycles of nutrients, of energy, the homeostatic mechanisms, constitute the dynamic of these ecosystems, which can be in equilibria or not. The various components and the external factors (physical, chemical and biological, and if man is concerned, also cultural) form the structure of an ecosystem, and are studied by specialistic disciplines. These are: *environmental biology*, *environmental geology*, *environmental chemistry*, *environmental education*, *environmental economy*, *environmental right*, etc. These disciplines, which correspond to the basic sciences: biology, chemistry, geolo-

gy, etc., enriched by the principles and the methodology of the systemic approach of ecology, constitute the Environmental Sciences.

Ecology is an environmental science which studies the processes governing the environment, and analyses an environmental system considered globally, using the contributions given by the different specialistic approaches to the components and the structures of ecosystems. Environmental sciences deal with the dynamic equilibria of life on earth, which can be studied and developed through an interdisciplinary approach. Thus chemistry, botany, zoology, biology, genetics, physics, mathematics, etc., concur in the study of ecology, which is only possible through the integration of these disciplines in a unitary approach. This shows that all living organisms are intimately bound one to another through a number of chemical and physical changes, from the synthesis of carbohydrates to that of proteins regulated by energy changes, which influence animal behaviour and govern the biological equilibria from those of the soil of a forest to those among higher animals or plant cultivars modified by man. Ecology has been also defined as "the science of all the interactive processes regulating life on earth", but all these processes should be considered as a whole — under a unitary approach — because the interactions between the various components of the equilibria are fundamental in their characterization. Populations making up the ecosystems are the fundamental units for the study of ecology; such ecosystems are governed by the laws of thermodynamics (*input* and *output* of energy), by the chemical transformation, which represent the various stages of that unique physico-chemical process which is life, studied at the different stages and aspects through the techniques and methods of modern biology. The changes, even very slight, in these equilibria, may cause drastic modification of the ecosystems which govern earth and may even open the way to a new geological era. In effect although the equilibria between population and environmental conditions may be buffered up to a certain level by several homeostatic mechanisms, e.g., biodemographic and biogeochemical. When the limit is surpassed the cycles are broken and a diminution of the flux of energy as well as the accumulation of non-biodegradable wastes takes place.

Evolution on earth is generally considered by us a question of the past but we are daily submitted to little changes which may

bring the global changes in hundreds of years or even in millennia. At present the effect of man on the ecosystems is enormous and it would be very difficult to forecast any scenario. It is not possible to synthetize in a few minutes the philosophy and the present trends of ecological sciences. We may only try to give some information.

Ecology is interdisciplinary in methodologies and ranges from the small ecosystem to the global. So the approach can be multiple: we may consider the soil as a complex of ecosystems and their substrate; a forest too is comprehensive of a number of ecosystems; there are also important aquatic ecosystems, in the rivers, lakes, oceans. Smaller ecosystems or microenvironments may be found for example at a level of the root of a plant or in a decomposing animal. I have to limit myself to report some of the aspects of ecology, which are the most important for our future development, i.e., the interrelationships of man with ecosystems.

The Stockholm conference, in 1972, brought to the attention of scientists the effects of the consequences of man's activity on ecosystems. The dynamic biological equilibria constituting on earth the ecological systems (populations, comunities, ecosystems, bioma and biosphere) are submitted, because of the exponential growth of the human species, to continuous stress and modification as a consequence of its activity, which can be represented, e.g., by human settlements, deforestation, agricultural practices, energy production, overgrazing of pastures, industrial production, waste disposal, etc.

A program for the study of the interaction between man and the ecosystems was proposed to all the governments and scientists of the world, with the name *Man and Biosphere*. The philosophy of the program, coordinated by UNESCO — is that *nature is one and not divisible* but that *man* should be the reference point of all the future programmes or initiatives for the conservation of nature, being not only an essential component of nature, but also dependent on it. According to the UNESCO this concept involves the definition of the term *biosphere*, which is "the thin layer of soil, air and water, covering earth surface and including all the living matter". In this thin layer during millions of years a number of successive events and interactions have taken place, giving rise to our present world. Until recently the influence of man on the processes and interactions of the biosphere was limited, but in the last centuries, and particularly in the last fifty years, the action of

man on the biosphere increased, following an exponential curve. This influence has reached a global effect and an intensity such that the regulatory processes involved in the balances of the ecosystem are critically influenced and human life is at risk of being deeply modified.

At this point we have to consider the frame where man lives: the environment. Up to now there are a number of different definitions and interpretations of the exact meaning of this word. It is quite difficult to find the one which is comprehensive of all the implications of the word environment. I should suggest that *Environment is the result of the interaction of ecosystems, including their abiotic surroundings*. Man lives in his environment and is compelled to modify it continuously by a number of activities: building, transport, industry, extensive agriculture. Since the environment is the result of interaction of many ecosystems, i.e., of a number of dynamic related equilibria, it may react to the induced modifications reestablishing the equilibria only if the latter are quantitatively and qualitatively compatible with the compensative power of the system. Modification of the soil by agriculture, overgrazing, mining, misuses of surface water as well as of non-renewable resources are dangerous stress for ecosystems. Human ingenuity has moreover produced in less than a century about eight million new chemicals. Others are produced in many industrial processes: combustions, incinerations, etc., of which we know very little; to say nothing about the great number of radioactive isotopes. These products constitute a menace for all the constituents of the biosphere: soil, air and water and living organisms. Even more the energetic balance of humankind is always more difficult due to the population growth.

So far we have considered the biotic aspect of the environment, but there is also an abiotic aspect — governed by physico-chemical laws, which generally possess a good buffering power between atmosphere, oceans and soil. Naturally this buffering capacity is proportional to the amount and the type of the modification. The concern about the effects of increasing percentages of CO_2 in the atmosphere is well known. The environmental systems are also the main source for supplying man with energy (such as food and heat and power) water, minerals etc. At present the MAB program has focused research on 14 main subjects which take into account general problems but also those involving large areas of our world.

For example "ecological effects of increasing human activities on tropical and subtropical forest" which is a dramatic question, due to the need of land and energy by the growing populations of the Southern Hemisphere. Or "ecological effects of human activities on the value and the resources of lakes, marshes, rivers, delta estuaries and coastal zones" which face the great problems of water protection and conservation. Even the problem of the towns, "ecological aspects of the urban system with particular regard to the utilization of energy" which represents a great challenge for the future.

And finally the most important aspect for its practical and political implications: "the effect of pollution on environment" with all its implications (chemical and biological) going from chemical monitoring to the biological studies of the effects of pollutants on man, on ecosystems and abiotic surroundings, and even on products of man's own activities, in which we have also to consider buildings, art masterpieces, etc. Pollution, as known, may be due to biological, industrial, mineral and radioactive wastes. The latter are causing growing concern for the increasing use of nuclear plants as a source of energy in the world. On the other hand we have to recognize that man has influenced his environment also positively: marshes, swamps and even deserts have been transformed into cultivated lands, and even gardens; many vectors of diseases have been reduced. I should only quote the fact that during the last centuries the number of deaths from malaria in Europe was high. It is reported that in the XVII century even in the Vatican there were many casualties from malaria. Fifty years ago large areas of Southern Europe and even of the Italian territory from Sardinia to Maremma were malarial. Fiumicino was a rather dangerous spot, where professor Grassi had his field laboratory for the study of this disease.

A second aspect of Ecological Sciences involves the methodology, i.e., the interdisciplinary basis of the approach to the problems and not research in single disciplines. Ecological sciences have had a great impact on the world's new consciousness of the danger of the degradation of the environment, that is, of the menace of the irreversible modification of the ecosystems governing the equilibria of nature. In order to solve the primary problem that is the coexistence of man developing on the earth with his biosphere, it is necessary to have more information about the very complex modification occurring at every level in our planet. That is, we need to

develop research: a systemic approach and more information, i.e., monitoring about the chemical, biological, geophysical modifications due to various factors of ecosystems, and we need also to compare and integrate these data with the methods of system analysis which can give us new indications. We need also mathematical models in order to interpret changes and predict situations which may be then modified. In a dynamic system we have also to take into account not only the relationships between man and his environment, but also all the interactions between animal and animal, plant and plants, plant and animals, from the microscopic to the macroscopic level, thus including all the phenomena occurring in bacteria, protozoa, fungi and all microorganisms which are governed by the most different enzyme systems. Under this optic we must also examine the modifications of the abiotic systems (soil, air and surface waters) due to the changes of the biotic as well as the physical and meteorological activities.

Basic research should also be developed on the mechanisms governing biological equilibria and the regulation of ecosystems. Physics and photochemistry will be most important for a better knowledge of the energy aspects. Chemistry, now at a molecular level, may be of fundamental importance to understand, both in natural and man-modified ecosystems (such as extensive agriculture), the role of natural products to regulate the equilibria between the various components of nature (we may even consider these substances true *ecological mediators*) which may — as a new idea — even constitute a new approach to the study of ecosystems. We need more information from the direct observation of life at every level and how it is influenced by change. It will be also necessary to develop a technological innovation based on prevention as well as on the study of new methodologies for the transfer of the results. Moreover a global approach should encourage the scientific and professional formation of the operators of the environment, and an effort should be dedicated to environmental education, information and divulgation.

We have before us a great task and I believe that a reorientation of basic sciences to the problems of the dynamic of the processes of life on earth will be most important for our future.

Johanna DÖBEREINER

PROGRESS OF SCIENCE IN AGRICULTURE AND THE FUTURE OF MANKIND

Agricultural sciences seem more directly linked to ecological problems and to the future of mankind than any other branch of science. We have to find ways to produce food for the growing world population without destroying the environment. This will be possible only to a certain limit and therefore education envisaging a strong commitment with the environment and with the future of mankind must also be concerned with measures which ensure the restriction of population growth within this limit. In contrast to traditional agriculture, which during the green revolution was mainly concerned with increased food production in the developing countries, recent progress in agricultural sciences has focalized rather on agricultural systems which make maximal use of biological processes and miminize hazards to the environment due to excessive use of chemical fertilizers and pesticides. Such systems should be designed for small farmers as well as for larger production enterprises. The first seems the key element to avoid the continuous emigration towards the large cities and the second is necessary for the food production for the population in the cities.

Today we know that it is not any more the total amount of food produced that matters but rather its distribution. Often transport, living standard or even firewood are the limiting factors. In many regions water is limiting agriculture and it is there where the major problems are. Poor education goes hand in hand with an unappropriate use of the land followed by progressing desertification, poverty and hunger.

Agricultural sciences must deal with all these problems.

Natural equilibrium systems like rain forests or savannas have adjusted their vegetation according to the availability of water and plant nutrients. These are recycled very efficiently especially in

forests. The only elements which never will be limiting plant growth in natural systems are carbon and nitrogen, which both come from the atmosphere. Therefore photosynthesis and biological dinitrogen fixation are the two key processes responsible for the maintainance of life on earth.

When such a natural system is converted into agriculture drastic changes occur in the soil. The organic matter is decomposed and liberated nitrogen is rapidly lost through action of water or denitrification. This accelerates the loss of soil organic matter, and the natural soil fertility is lost within a few years if the new agricultural systems do not take appropriate precautions for soil conservation. Such systems must however be based on solid scientific experimentation rather then empirically or even demogogically explored mystical concepts.

There are many possibilities for technologies which can help conservation of the natural soil fertility or even restore that of eroded soils. We will give a few examples.

The legume-Rhizobium symbiosis

Even though there is an unlimited N_2 reserve in the atmosphere, this element is the major limiting factor of agricultural yields and represents, in developing countries, more than 70% of the fertilizer costs. Crop rotations which include pulses and green manure legumes can replace nitrogen fertilizers to a large extent but such systems require well defined technologies. They are based on the exploitation of the highly sophisticated symbiosis of plants of the family Leguminosae which harbor in root nodules more or less specific *Rhizobium* strains which are fed by the plant and in exchange furnish all the nitrogen necessary for optimal yields, in the form of combined nitrogen to the plant.

Forest legumes

Brazilian reforestation projects, until recently did not consider one of the important characteristics of so many native legume trees: their ability to fix N_2. The most precious hardwood species and many native fast growing trees are legumes but little is known about their capacity to nodulate or fix N_2. Surveys in the Northeastern dry regions (Vasconcelos & Almeida 1979/1980) in the Amazon rain

forests (Bradley *et al.*, 1978, 1980, Magalhães *et al.*, 1982) and in Southeastern Brazil (Faria *et al.*, 1984a, b) revealed many economically important N_2 fixing trees not known as such before (Table 1). Mesquite (*Prosopis juliflora*), called algaroba in Brazil, is being planted in large government projects in the Northeastern dry regions, and since 1982 is inoculated with commercially available inoculants.

TABLE 1. - Nodulation of Brazilian forest legumes (Faria *et al.* 1984a, b, Bradley *et al.* 1978, 1980, Magalhães *et al.*, 1982, Vasconcelos & Almeida, 1979/1980).

	Subfamilies			
	Mimosoideae	Papilionoideae	Caesalpinoideae	Total
No. of species verified	60	75	72	207
No. of species with nodules	51	53	9	113
No. of species found for the first time with nodules	25	37	8	70
No. of genera found for the first time with nodules	0	4	2	6
No. of *Rhizobium* strains isolated	257	218	62	537

The development of agroforestry systems which include in the crop rotation ten-year periods of legume forests, which supply the farm with energy, emergency fodder during dry years and recover eroded soils building up organic matter from the large amounts of protein-rich leaves which fall on the ground, seems another prospect as yet almost unexplored.

Legumes for green manure

A large variety of tropical legumes is available which can be planted in between crops either as intercropping or after the crop is harvested. Several of them can fix large amounts of dinitrogen and some assimilate phosphates which are unavailable for grain crops. The example in Table 2 shows that, e.g., *Stizolobium aterrimum* can

TABLE 2. - Yield and mineral assimilation of two green manure legumes from rock phosphate (Silva *et al.*, 1985).

	Plant dry wt. (t/ha)	N	P	K
		kg/ha		
Stizolobium aterrimum				
Thermophosphate	14.8	353	37.2	184
Rock phosphate[a]	14.0	318	35.8	164
Crotalaria juncea				
Thermophosphate	16.6	253	31.7	237
Rock phosphate[a]	8.4	151	15.7	86

[a] Phosphate from Patos de Minas

obtain as much phosphorus from rock phosphate as from soluble phosphates. When such green manure cover plants are incorporated into the soil besides the organic matter, phosphorus and nitrogen are incorporated in slow release organic forms. These features will contribute substantially to make green manuring economically viable and a valuable constituent of crop rotations. An estimate of the economic returns of a crop rotation including such green manures in comparison with monocropping of maize is given in Table 3.

TABLE 3. - Effect of crop rotation on maize yield (kg/ha) and profits of 5 years (F.F. Duque & G.G. Pessanha, in preparation).

	Maize yield 1982/1983	Maize yield 1984/1985	Profit all Crops after 5 years (US$/ha)
Maize in monoculture	4480	1855	1178.51
Maize in crop rotation[a]	3696	2703	1869.35
With rock phosphate	4808	2671	1780.38
With rock phosphate and green manure[b]	5283	3023	1575.24

[a] The crop rotation from 1981 to 1985 was *Phaseolus* beans — maize peanuts — cassava intercropped with cowpea — maize.

[b] Green manure was *Stizolobium*.

Grain legumes

One of the most successful examples of the impact of biotechnologies on the agriculture of a country is that of soybeans in Brazil. *Rhizobium* strain selection for Brazilian conditions was started for soybeans in 1949 (Freire , 1982). The Brazilian soybean cultivars, in contrast to the U.S. and Japan, were bred since the 1960s without nitrogen fertilizer and with highly efficient *Rhizobium* inoculants. As a result this major crop needs no N fertilizer and competes better in the world market. Brazil's highland edaphic savannas called "cerrados" comprising 180×10^6 ha are being rapidly taken into agriculture. Economically viable and highly productive farming systems must rely on crop rotations with legumes as their major nitrogen input and soybeans are one of the major crops (4×10^6 ha in 1985). For more than 10 years the commercial soybean inoculants did not work in new lands until specifically adapted *Rhizobium* strains were found (Vargas & Suhet, 1980). These strains were found to be resistant to high levels of streptomycin, a characteristic later found to be a general feature of *Rhizobium* strains isolated from cerrado soils (Scotti *et al.*, 1980). Soils with similar problems occur in the Colombian llanos and also in newly cleared Amazon land planted to cowpeas (Döbereiner *et al.*, 1981a). The resistance to certain antibiotics, however, is not the only cause of better establishment of certain strains under adverse conditions. Tolerance to soil acidity problems (Munns & Franco 1982) and saprophytic competence (Vidor & Miller, 1980, Peres & Vidor 1980) play important roles.

Phaseolus beans, the major food basis of Brazilian people until 5 years ago, have not been bred for nitrogen fixation and therefore needed N fertilization for improved yields obtained with certain cultivars, and inoculants are already available which permit complete replacement of N fertilizer. These data stress the importance of plant breeding for N_2 fixation. As inoculation becomes a common practice the physiological factors affecting nodule functioning and limiting seed production are of concern. Differences were found among *Rhizobium* strains in the efficiency of incorporation of the fixed N into seeds which were correlated ($r = 0.80^{**}$) with the N transported as ureide in the xylem sap (Hungria & Neves, 1984). Similar differences between *Rhizobium* strains were also observed in soybeans (Neves *et al.*, 1985).

Plants inoculated with selected strains transport practically all fixed N as ureides which is directly incorporated into grain proteins. Soybeans inoculated with commercial inoculants transport the fixed N first into the leaves and produce 30% less. This places a new challenge on *Rhizobium* biotechnologies which will have to develop new ureide producing strains for the *cerrado* regions.

Cereals and Grasses

The extension of biological nitrogen fixation to the major cereals has been a major research challenge in the last two decades. Because plants such as other eucarionts cannot use molecular N_2 the most promising approach seems the search for more or less symbiotic associations of bacteria which are able to fix N_2 with cereals, which can be improved by modern technologies. The transference of N_2 fixation genes into plant cells seems a more pretentious alternative, which if successful could become the best solution. Unfortunately progress in this field is very slow while many new alternatives have become available during the last 15 years for improved already identified naturally occurring associations of cereals with N_2 fixing bacteria.

A typical result which leads to the conclusion that nitrogen fixation must occur under rice is that of App *et al.* (1980, 1984). In this study nitrogen analyses of long term fertility plots in two sites of the Philippines were performed before and after 17 and 24 crops of paddy rice, yielding positive N balances of 103 and 79 kg N/ha per year respectively. Under temperate conditions, after 82 years of continuous wheat at the Rothamsted Broadbalk experiment a positive N balance of 30 kg N/ha per year was estimated (Jenkinson & Rayner, 1977). Evaluations over shorter periods with forage grasses are in the same range (Jaiyebo & Moore 1963, White *et al.*, 1945). More precise estimates over short term periods can be obtained by the use of the isotope ^{15}N. There, either the incorporation of $^{15}N_2$ from the air or plants growing with ^{15}N labelled fertilizer have been used. Substantial although very variable amounts of N_2 fixation have been demonstrated with these methods in rice (Watanbe & Roger, 1984), sorghum (Wani *et al.*, 1984) and forage grasses (De-Polli *et al.*, 1977, Boddey & Victoria, 1986). Very recent experiments with sugar cane combining N balance and ^{15}N

dilution measurements have brought unequivocal proof of more than 50% of the plant nitrogen coming from the air (Lima *et al.*, 1986).

Now that it is known that amounts of nitrogen of economic interest can be fixed in association with cereals and other Gramineae, the understanding of the physiology is essential in order to start to manipulate and increase their efficiency. Many different N_2 fixing bacteria have been isolated from the rhizosphere and from roots of cereals, but only where plant-bacteria interactions exist can one speak of an association. Pathogenic plant-bacteria associations have been known for long, and there, effects of microrganisms are visible as damage to the plant tissue. Characteristic of these associations is the specificity that can be on strain or species level. Plant breeding for resistance to specific pathogens is one of the major objectives in agricultural research. Breeding for improved associations of plants with N_2 fixing bacteria will have to envisage opposite characteristics.

New approaches to the study of nitrogen fixation in the major cereals and grasses have been started in the last decade (Döbereiner & Day, 1975; Neyra & Döbereiner, 1977; Boddey & Döbereiner, 1984). Several New N_2 fixing bacteria have been described which associate with grasses and cereals. Besides *Azotobacter paspali* there are now three *Azospirillum* spp, one new Bacillus sp (*B. azotofixans*) and several ill defined Pseudomonads (Döbereiner, 1966; Tarrand *et al.*, 1978; Barraquio *et al.*, 1983; Magalhães *et al.*, 1983; Seldin *et al.*, 1984). A new acid tolerant bacterium was found to predominate in maize roots in cerrado soils and was initially classified as a fourth *Azospirillum* species (Baldani *et al.*, 1984). Later RNA/RNA hybridization studies showed it to be a new genus (E.C. Falk and N.R. Krieg personal communication) and it therefore was renamed *Herbaspirillum seropedicae* (Baldani *et al.*, 1986).

The mode of infection of cereal roots by N_2 fixing bacteria has not yet been identified but root hair deformations with specific *Azospirillum brasilense* strains could be associated with plant responses to inoculation with the same strains (Patriquin *et al.*, 1983), and numbers of cells of these strains within roots correlated well with plant N increases (Baldani *et al.*, 1983). Infection of maize root xylem during the growth cycle of field grown plants followed similar patterns as N_2 fixation (Magalhães *et al.*, 1979). Establishment of inoculated *Azospirillum* strains in roots of field grown

wheat and sorghum varied with strains. Root isolates became dominant within roots while the soil isolates seemed less competitive. In sorghum the distribution of the inoculated strain in the root system was not at random but localized in the upper system. Plant responses under field conditions to *Azospirillum* inoculation have been reported from many places (Okon, 1982; Subba Rao, 1981; Vlassak & Reynders, 1978) but as expected there are large differences between strains (Freitas *et al.*, 1983; Baldani *et al.*, 1983). Although such plant responses were usually accompanied by increased nitrogen incorporation, especially into seeds, unequivocal proof of N_2 fixation has not been brought forward in *Azospirillum* inoculation experiments. Attempts to show $^{15}NO_3$ dilution in a wheat experiment showed higher fertilizer recovery but no sign of N_2 fixation (Baldani *et al.*, 1986). Two sorghum experiments gave similar results. Bacterial hormones which proportion enlargement of the root system and a sponge effect were suggested by Okon (1982). Enhanced NO_3 reduction aided by the *Azospirillum* nitrate reductase is another possibility (Baldani *et al.*, 1986). In plant genotype comparisons however, N_2 fixation in the order of 10-40% of the total plant N incorporation has been shown by N balance studies (App *et al.*, 1980) and by $^{15}N_2$ incorporation (De-Polli *et al.*, 1977; Eskew *et al.*, 1981), and by ^{15}N isotope dilution forage grasses (Boddey *et al.*, 1983a, b) and by balance and ^{15}N dilution in sugar-cane (Table 4).

TABLE 4. - Nitrogen fixation in sugarcane cultivars (g N per 45 litre bucket) (Lima *et al.*, 1986).

Cultivar	Initial soil N	Total plant N[a]	Final soil N	Balance	^{15}N atom % excess
CB 47-89	53.6	30.3a	46.8	+ 20.9a	0.0586
CB 47-355	49.5	13.5b	44.5	+ 5.9b	0.1015
IAC 52-150	52.7	11.6b	45.1	+ 1.3b	0.1097
NA 56-79	54.2	11.1b	45.8	0.0b	0.1047
No plant	51.2	—	44.1	− 9.6c	—

[a] Total plant N obtained in two harvests in 21 months.

Although N_2-fixation in association with Gramineae is a very exciting field due to the importance of these plants for agriculture, it is improbable that complete replacement of N fertilizers will be possible because of the more primitive nature of these associations. Still it remains a major challenge to soil biologists and agronomists and prospects for new breakthroughs are good.

The recent confirmation of specificity — very similar to that observed with plant pathogens in experiments which show that it is possible to establish under field conditions selected or genetically manipulated *Azospirillum* strains (Baldani *et al.*, 1986) even in soils which contain 10^6 to 10^7 native *Azospirillum* cells per g — opens many possibilities to improve N_2 fixation in such associations. The two new acid tolerant species, *A. amazonense* and *H. seropedicae*, have not even been tested yet as inoculants. Plant breeding programs will have to start with more primitive genotypes which have not been selected for response to high mineral fertilizer levels. There the plant breeder may encounter problems in breeding for resistance to plant pathogens and at the same time susceptibility to *Azospirillum* infection.

The recent results indicating plant genotype differences in sugarcane may lead to entirely new concepts on the possibility to use sun energy through agriculture (Döbereiner *et al.*, 1981b). The success of the Brazilian alcohol program, which exceeded all expectations (more that ten billion litres of ethanol are now produced annually and 97% of all cars sold in 1985 run on 95% ethanol), is due to a relatively low N fertilizer input. In Hawaii producing sugarcane ethanol on large scale is considered energetically un-economical (more energy is used than it yields) because of the high mechanization and fertilizer inputs into this crop. Sugarcane breeding programs which yield cultivars which obtain more than 180 kg of nitrogen from the air as estimated from the data in Table 4 may even in industrialized countries become net energy yielders and may open to the world a new renewable energy source.

The use of the many new findings in all fields of N_2 fixation in agricultural systems will lead to more economical but still productive farming systems with reduced risks for the environment.

Acknowledgements. Thanks are due to FINEP and to the NAS-BOSTID program for financial support.

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Sune BERGSTRÖM

BIOTECHNOLOGY

We have just heard exciting stories on the time scale of billions and millions of years. We will now go to a microcosmos where centuries and decades are important and where science hopefully can play a great role in decreasing the possibilities for violent turbulence and chaos on our small globe.

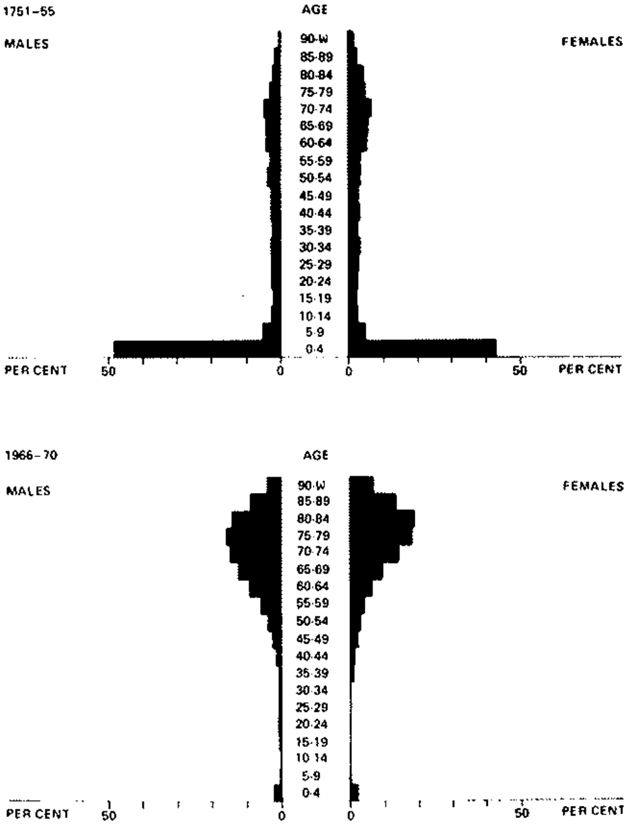
Everyone has a different opinion of what should be considered important components of the "quality of life" but the basic thing is to have good health.

Fig. 1 illustrates a typical situation in a developing country. The percentage is a distribution of the dead over different age groups. Almost 50% of the dead are less than five years of age, whereas in the lower part, most of the dead have reached a mature age. The first case is Sweden in 1750. Our Church had been commissioned to follow and record every birth and death, so in that way we have complete records since 1750 in some parts of Sweden. The lower part illustrates the situation about 200 years later. Early childhood death has almost been eliminated.

The elimination of childhood death in Sweden has, however, been a long and slow process (Fig. 2). You see how 200 out of 1000 children died at this early age in 1750; a certain break is seen in the middle of last century, coinciding with the introduction of the compulsory school system, and then there is a progressive slow decrease until today.

The birth rate in Sweden stayed up for quite some time as you see in Fig. 3 and decreased rapidly only in this century and is now practically identical with the death rate. If you compare that with a developing country (Sri Lanka), the fall in the death rate is very much faster, whereas the birth rate again stays the same for some time.

The birth rate will only decrease with improved education and general development. To reach a population balance quickly, these processes must be speeded up.


1751–55
AGE
MALES
FEMALES
90-W
85-89
80-84
75-79
70-74
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50-54
45-49
40-44
35-39
30-34
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PER CENT
50
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1966–70
AGE
MALES
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90-W
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Figure 1.

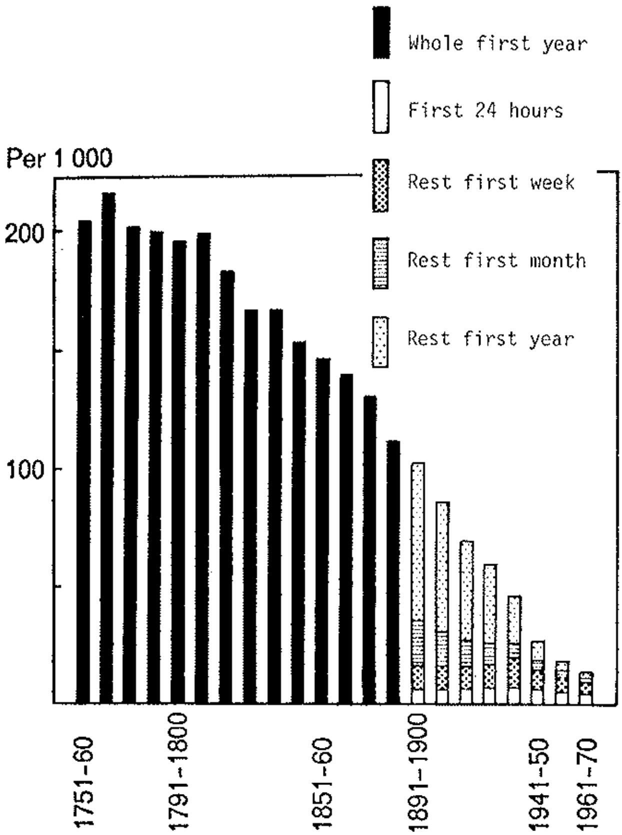
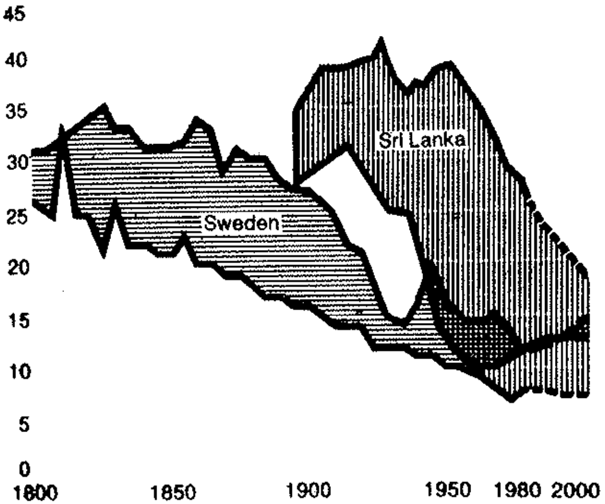

Whole first year
First 24 hours
Rest first week
Rest first month
Rest first year
Per 1 000
200
100
1751-60
1791-1800
1851-60
1891-1900
1941-50
1961-70

Figure 2.

Demographic transition in Sweden and Sri Lanka



Note Demographic transition in Sweden is compared with the much more abrupt transition through which Sri Lanka is now progressing Sweden has reached the stage of 'zero population growth and is expected to stay at about that level through 2000 Sri Lanka's birth rate has yet to decline to a level near that of its sharply decreasing death rate, which is now even lower than Sweden's because Sri Lanka's population is younger than Sweden's.

Source Mahler 1980

Figure 3.

Fig. 4 illustrates the World Bank's prognosis of the population development from 1980 to 2000. The developed countries only increase from 1.1 to 1.3 billion, the increase being mainly in the higher age groups. In the developing world, the increase is from 3.3 to 4.8 billions. The actual development after this period is difficult to estimate as it is very uncertain how quickly the birthrate will fall.

Various estimates have put the final balance in the developing countries somewhere between 8 and 10 billions whereas the presently developed countries would stop at only a billion and a half.

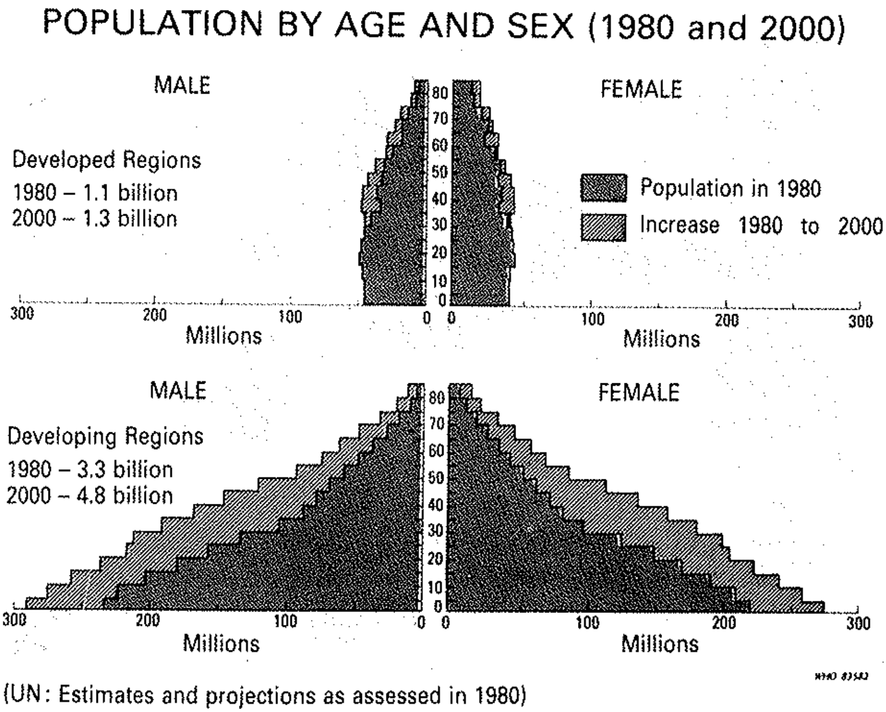


Figure 4.

In the industrialized countries located mostly in the temperate zone, the diseases causing mortality have changed drastically as shown in Fig. 5. In 1900 pneumonia, tuberculosis, chronic nephritis, diphtheria and tuberculosis are dominating. In 1967, cardiovascular diseases and cancer are the most common causes of death. Medical research in these countries has naturally concentrated on these latter diseases and is spending something like 6 to 8 billion dollars on research and development of these diseases.

In many developing countries, especially in Africa, child mortality is about the same as it was in Europe 200 years ago with twenty or more percentage of the newborn dying before the age of five. The average life expectancy at birth is rapidly going up but still some areas have a life expectancy between 35 and 45 years.

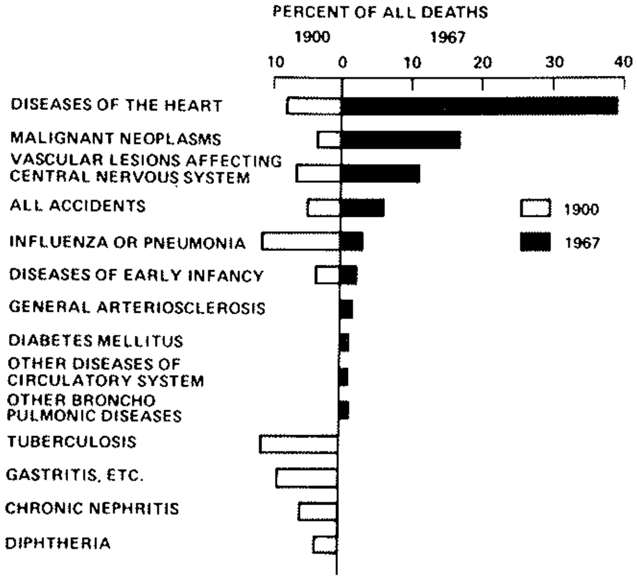


Figure 5.

In addition to the diseases in the temperate areas (Fig. 5) there are additional diseases in the tropical areas, *i.e.*, malaria, schistosomiasis, sleeping sickness, river blindness, leprosy, etc., many of which are spread by insects. These diseases afflict several hundred millions in the developing tropical countries.

Furthermore, in the 70s the chloroquine-resistant malaria spread and increased rapidly around the world.

The World Health Organization (WHO) became very concerned in many ways about the health situation in the developing world.

The Ministers of Health of the world form the governing body of WHO. Their consensus was that there was a great need for improved and new methods to prevent or cure many diseases mainly in tropical countries.

At the same time the research activity in these fields was not only very low but even tended to decrease, to some extent due to the fact that when the colonial powers left their colonies some hospitals and research institutions were left deteriorating.

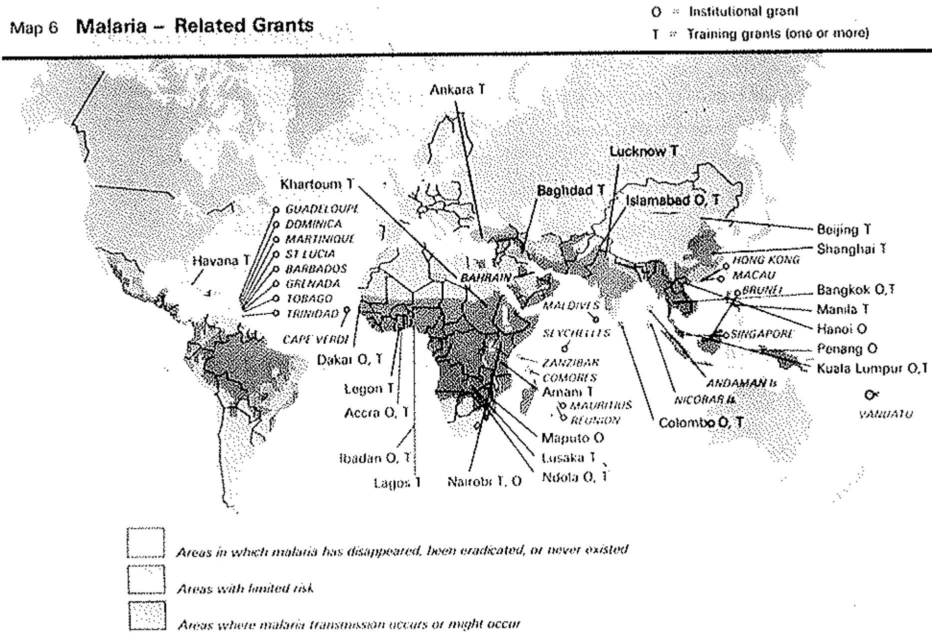


Figure 6.

However, the budget of WHO cannot support any research and development effort on the scale needed.

Plans were therefore made for several "Special Programmes", for which voluntary contributions should be asked for from member countries and other agencies or foundations.

The largest one is the "Special Programme for Research and Training in Tropical Diseases" (TDR) supported by the World Bank, United Nations Developing Programmes, WHO and about 25 member countries. The annual budget is now about $ 25 millions.

The programme has two purposes: research and development to improve existing methods and develop new ones to prevent and treat the six diseases: Malaria, Trypanosomiasis (African Sleeping Sickness and Chagas Disease), Filariasis (River Blindness, etc.), Schistosomiasis, Leishmaniasis and Leprosy.

Furthermore, a considerable part of the budget is used to build up and strengthen biomedical research capabilities in developing countries.

TDR has helped strengthen about one hundred institutions in developing countries. This support, that can last five to ten years, is only undertaken if the government of the country agrees to take over the support gradually to ensure continuation.

Professor de Duve gave an interesting review of malaria research yesterday. The involvement of TDR in this field is illustrated by Fig. 6, in which the location of malaria related grants is indicated.

Most projects are located in areas where the problem exists, focusing on following the spread of the drug resistant parasite or conducting clinical trials with new drugs. The vaccine development is mainly supported in laboratories in the developed countries but still about half of the support goes to the developing countries.

A similar case is shown in Fig. 7, where the localization is shown of TDR grants for Chagas' Disease in South America. Considerable research support is also forthcoming from the Chagas Foundation and other national sources.

In the field of Filariasis, work is going on in a coordinated way in an international network of several clinics and laboratories covering synthesis, screening, metabolism, clinical trials and field trials.

In the case of leprosy it was observed, just before TDR started, that leprosy bacteria could grow and multiply very rapidly in armadillos of Central America. This discovery meant that this bacteria for the first time could be produced in large amounts for the vaccine work.

In a few years' time several vaccines have been produced that are now under clinical trials in several countries after safety trials in Norway.

Research programmes similar to TDR have also been initiated by WHO in the field of human reproduction as well as in diarrhoeal diseases, the greatest killer of small children in developing countries.

These three programmes, that together have a budget of about $ 50 millions annually, are run strictly as international research councils — in the same way as most national medical research councils.

Each is divided into specific disease areas in which a "Steering Committee" of internationally well known scientists (8-10) proposes the detailed plan of action, decides on funding and evaluates the results annually.

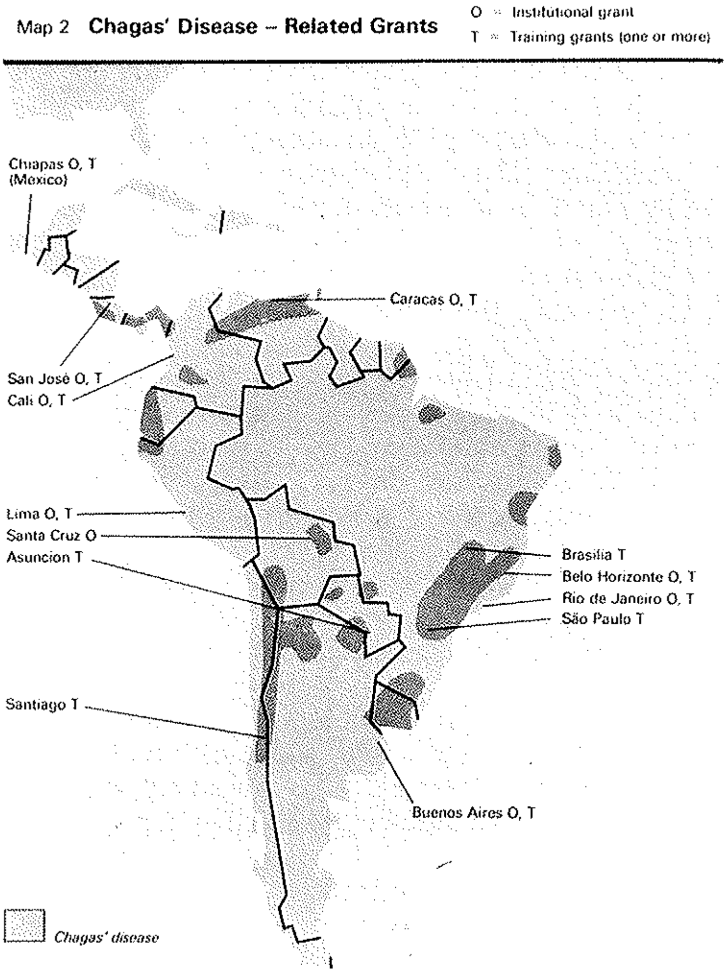


Figure 7.

Each whole programme is furthermore evaluated by a scientific and technical group of independent experts that recommend a budget to the governing (joint coordinating) board of TDR that consists of 30 persons — at present with one representative from the World Bank, UNDP and WHO and furthermore government appointed representatives from 27 countries — the majority from developing countries.

This body thus represents scientific subcomittees of the World Health Assembly for research in respective areas.

The composition recently of the TDR board is shown in Table 1.

TABLE 1. - TDR: Joint Coordinating Board

UNDP	WORLD BANK	WHO
Australia	Belgium	Brazil
Burma	Canada	Denmark
Egypt	France	Germany, Federal Republic of
India	Liberia	Netherlands
Madagascar	Malaysia	Pakistan
Nigeria	Norway	Switzerland
Philippines	Sweden	United States of America
USSR	United Kingdom	
Venezuela		

Fig. 8 illustrates how the funds to these research programmes have increased from the early 70s, when they started, and now are hovering around 50 million dollars. The largest country contributions are listed in Table 2.

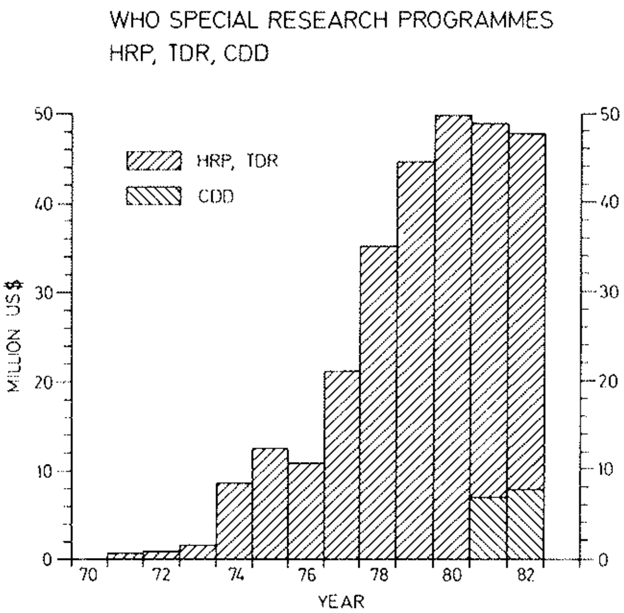


Figure 8.

TABLE 2. - Total contributions to TDR 1974-1984 by selected countries

	$ × 1000
Australia	2.769
Belgium	3.935
Canada	5.848
Denmark	25.560
France	1.506
FRG	6.602
Netherlands	7.784
Norway	9.681
Sweden	17.962
Switzerland	5.909
UK	5.285
USA	20.403
Minor contributions	11.706
	124.950

These programmes are quite unique for the UN system and might be one of the most successful projects undertaken. About 6000 scientists are working actively in these projects. This represents, undoubtedly, the biggest coordinated medical research effort ever and hopefully this will be a model for other fields.

I cannot resist making a suggestion on the future activities of this Academy. The Catholic Church is registered as a country in the European region of WHO. The Vatican is registered, but the Academy here is its international research advisor. The Catholic Church has something like 250 hospitals around the world that will, to some extent, collaborate with these programmes.

I am wondering if the Vatican and the Catholic Church couldn't play an increasingly important role in furthering medical research for developing countries in many respects. First of all, by making a contribution to one of these programmes. If so, maybe, this Academy could help in proposing a member on these global steering groups that are guiding the programmes.

I also think it is tragic in some instances to see how little the present aid agencies of large countries appreciate the need for support of these efforts, that are very important components of the development process in developing countries.

The Catholic Church has special possibilities to inform its membership of the importance of these projects that are aiming especially to improve the possibilities to prevent and cure diseases of children in the developing countries.

Govin Kumar M. MENON

SCIENCE AND DEVELOPMENT OF THE THIRD WORLD

Mr. President, you have asked me to make a presentation at this session on «Science and Development of the Third World». You have yourself addressed this question in your opening Presidential Address to the Academy; and in particular, you wanted that before we go on to discuss the role of the Pontifical Academy of Sciences over the future, we might consider the way in which science could bring real benefits to what is essentially the major part of human society — which lives today in what is referred to as the «Third World».

It is important to stress at the outset that this is not a new topic at the Academy. A document entitled «Science and Technology for Developing Countries» was produced some seven years ago. It would be worthwhile if I read the opening sentence of this document, to give a feeling for why we are concerned with this topic. The first sentence was: «The search for a new world order which will guarantee peace must be based on an adequate and well-coordinated development of all nations», for as Pope Paul VI said in his Populorum Progressio, «the new name for peace is development». Indeed, in several addresses that Pope John Paul II has given to this Academy, he has emphasized a basic feature, namely that the hotbed of all unrest, of conflict, and of wars, lies essentially in social injustice, whether real or perceived; and therefore, I do believe that an Academy such as the Pontifical Academy of Sciences has a very important role to play in considering what can be done to reduce injustice, to improve the quality of life in the developing countries, and to reduce inequalities between nations and within nations. Science has an important role to play in this, but to play this role successfully there is need to create appropriate organizational, management and institutional structures, establish interfaces between science and society, and develop effective link-

ages and relationships between developed and developing nations in pursuit of this common global objective.

The purpose of my talk today is not to go into the details of the total spectrum of all problems involved in this gigantic task. I shall only try to provide a broad perspective and outline a few basic thoughts which run through all of this complexity.

Let me give you three illustrative numbers. In our Academy we have today eleven Academicians who live and work in the developing countries; in contrast seventy-seven are from the developed countries. Again, in terms of the number of scientists engaged, or the extent of investments, less than five percent of research and development in the world is carried out in developing countries. On the other hand, if you look at the population statistics, of the predicted figure of world population of little over 6 billion by the year 2000, almost 5 billion will be in the developing countries, i.e., more than 80%. So you see the reverse situation, of the bulk of the world's population, only a small fraction of the world's scientific effort is made in the developing countries. Therefore, we have to address ourselves to the basic question: how does one ensure that science and, in a symbiotic relationship, technology, get nucleated, can be grown and appropriately applied in the developing countries.

As a background let us look at some of the basic characteristics of the developing countries. Prof. Sune Bergström has just shown a series of slides and maps relating to these countries. They are mostly located at low latitudes, in the tropical belt.

The populations are large, and growing rapidly. Most of the population growth figures range from 2 to 4% per year.

The literacy levels are extraordinarily low. In my country India, for instance, 40 years after Independence, we have attained a literacy figure of only 38%; and this essentially means that, with a population of around 780 million, we have one of the largest numbers in the world of literates, but equally one of the largest numbers of illiterates. Without question, the development of science is related to the development of education. I shall deal with that a little later.

Another aspect relates to the poor (immediately accessible) resource base. Normally, when one talks of resources, one tends to think in terms of money; and resources required for investments. There are other resources, namely the various types of national endowments. What most people tend to forget is that the most

important single resource of a nation is its human resource; but for this to be a truly meaningful resource it has to be nurtured and developed by education and by being kept healthy. At present, while populations are large and growing rapidly in the Third World, they have not become the resources that they potentially represent because of their poor educational and health status.

Another aspect which is characteristic of the developing countries is the extremely poor infrastructure that exists in terms of energy, transport, and communications.

These characterize all developing countries, though in varying degree. Some are better off; and some are worse off.

Let us now look at the basic problems that one encounters in the case of these countries. I shall list a few important ones, without attempting to be comprehensive.

First, there is the problem of population. I had referred to this as one of the characteristics of developing countries. The populations are large. They are rapidly growing in contrast to the largely stabilized populations of the developed countries, the industrialized North. This was not always the case. In the period say between 1750 and 1850, populations in the North grew faster at around 0.6%, while those in the South (the developing nations of today) grew at about 0.4%. In the next hundred years, 1850 to 1950, the North grew at 0.9% and the South at 0.6%. Thus whilst both went up, it was very gradual, with the South (or the Third World) growing at a lower rate. Today the situation is completely different, with growth in the industrialized countries being about 1%, and in the developing countries averaging 2.2%.

This has consequences across the whole spectrum of socio-economic development, particularly in terms of the basic needs of food, shelter, clothing, energy, etc., that have to be met. In this regard, let me give you just one illustration from my country. We have today a school-going population of roughly 110 million. A principal objective is to achieve universal elementary education. This is contained in the Constitution of the country, and was to have been accomplished long ago. And if that is to be accomplished by the end of our current five-year plan, ending in 1990, we will need to reach a total enrollment of almost 170 million children in schools. Just think of the magnitude of the problem; of putting 60 million children into schools before 1990; the demand for buildings, teachers, equipment, etc., is just staggering. And that is the sort of

scale factor that developing countries are faced with. Countries like Nigeria, Indonesia, Bangladesh, Pakistan, are all large countries; and none of them can be bailed out except through their own efforts.

The inability to provide satisfactory education, to the entire eligible population, leads to inequalities of all types. The dice are loaded against the poor, against the rural, against the female children and the older groups. They are the groups who suffer.

This, in turn, leads to problems on other fronts. For example, there is a clear correlation between population growth, birth rates and education. Let us consider two contrasting parts of my country. The southwest coastal State of Kerala has a low infant mortality with the highest literacy figures of India; whereas the Gangetic belt in the North has low literacy rates (and extremely low female literacy rates), the highest birth rates, the highest infant mortality rates with the highest population growth rates. Thus education, particularly of girls, is a key factor for control of population growth. This is because awareness, understanding and motivation are called for; these come from within; one cannot deal with this as a technological fix.

I have just referred to the strong correlation between growth of population and high infant mortality rates. The simple reason is that within the human being there is a basic desire for a continuation of life: as a species, and at a more personal level of oneself. Children are also regarded as a means of economic support. In earlier days, with high infant mortality rates, it was but natural for couples to have many children so that a few would survive. That is the situation still obtaining in most developing countries. If we can reduce infant mortality and, thereby convince people that a small family will be a surviving family, this will militate against high birth rates.

This is where the revolutionary developments in modern life sciences come in, which are capable of reducing morbidity and mortality. Prof. Bergström has dealt with these aspects in detail in his lecture. One of the important areas that he mentioned is that of infant mortality due to diarrheal diseases of childhood; here, a simple, oral rehydration therapy is what is called for, which has nothing to do with the miracles of modern science, or of frontier science. A little salt and glucose given with water to children would prevent a large part of the deaths arising out of shock caused by

dehydration. I have given this example because when you consider science in developing countries, there are two aspects. One relates to the optimal use of existing knowledge; this use has to be on a very large scale; and when I say large-scale, I am talking in terms of a scale of a billion humn beings. This involves education, awareness, creation of a scientific temper and management. The other is that in many other sectors, we need the most advanced science, and technologies stemming from the most recent developments at the cutting edges of science. This is so for areas in the health sector such as immunodiagnostics, vaccines, etc., in the telecommunications sector and many such areas.

Let me now come to an area of crucial importance for the developing nations: energy.

The developing nations consume, per capita, around 500 kg coal equivalent (kgce). The developed world consumes ten times as much, around 5000 kgce. North America consumes twice that amount, i.e. about 11,000 kgce. India consumes 250 kgce, around half that of the developing world. This brings out the tremendous variation in per capita energy use in the world. It is not my intention that 760 million Indians, growing at 2%, need to consume at 11,000 kg coal equivalent to achieve a meaningful quality of life. This would be a totally unreasonable extrapolation. But I would like to emphasise that energy is the key to development, apart from human resources developed through education. Energy is needed for agriculture, industrialization, generating employment, transportation and for meeting domestic needs. A minimum per capita availability of around 2000 kgce is called for.

Energy can be provided from multiple sources. There are the classic large production sources for energy: nuclear, thermal and hydroelectric; these generate bulk power which then has to be distributed through extensive transmission networks. But we must remember that a very large part of the developing world is in the rural hinterlands, which consume non-commercial, locally available energy, e.g., animal dung, fuelwood and agricultural residues. Three-quarters of India's population lives in its villages; 45% of the energy consumed in India is non-commercial. In this situation even when you set up centralized power stations, you get urban industrialized conglomerations in the vicinity which absorb that energy. Very little energy gets out for distribution; and the cost of the transmission and distribution network to carry the electricity to all

consumers is twice that of setting up generation. Thus for a long time to come, even with increased power generation, the rural areas, where the bulk of the populations live in the developing countries, will be short of electricity per capita compared to urban areas. This automatically reduces the quality of life in rural areas, particularly the opportunities for employment, thus leading to the rural to urban migration.

Let me now deal with some energy-society related areas. The primary use for energy in the developing world is for cooking. This is met principally through non-commercial sources in rural areas; and to a limited extent through the use of kerosene. In urban areas, it is met through kerosene, and firewood, and more recently natural gas. The principal use of oil in developing countries is as diesel/petrol for transportation and kerosene for cooking. Huge amounts of firewood from rural areas are brought to the towns for sale, to be used for cooking. With the growth of population and increased needs for firewood, there is destruction of forests, and of all green cover in the vicinity of human habitation. This leads to significant soil erosion, loss of topsoil and ultimately to desertification. Therefore, an important need (and I would like to stress this as a scientific problem), relates to providing energy where it is needed, even in small quantities. At the present, at these places, it is not needed in bulk. You require it for cooking, for heating water, for pumping water from below ground, and for small industrial operations. Renewable energy based on the sun can be accessed for this, through both physical techniques, like solar thermal, solar photovoltaics and wind, as also through biological techniques such as biogas, biomass conversion and energy plantations. The pity is that, in spite of a real need that can be clearly defined, with all the powers of science and technology, we have not been able to make headway in this vital area.

I have referred to deforestation; and I would now like to deal with its implications briefly. The National Forest Policy of India says that one-third of the country should be covered by forests. Officially one is told that the forest cover is 20-23%. If you look for real forests, figures will be closer to about 18%. Those who measure forest cover from remote sensing maps say that it is no more than 14%; and that India is losing 1.5m hectares of forest cover annually. Thailand has lost one quarter and Costa Rica one-third of its forests in the last ten years.

That brings me to a basic question which was referred to earlier, that of genetic diversity, which Prof. Arber has spoken about. The richest genetic resources in the world are probably in the tropical belt. A large part of these are in the natural forests of this region. But with deforestation and soil removal taking place, on the scale that is occurring at present, we would rapidly have lost forever these resources, whose value we may recognise only when it is too late. We have to conserve the natural tropical forests that are now left, and learn to create biomass to meet our needs. At present forestry is practised only as pure forest management. We did bring science and technology into agriculture, but this has not happened in forestry. It is important that we make this happen, with tissue culture, understanding of whole plant physiology, pest control, genetic engineering for various end objectives such as meeting stress conditions and so on. With this, the productivity for biomass generation should be improved so that the pressure on the natural forests reduces.

Food is a prime need of humankind. Dr. Johanna Döbereiner has, in her talk, covered at some length aspects of food production, particularly in relation to soils, nutrients and microbiology. I will therefore not go into any detailed technical discussion on these. What is clear is that we certainly need to grow more food to feed the already large and growing population of the world. We need to buffer humanity against adverse periods of weather. There is need for national and global food security systems. India is planning for a growth rate in agriculture of 4% per annum. From being a food importing country in the mid-sixties, we now have a large buffer stock of tens of millions of tons of food in the country. From a production of 50 million tons of grain in 1950, India produces 153 million tons per annum. It is hoped to reach 178 million tons by 1990 and around 225 million tons by the year 2000. These increases are needed; but how are they to be attained? We have reached the limit in terms of using available arable land. A great deal of agriculture today is being carried out on land that was once forest covered; this cannot continue without wiping out forests. A great deal of land under food production is rain-fed, arid or drought prone. So we have to ensure intensive agriculture by increasing crop yields through increased productivity. We accomplished the so called 'Green Revolution'. This was in a limited area of the country and needs to be extended. Our productivities are still quite low; in a

sense we have a great deal of slack that can be taken up.

In 1975, 54 of the developing countries were unable to feed their populations, covering one billion people. This figure will increase on the present basis to 64 countries. And so the numbers are going to increase in terms of the numbers unable to feed themselves. Such large numbers cannot be fed by food produced elsewhere. Even if food were to be so available, there will be no buying power in the deficit regions. We therefore need to work out solutions for food production on a decentralized basis which can grow with time. But intensive agriculture has so far been also energy intensive; and with energy becoming more expensive, food will become more expensive. The solution lies in low-energy intensive agriculture. Increased nitrogen fixation, and biological nitrogen fixation are fundamental areas of science where we need urgent progress.

Let me refer to the area of health rather briefly, since it has been covered rather extensively by Prof. Bergström. Prof. Christian de Duve concluded his address with the statement that there has been a fantastic revolution in modern biology, but we do not yet see a corresponding impact of it on society; he said, "please don't make promises of vaccines, don't make promises about cures for cancer,". I do feel that there is one area where these new developments in biology, particularly in immunology, can make an immediate profound impact, and that is the area of immuno-diagnostics and immunoprophylaxis. To illustrate: Prof. Bergström showed the epidemiological status of leprosy. The largest number of patients of this disease are in India. As of now this disease manifests itself in terms of deformities and discoloration. An individual with these outward signs of leprosy is a social outcast; and one's mind goes back to Father Damien and the compassionate pioneers. But leprosy is a curable disease. If one could know, well in advance of its physical manifestations, whether an individual has leprosy, the treatment can be started much earlier; the cure will be at lower cost, but more important, before there are the outward signs that society dreads. Leprosy is a disease which takes a long time to develop in the human system; and so there is plenty of time to diagnose; but this diagnosis will have to be based on immunodiagnostics, which is now feasible.

Again, in India we have 250 million people in the endemic belt for filariasis. This disease, transmitted by the mosquito, has to be

detected using samples of midnight blood; here again it should be possible to detect those who are infected through modern immuno-diagnostics; one can start treatment earlier and also reduce carrier populations.

Tuberculosis is still a killer disease in developing countris. One knows about tuberculosis when a patient comes coughing out his or her lungs in blood; or when it has done serious damage to other parts of the body. Early diagnosis of tuberculosis will imply early start to treatment, with greater chances of recovery. I believe that the development of immunodiagnostics at low cost and on a totally reliable basis is a possibility opened up through the spectacular advances in modern biology; and through this, morbidity, mortality, social stigma and costs of treatment can be reduced in the case of many diseases, particularly of relevance to developing countries.

Then there is the whole area of immunoprophylaxis. Prof. Bergström has made a brief reference to it. I would only like to mention that we have today vaccination against tetanus; and yet it is the second largest killer in India, and would be so in most other developing countries, particularly affecting pregnant women. We know again of vaccines available against poliomyelitis; these have been in existence for quite some time. But in India today we have the world's largest population of paraplegics due to polio. It is a rampant disease. It is not that vaccines are not available in the case of these and many other diseases, but the rest of the management system — e.g., the cold chains and quality control to ensure vaccine efficacy, delivery of the requisite number of doses, etc. — which is faulty. Scientific efforts are called for to improve delivery systems in the case of tools and techniques already available. But advances at the frontiers of science are also relevant to improve the efficacy in delivery. Can vaccines not be made more heat stable? Can we not ensure that fewer doses are called for? Can we not have cocktail vaccines to deliver several vaccines in one go? Can vaccines not be made more effective and with less side reactions or toxicity? Can we not have vaccines to cover a wider range of requirements? These are all feasible and will come about. The earlier we succeed, the more suffering and damage we can prevent.

Let me now refer to an area mentioned by Dr. Johanna Döbereiner: that of migration from the rural to the urban areas. If you take the number of cities with populations of more than 7 million, you find that there are, at the present moment, nine such

cities in the North and sixteen in the Third World. Mexico City is the largest of these. But if you consider the situation in the year 2000, there will be 60 such cities; 45 of these will be in the developing countries; and some 18 or 20 of these are going to be more than 10 million. We will be faced with a very large number of megacities and all the problems of urban growth, needs, conflicts and the like. Why does this happen? Why do people move from the rural areas to the urban areas? Very largely because of the neglect of the rural areas, in terms of the quality of life, in terms of energy availability, in terms of employment opportunities, in terms of entertainment. Modern developments in science and technology provide us possibilities to redress this neglect. These opportunities arise through space technology, renewable energy technology, biotechnology and so on.

We now have geostationary satellites which can look down at one-third of the globe from their vantage point. With such a satellite, instead of building a very elaborate wholly ground-based communications system, every hamlet in the country can be connected to every other hamlet using space communication technologies. Modern microelectronics has made possible extremely complex systems with very large functional capabilities, at extremely low cost, of low volume, and with low power consumption. Because of this, satellites can handle extraordinarily high degrees of complexity. Contrast this with the first Echo satellite where you just bounced signals off a balloon satellite! Thus, modern communications satellites, meteorological satellites, broadcast satellites are all capable of very complex operations. As a result there is much less complexity on the ground. The ground systems are low cost and can be extensively deployed. This has totally altered the picture concerning the economics of ground systems for communication, broadcasting and remote sensing. As a result, being in a village in a rural area need not be a handicap. You can be connected to everywhere else in the world in every sense of the word. Removal of isolation and possibilities for entertainment that are opened up will be major steps in reducing the handicaps of rural life. With renewable decentralized energies when these are developed, it should be possible to set up industries and significant employment opportunities in rural areas reducing another of the major handicaps to living in such areas that exist at present.

I therefore believe that space technologies and renewable

energy technologies improve the quality of life in the rural areas and may therefore stem the tide of rural to urban migration. But for all of this to happen there are certain requirements. Dr. Chagas referred in his Presidential Address to the Conference which was held in 1964 in Geneva, the UN Conference on Science and Technology for Development. This was followed, fifteen years later, by another Conference in Vienna on the same topic. When the 1964 conference was held, there appeared to be the feeling that there was a technological fix for all problems faced by humanity. There was a feeling of euphoria that science was a magic wand. You wave it and you have development. One learned in the fifteen years between these two Conferences at least one lesson, that this is not so; and, if you want to develop the developing countris, they must develop their own internal strength. This means that endogenous capacities must be built in the developing countries themselves; and our role in the Pontifical Academy, or indeed of any international academy would be on how to support and grow those capabilities.

Let me give you one instance of an initiative that arose through the Pontifical Academy, not directly through a scientific meeting but as a fallout. Five years ago, Dr. Chagas, Dr. Salam, Dr. Pavan, Dr. Döbereiner, Dr. Roche and myself were having lunch, when we discussed the problems that I have just referred to. We felt that there are several developing countries such as China, India, Brazil, and so on, which have their academies of science to bring about a coherence and cohesion in their national scientific communities. This is not the case of a large number, of a hundred-odd developing countries. The number of scientists in these countries is very small; and there is no viable national structure. They can belong to academies of other countries as foreign members; for this they have to be very distinguished. We felt that there would be an advantage in creating an Academy for all the scientists of standing in developing countries, an Academy of Sciences to which they feel they have a right to belong. The Third World Academy of Sciences was thus born in 1983.

I shall not go into the history of what followed. All I need say is that the Academy has been in existence for just three years and has moved ahead with great vigour largely because of the initiative and efforts of our founder, President, Prof. Abdus Salam. Election to the fellowship, Council and Academy meetings, North-South and South-South Conferences on Science Co-operation have all been

organised, as also an extensive programme of action. An African Academy of Sciences has been born as a result of African scientists coming together at a Conference of the Third World Academy of Sciences. We now have a range of South-South fellowships, of the order of 200, which will enable scientists from countries in the South to travel to other countries in the South. There is provision for research grants, for research to be carried out in developing countries. There is provision for library and equipment grants where this is required. Very significant support has been provided by the Government of Italy. The purpose of this whole exercise is to find points of nucleation for science in the Third World and to grow them, whatever the areas are, because this will lead to the generation of leadership which will in turn have the capacity to find out what the problems are and what should be done about them. Without endogenous capabilities in the developing countries, it will never be possible to tackle their problems.

I would now like to refer to one area which is of very great concern. In general, at meetings of this nature we talk about science. We also know that, today, with relatively short gestation periods, technologies result from these scientific advances; these in turn have an impact on the growth of science.

One such major area is microelectronics which is leading us to an information society with all of its ramifications in computerization, automation, robotics and with a wide range of sectors which have already been transformed in terms of manufacturing techniques through computer-aided design, computer-aided manufacture, flexible manufacturing systems, etc. Industrial processing is thus being transformed rapidly.

Totally new materials are now being developed. A large number of developing countries depend on commodities such as cotton, jute, sugar, which they produce and sell. These can all be largely replaced through new materials. Developing countries depend on employment-oriented industries, but the very nature of industry and employment opportunity arising through it is being rapidly changed. These developments have extremely serious implications in the future of all developing nations.

One of the most serious problems that the developing nations are faced with is that of so-called external debt. This is a result of adverse balance of trade, with commodity prices going down and increasing protectionism, increase in oil prices which has particular-

ly affected oil importing developing countries, drying up of concessional aid, serious difficulties in international exchange rates and poor management of many developing countries. The external debt of the Third World is currently close to 1000 billion dollars. Latin America by itself has a debt close to 400 billion dollars. There are individual countries like the Sudan, the external debt of which is larger than its gross domestic product.

It is clear that new initiatives and restructuring of the international financing system are called for to solve this problem in a meaningful way. Small adjustments will not suffice. The developing countries need to export and be helped to do so. What can they export? In the past their exports have been raw materials, but prices of these have gone down significantly. The need for exports from, and for employment in the Third World countries would call for new trading arrangements that will ensure significant value added production in the developing countries. Technology blending of the new emerging technologies with the more traditional technologies that Third World countries are familiar with, would need to be worked out and implemented. Where production based on wholly new emerging technologies has been established in the recent past, for example in South Korea, Taiwan, Singapore, an examination of their economies shows that all of them have gone down in the recent past; this has been a result of changes in industrial and trade patterns and exchange rates. Developing countries will for a long time to come have to be anchored to their low cost traditional technologies, but enhanced appropriately through judicious blending of new technologies.

We have to accept the inevitability of rapid scientific advance. We have had glimpses of the advances taking place in various presentations over the last two days. These advances will result in new technologies, that will impact on production, employment in which warp will be structured the future. These will increase the gap between the developed and developing nations. It is not a question of keeping up with the Joneses when I talk of the gap. What is important is to realize that there will be a total separation of economies of the world, with inability on the part of the developing countries to lift themselves up by their own bootstraps. A very large country like China or India may be in a different position, but I am talking about the hundred-odd developing countries as a whole.

I believe, therefore, that new initiatives and innovation are called for. I am not talking of scientific innovation only, in the narrow deep areas of individual sectors of science. We need innovation relating to large systems, covering the broad complex areas of developing new knowledge and techniques at the frontiers of science and relevant technology, application of this and existing knowledge, management of such applications involving highly transdisciplinary sectors including societal aspects and evolving a spirit of true cooperation. Over the past few days we have heard about spectacular new discoveries and ideas relating to high energy accelerators, the structure of nucleons, the discovery of $W^{\pm}$ and Z^{o} particles, cosmology and the origins of the universe, advances in chemistry, the basic structures and functions in living systems and engineering these, etc.

All of this is the reflection of an increased understanding of nature, and is the heritage of humankind everywhere. We see a whole range of diversity of life forms and yet the underlying unity; we can marvel at our increased knowledge and capabilities and still feel small about our inability to deal with the myriad problems faced by humanity, some of which I have touched upon in this talk. We have a diversity of cultures and it is this diversity which is the richness of the human heritage. It would be unfortunate if science and technology, which have made us so aware of the underlying unity in physics, cosmology, biology, etc., which has made the world a small place through advances in communication, transportation, space technology and so on, should be the means to divide the world into compartments of haves and havenots. So I would like to read to you one paragraph from the volume on "Science and Technology for Developing Countries" (PAS, Scripta Varia *44*, 1979):

"To preserve the culture of each nation and to develop it in a way that is conducive to true progress for civilization, we must avoid all forms of colonization, not replace political with scientific-technological colonization. Therefore the scientific-technological set-up in each country of the Third World must be made autonomous, so that progress can be made toward scientific collaboration among all nations of the world. Indeed it is not possible to conceive of the international community except as an ideal centre in which all the countries of the world come together, thus creating a group of national scientific communities. A country that is scientifically

backward cannot become a part of the world scientific community and will always be regarded as inferior or backward. Cooperation among nations requires that the more developed nations honestly warn the developing countries against the errors and the harm that have been caused by the undue predominance of scientific-technical activity over man's other activities, with the resulting serious cultural disequilibrium and disregard or loss of fundamental human values and the irresponsible exploitation of nature which have disturbed the ecological equilibria."

I therefore hope that we will bend our efforts in growing these and other scientific capabilities in the developing world, and work together in many areas at the cutting edges of technology and at the frontiers of science. The primary capability to work at these frontiers lies no doubt in the developed countries, but a large part of the problems that exist, to which these capabilities can be applied with great creativity and great satisfaction, are in the developing countries. I hope that through these discussions in the Pontifical Academy of Sciences we can move towards the achievement of a true spirit of cooperation.

Crodowaldo PAVAN

SCIENCE AND TECHNOLOGY IN AND FOR BRAZIL

The world is now going through a scientific and technological revolution whose impact on human society can be considered equal to or bigger than the pressure put on men by the discovery of fire, the use of metal tools, and the transition to industrial production on a large scale.

The true inner nature of this revolution is characterized by the rise of new perspectives for man through the potential use of his intelligence and collective labour. Such impulse is so vigorous and above all necessary that, in industrialized countries, 70 to 90% of the GNP increase is due to conquests accomplished in the scientific and technological field.

Due to this fact, Third World countries like Brazil, immersed in economic crisis without precedent, set themselves in the struggle for the creation of a technical and industrial complex, capable to develop what is called the «science of the future». We hope that this initiative will provide a significant change in the productive structure and international relations at middle term.

Today Brazil holds an important place among Third World countries. We have a well developed industrial park, ranking the 8th in the world, where modern goods are manufactured through efficient and competitive techniques.

Nevertheless, in parallel to this developed industrial structure, a perplexing social frame emerges. Brazil with all its potentialities reflects one of the worst income distributions, making practically more than half of the population, which reaches 130 million inhabitants today, live in poverty.

We have a GNP (gross national product) of US$ 1,900.00 per capita. This, nevertheless, does not reflect reality, as 20% of the richest people in the country accounts for 70% of the income and the other 40% of the poorest only accounts for 5% of the income.

Brazil has an infant mortality rate of 80 out of 1000 for children up to one year of age. 400 thousand children die, every year, in the country. These figures are too high and are not compatible with its economic development.

According to recent statistics, the Brazilians have a life expectancy of 63 years, that is at least 10 years less than a citizen born in a developed country. The illiteracy rate reaches 20% among people over 15, that is, more than 15 million people cannot read or write.

These are very alarming figures. They show our state of social underdevelopment. Nevertheless those are figures similar to 60 to 70% of the underdeveloped countries in the world. The solution to our problems, as to other developing countries' problems, must necessarily go through the economic sphere and more precisely through the negotiation of our external debt.

In our case, we have today an external debt of approximately US$ 105 billion American dollars and we are paying US$ 9 billion per year of interest, which is equivalent to 5% of our gross national product (GNP). This is an extremely high amount of money that Brazil is sending abroad each year if we consider the level of poverty existing whithin the country.

At short term, this continuing remittance of funds that are generated in the country is a burden too heavy for us Brazilians and completely unfeasible at long term.

We will only be able to solve our serious social problems if we begin using more efficiently the income we generate.

Parallel to these problems we do witness that industrialized and even developing countries are not interested in the solution of human poverty. Expenses with war weapons go on increasing to the detriment of development. Nowadays, the world is giving more than 600 billion American dollars in payment for defense. For human health it spends 450 billion, whereas developing countries only spend 41 billions or less than 10% of the total of the world expenses in this area.

On the other hand, the developing world is giving twice the amount it spends for child care in payment for war weapons. On the whole, world expenses for weapons exceed all the income of half of the poorest people of humanity. These figures show a complete lack of respect for the human being.

To react to these uninspiring figures, I maintain that we must direct scientific and technological development to search for a

solution for all our problems. I believe that science and technology can make an important contribution to the well-being of humanity.

Nevertheless the mastering of scientific knowledge and its technological applications has also become one of the most efficient forms of domination and demonstration of power in this modern world.

At present 95% of what is generated in Science and Technology is concentrated in very few countries, the developed countries, while the other 5% is generated by the rest of the world. Within this 5%, Latin America generates only 1%.

Data show the increasing technological gap that keeps developed apart from developing countries. However, we in the Third World are aware of this situation and we have been discussing and acting in order to improve the scientific and technological performance of our countries.

In this sense we defend some general proposals for the Brazilian Society, some of which we are going to present as follows:

— Specialized human resources training should be intensified and oriented to national problems. We must develop the exchange between universities of developing and developed worlds aiming at achieving an efficient use of our resources.

— We must rethink the present structure of preparation of our high level human resources. The costs are too high when compared to our deficient financial resources. The simplification of doctorates is extremely necessary. It should be done through their orientation toward national problems and their solutions and not imitating courses or curricula of foreign universities.

— We think that information exchange among Latin American countries will strengthen the whole scientific and technological structure of the region, generating a multiplying effect on the production sector of the continent.

— The elaboration of national projects in the sectors of high technology is one of the biggest challenges Brazil is facing at present. We are undergoing deep social changes that require the adoption of a new industrial structure and new ways of social conviviality. The technological gap between first and third world countries reflects the enlarging levels of dependence in relation to the great nations.

Finally we must elaborate an efficient strategy for scientific and technological development so that it will meet national requirements emphasizing social, cultural and environmental aspects.

Today the lack of technological innovation threatens with obsolescence the industrial structure of the industrialized countries. Less developed countries have little to lose, considering their relatively smaller assets and interests. The moment we face is one of exercising the right to decide our own future, of consolidating our autonomy of decisions, and of making good choices regarding the uses of science and technology.

Brazil is now trying to identify its relative opportunities and propose to society as a whole orientations that will lead the nation to take the most and necessary possible advantage out of each decision.

Our experience indicates that the integration of education, scientific research, technological development and industrial production is the best way to be pursued. This integration is the indispensable means to reach a sovereign development at the service of a democratic society whose progress must be shared by all.

Brazilian society can generate the technology it needs and it already has the conditions and knowledge to do so, with economic and social results echoing within and outside the country.

The Brazilian government has engaged itself in the promotion of the integration between basic research organisms, universities, technological institutes, industry and business groups.

Industrial centers of technology are emerging all around Brazilian universities. In some of these corporations scientists and businessmen develop important outputs in the optical, metallurgic and ceramics sectors. More ambitious projects are being developed in these industrial centers and, in some cases, they can make Brazil pass from technology importer to exporter.

Still in the context of making efforts to develop new technologies, it is necessary to emphasize biotechnology, which emerges as an important segment of the economic activity in order to incorporate scientific knowledge into industrial and agricultural production.

The technological innovation that brings us biotechnology represents a great impact on some strategic sectors such as health, energy and food. These sectors present the possibility of expanding their production and productivity at levels compatible with the increasing demand of biotechnology. Generating our own technology will reduce our degree of dependence in relation to central countries; this also can apply to the sector of pharmaceuticals.

In this field, ranking seventh on the medicine western world market, Brazil imports 85% of the chemicals that are present in our medicines, which is equivalent to US$ 350 million American dollars per year.

Essentially, the Brazilian pharmaceutical industry manipulates imported input of high technological content and high aggregated value produced in an extremely concentrated form. The 50 largest companies hold 82% of the world market.

The fortification of the industrial and technological capacity of the private national companies and qualified human resources training is necessary due to several economic and strategic reasons and to make the increase of internal pharmaceuticals production possible.

Brazilian society cannot continue so dependent and vulnerable in such an essential field to social life and therefore to its independence. In this sense, this month we signed an agreement between public and private national corporations aiming at establishing a pilot unit to absorb and develop biopharmaceuticals. This will be the first step for the creation of a national competence in the sector, reducing external dependence.

Informatics also constitutes one of the most powerful tools to irradiate innovations aiming at the creation of new products and new markets. The impact of the so-called "Micro-electronic Revolution" accelerates the technological progress, continuously modifying several industrial branches of the production structure.

In Brazil, informatics developed in an exceptional manner. From 5 national and 3 multinational corporations in 1978, we moved to over 300 national companies. Only the national manufacturers of equipment engage more than 30 thousand people. They generated around 6500 new jobs in 1985, having a fundamental role in society.

In the recent past there were a very small number of Brazilian researchers working on the base of projects in micro electronics. Today with the market reserve established by law, we have several thousands of them.

The sector is developing at high rates, around 30% per year. It tends to maintain this rhythm during the next years due to the huge potential of applications and size of the market. The applications of informatics are diffused at the electronic complex level as well as at other levels, irradiating its effects on the whole set of productive

activities either private or public, and mainly at the industrial and service levels.

We do consider it, therefore, as an industry still in formation with aspects related to the national security, and to the strengthening of the country's balance of payments. For these and other reasons the present policy for informatics should be maintained.

Ladies and Gentlemen, I have stated facts and opinions on various topics of our concern: the relationship between science and development; the ambiguity that exists in the potential use of science; the incoherence in nations' attitudes towards war weapons vis-à-vis the basic needs of their people; and the contradiction posed by Brazil's enormous achievement in industrial production and the miserable condition of its population.

I have also manifested my belief that science and technology are sources of hope to mankind only if fused properly. If paying due respect to the environment, to established culture, social values and political systems, I have also tried to suggest that science and technology are means to achieve a good life, both material and spiritual.

Moreover, I have given illustrations of what I think are good uses of science and technology for development such as the efforts made in Brazil with biotechnology and informatics.

To end this presentation I want to share with you my feelings of caution and hope. I wish to call your attention to the great responsibilities that face this Academy and all of its members in present times: we must continue to act and endeavor to make a transition to a better stage of life, intense in its recourse to science and technology but, at same time, mature and experienced enough to know the limits of these activities. Enough not to overestimate their potential.

It is our duty, as members of this important centre of reflection about science and its use, to defend scientific activity, to recognize our social responsibilities and to be active in the struggle for a humane scientific development. To me, this is the essence of the discussion about the progress of science and the future of mankind.

Sa Sainteté Jean Paul II est reçu par le Président Carlos Chagas.

SESSION PLÉNIÈRE

LE RÔLE DE L'ACADÉMIE PONTIFICALE DES SCIENCES DANS LE PRÉSENT ET LE FUTUR

La discussion sur ce thème a été précédée d'une brève introduction prononcée par le prof. Carlos Chagas:

We have to go now to the last theme of our agenda, which is the "Future Role of the Academy and its Problems". Thank you, Dr Pavan, my dear colleague and friend, and I think that from the discussions that we had here, the previous discussions, the discussions of this day, we have had the opportunity to see, first of all that in a certain way the Academy has followed the progress of science and has informed the Church and has been able to establish ties between the scientific community. We should now discuss what we expect from the Academy. I think that any Academy in the world has to orient the government in questions related to science and technology and the interaction of science and technology. This is the role of the Academy: to promote science and to study the impact of science and technology on the society.

Now we are not in a State, we are not a State in the sense of other nations, but I think that the Academy can really influence very much, in many aspects it can contribute to the understanding of science by the Church, the progress of science by the Church, but also it can, in my opinion, be a centre of the development of many ideas which are rather difficult to be discussed in an academy, a national academy in which there are certain ties related to many problems which cannot be passed over.

I would like to give the floor to any of you who wish to speak, but I would only say this: that our activity presents some difficulties. First of all is that when we organize a meeting, we have always to find some help to coordinate the meeting and this is not easy. So

that it's much easier to say that we should take this and that subject, but it's not so easy to find who will help me organize the meeting but I think that the Academy has been quite active in a certain sense, yes, in all senses. I'm extremely grateful for the help which has been given to me, either directly or indirectly by my academician friends, but also by many of my friends of the scientific community. Now the theme is open to discussion.

Plusieurs Académiciens sont intervenus sur ce thème.

Anatole Abragam

Mr. Chairman, if I may make a brief remark in connection with everything that has been said about ecology and about the Third World and the developing countries. I know very little about ecology and very little about the Third World but I do know a little of developed countries and there is one remark I wish to make which I think is very central. It is about the nature of man: we all know that men are selfish, opinionated, jealous, vain.

So far I have described our own scientific community; but then they are also, lazy, greedy, cruel, often murderous. All of what I am trying to say is not necessarily a matter for despair, but I think that whenever one makes plans to help humanity one has to keep this in mind in an objective and dispassionate way and to remember that the best plans and the best intentions can fail unless at all times one remembers these characteristics of humanity. Thank you, Mr. Chairman.

Christian Anfinsen

On the basis of Dr. Abragam's wise statements on the nature of man, I would like, first of all, to nominate Professor Abragam for the Presidency of the United States or some other equally influential office. I found the talks on ecology, on population and disease very interesting because they are so very important for the human animal. However, I simply want to state, whether or not it is a function of this Academy, that, in my mind, there is really only one

important problem to consider, now and henceforth, and that is how to abolish the nuclear bomb from the surface of the earth. If there is some way we can help with that, I am sure we would all be eager to participate.

André Blanc-Lapierre

Je voudrais faire une remarque. Je pense que les travaux de l'Académie Pontificale et ceux des semaines d'étude sont de très bonne qualité mais que nous devons faire un gros effort pour accélérer leur publication et étendre leur diffusion. De même, j'ai constaté, en posant des questions dans mes relations, que l'Académie Pontificale des Sciences était peu connue, dans le monde laïque mais aussi dans celui des autorités religieuses locales. Ce sont là des points dont l'Académie Pontificale des Sciences doit se préoccuper, ce qui signifie, aussi, que nous tous, ses Membres, devons l'aider dans ce sens.

Alexander Rich

I believe that one of the most effective meetings we have had in the past few years has been the meeting of the Presidents of Academies. It addressed the problem of nuclear war. It was referred to in several of the comments made by the delegates from visiting Academies and in many countries it was widely publicized. In the United States this publicity was one of the principal vehicles for letting the population as a whole know of the existence of this Academy.

This Academy is in a unique position in that regard. It is an international Academy, as distinct from all the others, which are generally national. That statement was a very good one and very effective. But of course, to put it mildly, it did not solve the problem. The nuclear problem is with us and it will be with us for many years to come. I would suggest that it would be reasonable to think of having other meetings of that type. It represents a way of periodically pooling our collective wisdom and making some observations which are then delivered to the Heads of States as these

were. I believe it is an opportunity for us to work on this problem in a continued fashion in the future.

Marcos Moshinsky

I would like first to address myself to the observation of Professor Anfinsen. We certainly agree with him about the importance of the problem of the dangers in nuclear war, but I don't think that this is the only grave problem that we face. Probably people that live in the developed nations don't realize the amount of frustration and of hatred that there is in the Third World and maybe the best illustration of it could be by saying that it is not communism that these people can turn to, but Khomeinism, because Khomeini represents this type of reaction maybe better than anybody else. So I think that in connection with the problems of the Third World, this is just as grave a problem as the other one because this can also bring very serious consequences. Now I certainly agree fully with what Menon said and he expressed very well the necessity of self-reliance. In fact there is this big problem about the cultural well-being of the people in the Third World in the sense that, for example, you have the people living in shacks, they have no running water, no sewerage, but they have television and they can give you the names of the rock stars that are popular all over the world, of the soccer players, but they know very little really about their own countries.

So the necessity of self-reliance is a very fundamenal thing, that we must develop from the inside. But I want also to be rather modest. Certainly the Pontifical Academy of Sciences is a very important institution but what it can do is limited. So I would like very specifically to propose the following: that in some way we study here in the future how to improve the level of science education in the Third World.

Salimuzzaman Siddiqui

Thank you, Mr. President, I have just a few words to say with reference to all that has been talked about. Firstly, that in the Third World countries very little is spent on research and development

because most of the budgetary provisions are swallowed by armaments for defence. This is mainly due to what Aldous Huxley has called "the curse of nationalism", as against the one word concept inherent in the philosophy of the Vatican Academy of Sciences. In the present global situation which is threatening human survival on this account, the superpowers avoid direct conflict and fight out their battles in the Third World countries. The resulting balance of terror that we are going through has been aptly summed up by the great historian Toynbee in his observation that "the yawning gap between man's capability to kill and his moral status is of such dimensions that the mythical hell could barely fill it". Unless this situation changes, all that is left to us today is to do whatever we can in this world of darkness.

Charles Townes

Well, I would agree that the possibility of nuclear war is the most immediate and profound threat. We have worked on this problem. I think we should continue to work on it and also on problems of conventional war and conflict. Nevertheless it does seem to me that the other most serious problem is that of the developing countries. The problem of population pressure, the problem of differentiation between rich and poor and, if not social injustice itself, at least the perception of social injustice. Science not only has brought atomic weapons but has also exacerbated the problem between the rich and poor because science has changed the nature of wealth, and the nature of power. Science inevitably emphasizes possession of capital, and of education, particularly a background in science, and thereby makes much less valuable human physical labour and raw resources, putting the underdeveloped countries in a still more difficult position. Hence while science has in some ways, certainly in health, improved conditions for the Third World countries, yet I think it has enlarged some of the differentiations and given a new twist to the situation of poor understanding between the different worlds of the rich and the poor.

I believe that this area is worth a good deal of thought on the part of a scientific body like this as to what to do, and what types of approach, education, emphasis, or accommodation in both de-

veloped and undeveloped countries might be most helpful. Even helping the world realize that it's science and technology itself which has exacerbated the problem, might be of some value. Finding ways in which these developing countries can in their own right make their way, also involves some aspects of science. I presently believe that perhaps the most important and clearest solution is one of education because, given the fact that human raw labour and raw products are no longer so important from the economic point of view, education is itself a very important form of wealth. Education, furthermore, is something which is not in itself capital-intensive, and towards which the effort of the people themselves and the local governments can accomplish a great deal.

One sees in the communist countries perhaps the most striking success in this respect. At least in the lower grades of education they have done remarkable things and I think the democracies have not shown up very well by comparison, primarily for lack of emphasis on education. It seems to me that in areas of education there is a real opportunity for countries to help themselves. We in the developed countries must of course do our part. Education not only will create a kind of wealth and understanding but, as has been pointed out, it is also a very big factor in the control of population.

My own ideas on these matters are not well-formulated, and I wonder if the ideas of any of us, particularly those from the developed countries who are not accustomed to working with these problems, are adequately developed. It does seem to me that the thought of the Academy, and an effort to understand these problems and bring them to the world's attention, could be important along with our efforts on the problems of military conflict. I would also link the two in a certain sense. It is indeed true that military expenditures and terrorism are a real part of the economic problem for developing countries and that these are linked with actions of the great powers and with their weaponry. There is a very close interplay between these two.

Bernard Pullman

I would like to make two comments, two different comments on quite different subjects.

The first one concerns the problem of the nuclear bomb. Of course, the nuclear bomb is a scourge, a disgrace for humanity and it

is thus a natural request that it should be abolished. A number of scientists feel a particular responsibility in this respect because of the contribution of fundamental science to the development of this horrible weapon.

The problem is, however, that if we concentrate exclusively on the atomic bomb and its abolition, we are not going to liberate the world from the danger of war. On the contrary, such a simplified approach may even lead to a reverse effect. Suppose that by some miracle, the atomic bomb would disappear just today from the surface of the earth. Just today and by a miracle. I am afraid, that what we didn't have for forty years now, I mean a world war, the very thing that we are afraid of, would break out very quickly.

This is so because, although the atomic bomb is a particularly horrible means of destruction, there are many other means of destruction also, which unfortunately have gained today a great potency, and the disequilibrium in the distribution of these other means of destruction is so great and so significant that one can unhesitatingly say that if it wouldn't have been for the equilibrium in the terror of a nuclear conflict, a war would have occurred already or would occur rapidly in the world today.

Therefore I think that it is dangerous to stress only uniquely the necessity of destroying the atomic bombs. Disarmament has to be operated in such a way that the disappearance of these bombs should not produce a disequilibrium which would immediately result in a war, whether "classical", chemical or bacteriological, who knows. A proof of the validity of my viewpoint can be found in the very recent events related to the Gorbachev-Reagan meeting in Iceland. When the media started suggesting that the goal of this meeting could be a drastic limitation or suppression of atomic bombs, one could immediately feel, in particular in Europe, the fear that if such a disarmament would go far, then the absence in Europe of equilibrium in other forms of armaments would create a void in many places. And nature has a horror of a void. So that this could have very disastrous results.

It must be clearly realized that peace is one and envelops a number of factors. We should not be hypnotized by this horrible atomic bomb so as to forget or neglect the other "bombs". Whether you want it or not, the horror is to a large extent what keeps the equilibrium now and preserves peace. Surely it seems degrading for an intelligent humanity to owe its preservation to such a situation,

to owe it to what seems to many an absolute evil, but as was reminded here earlier we live in an evil world.

My second comment is completely different. As you have said yourself, Mr. President, in your introductory talk, when the Academy was created it consisted of 70 members, the same number as that of the Cardinals. Since the creation of the Academy, 50 years ago, the number of Cardinals was greatly increased and this corresponds to the increased complexity of the present world. Would it be reasonable that the Academy could evolve in the same direction? There are a number of nations that are not represented here. I know the problems that the representation of some of them raises. Would it not nevertheless be advisable that we keep in mind the necessity of our development so that we could represent as much as possible all humanity?

Max Ferdinand PERUTZ

I should like to talk, not about the problems of the Third World, but about those of Britain and other Western societies. Britain is in the process of being split into a developed and an underdeveloped country. The developed one consists of the employed, whose standard of living is high and still rising, and the underdeveloped one consists of the unemployed who now number about 3.5 million and who live at the subsistence level. In Spain 20% of the working population is unemployed, and many of them have to beg in the streets. Unemployment has several causes, one of them being the high technology and automation created by scientific advances which we, the scientists, have made possible. There is no way of averting this trend. We cannot turn the clock back.

In Britain mass unemployment goes hand-in-hand with a shortage of skilled labour. There are many vacant jobs, but they cannot be filled, because there are no candidates with the necessary qualifications. Many of the unemployed lack the basic education that makes them employable in a modern world. Adults of all ages could become employable if there were the teaching methods and the political will to give them the required technical education. Similar problems exist in many Western societies, including the U.S.A.

The split of our societies into those employed and prosperous,

and those living at the subsistence level without hope of ever finding any creative or productive work, is just as immoral and politically explosive as the North-South divide that other speakers condemned. You may argue that this is not a problem to which our Academy can make a useful contribution, but I believe that we could do so by organising discussions on the educational and economic problems of re-integrating these millions of unemployed, who are our own people, into our prosperous societies. The least we could do is to show our concern, as scientists, for a problem for which we are at least in part responsible.

Stanley Runcorn

I would certainly like to support what Dr. Perutz has just said. I think that widespread unemployment is a developing tragedy in the Western world which is an unhappy result of the increasing development of science and technology. But I would also like to ask the Academy to pay increasing attention in future years to the serious and accelerating overloading of the biosphere, maybe a catastrophic overloading. I am not an ecologist but I've seen figures which are truly frightening. One, by the World Wildlife Organization, is that by the end of the century one-third of living species on the planet will be extinct. It is of course due to the pressure of population and the natural desire to raise people above the subsistence level by clearing land for agriculture. Of course, the destruction of the rain forest is attracting much attention: some figures on that are also very frightening. Apparently the rain forest is disappearing at the rate of ten times the area of Manhattan a day. An area equal to the Amazon rain forest will have been cleared by 2010 A.D. It would indeed be absurd if we managed to avoid the great catastrophe of nuclear war and yet allowed the human race to destroy the biosphere on which it depends. Our theological colleagues here would say it much better than I can, but central to the Judeo-Christian tradition as set forth in the Bible and also in other religions, there is central respect for God's creation. I feel this is very much bound up with the problems of ecology and I think that the Academy should pay great attention in future years to these issues.

Maxine F. Singer

Thank you, Mr. President. From the comments during the last half hour, and also listening to the various talks this afternoon, there are a variety of problems that many people have identified as being critical. Among them are the problems of food, the problems of health, particularly as it's impacted by infectious diseases, the problem of ecology and even the problem of greed. All those problems are exacerbated by the population problem, which people have also mentioned. Thus a large number of issues are influenced by that problem. In trying to put things into a better equilibrium, both with regard to food supplies and with regard to health and perhaps even to greed and ecology and the environment, I think we need to pay attention to the problem of population.

I was very struck by something that Professor Menon said in the course of his wonderful remarks. He talked about the very direct effect of the education level, particularly of women in Third World countries, on the birth rates. I was interested in that because, in coming here, I've been particularly interested in trying to think about ways to deal with population problems in a manner that would be appropriate and acceptable for the Church. I think it is part of the duty of our Academy to consider the scientific advances and, I now learn from Professor Menon, also questions of education, that would lead to appropriate and acceptable ways to deal with population problems. I think to a very large extent this is a scientific problem and therefore it's the kind of problem to which our Academy could address itself usefully. I would hope that this could be on our agenda for the near future.

John Charles Polanyi

Thank you, Mr. President. I actually put up my hand some time ago and I'm glad that time passed because I find myself in warm agreement with much of what has been said.

A discussion by this Academy of the problem of the control of the world's population, what approaches might be used, I think would be a very appropriate and worthwhile thing. We've just heard about that from Dr. Singer.

The subject that was first introduced by Professor Anfinsen

and then picked up by Dr. Rich and Dr. Townes, the danger of nuclear war. I sympathized with Professor Pullman's reservations; the way I took them was: let's not be obsessed with schemes for disarmament to the exclusion of all else. On the other hand, I feel that this area is of enormous importance and can be approached in a way which would probably meet Professor Pullman's reservations. We should ask ourselves what we would consider to be a world in which (I was going to say survive, but let's try and do better) a world in which we could live and prosper, given the fact that a whole range of weapons of mass destruction have been discovered and are not likely to vanish from the face of the earth. Somebody mentioned Reykjavik and one couldn't help but be struck there by the fact that the discussions were confused, oscillating from one "liveable" world in which we would hide ourselves from nuclear weapons behind a shield, to another liveable world in which we would disinvent nuclear weapons (so it seemed to be implied) by removing them from the planet. I don't think that either of these are worlds that one can really contemplate, and I think that the wisdom of this group in trying to define a world in which we might survive and prosper would be very helpful. Let me say that I don't talk about problems of development because I am so ignorant about them, but the tragedy of nuclear war that Dr. Anfinsen first referred to would be a tragedy for the entire globe, and equally for those who are at present clinging to existence.

If I might raise one topic which hasn't yet been raised, I do so because I promised I would in conversation with other people here. That is the possibility of a discussion on the ethics of science, ethics in science, or the ethics of a scientist. That may not be so tempting for us because we're all of a pragmatic sort of strain of mind. On the other hand we're members of an Academy which would seem to be peculiarly well-suited to a discussion of ethics in science. Ethics is to be distinguished obviously from morals. Ethics is a matter of trying to think of ways in which scientists can behave so as to minimize the dangers and maximize the benefits. The sorts of responsibilities one would be discussing would be the responsibilities a scientist has to his craft, to protect it from various sorts of subversion and interference, and the sorts of obligations he has to society. I wish I understood those obligations better. When I talk to students, I find a wide range of views as to what our obligations as scientists are. Some imply that we should seize hold of the levers of power, and

that we are culpable if we do not do that. I don't see that point, but I'm trying to delineate an area for discussion. Thank you very much, Mr. President.

Janos Szentagothai

I am glad being able to skip some of my intended remarks because they have been very well articulated by Professors Pullman, Polanyi and Singer.

All of us are probably in complete agreement in our rejection of all kinds of discrimination and prosecution on the basis of race, religion, political opinion and — at its worst — as practiced in the form of "apartheid". We are also united in our abhorrence of warfare, especially in the form of nuclear confrontation. I have to agree, though, with the reservations of Professor Pullman about the abolition of all nuclear weapons, but for very different reasons. It would be indeed magnificent if we could abolish the threat of an atomic holocaust. Unfortunately, even if we were able to remove all existing nuclear weapons, the knowledge how and the technical means to produce them could not be made non-existent. Any major confrontation in open warfare could thus sooner or later degenerate, as an ultimate resource, into the use of nuclear weapons. There is simply no other option for humanity than to renounce completely the use of force between nations.

I am afraid that the industrialized world takes a very hypocritical view in selling weapons to the developing countries, with the flimsy argument that "if I do not sell, somebody else will, and then I am better off to keep my weapons industry busy and my people employed". Not to speak of the even less reputable motive of fighting wars by proxy.

Finally, to return to my own field of research, I am upset about the apparent deterioration of human behaviour. True enough, the elderly have deplored the abandonment of venerable traditions and disregard for values by the younger generation; since classical antiquity and even before that in ancient Egypt, however, the changes of today seem to run deeper. I am thinking of the use of drugs all over the world, irrational subcultures, glorification of aggression, organized mass-hysteria in the rock scene — although much of the same has happened in the so-called "dark middle ages",

usually during great epidemics — and particularly political terrorism. Some kind of political terrorism was with us throughout history — remember the anarchist movement of the XIX century — but the change in technology may bring about a qualitative change in the final consequences. One wonders, indeed, whether the affluence and security of modern societies, the increasingly artificial environment, absence of the healthy stresses to which humanity was subjected since times unknown, and above all the increasing differences between different parts of the world — notably between the affluent and the poor — will not go beyond the capacity for adaptation of human society. It is therefore that I would recommend for our Academy to devote part of its efforts to the study of these problems.

Jérôme Lejeune

Monsieur le Président, bien que notre Académie soit scientifique, elle aura, un jour ou l'autre, et probablement bientôt, à se prononcer sur des questions purement morales. C'est vrai que nous pouvons déchaîner la puissance atomique et que nous sommes devenus, nous les hommes d'aujourd'hui, plus dangereux que les hommes d'autrefois; mais je suis tout à fait d'accord avec ce qui a été dit, nous ne devons pas nous laisser hypnotiser par un seul danger; la puissance que nous avons sur l'atome nous sommes en train de l'acquérir sur la vie. Les manipulations que nous ferons, dans les années qui viennent, sur le patrimoine des êtres vivants ne peuvent être prévues par aucun de nous. Aucun de nous n'est capable de prévoir l'étendue de notre action. Mais ce que nous savons déja c'est que certaines des grandes nations ont déjà perdu une partie du respect de la nature humaine. Il me semble très grave de dire à des adultes américains qu'ils ne doivent pas tuer à coup de bombes atomiques des adultes russes, et à des adultes russes de dire qu'ils ne doivent pas tuer des adultes américains quand on dit tous les jours aux grands russes et aux grands américains qu'ils ont le droit de tuer leurs propres enfants, les petits russes et les petits américains qui sont encore dans le ventre de leurs mères. On ne peut pas dissocier le respect pour la nature humaine: quand la puissance biologique nous sera donnée, et elle n'est pas loin, les généticiens seront dans la même position que les physiciens atomiques; beaucoup d'entre eux

risqueront de dire: “nous n’avons pas voulu cela”. Il est peut-être bon qu’une Académie comme la nôtre, qui est réellement Pontificale (qui sert à faire un pont), soit capable dans les années qui viennent de prévoir ce danger et de tenter d’y apporter remède. Le remède ne sera pas scientifique pour une raison élémentaire, c’est que la technologie est cumulative mais que la sagesse ne l’est pas.

Nous avons, nous scientifiques, à annoncer cela: finalement ce sont des décisions morales qui sauveront l’humanité de ces dangers; ce ne seront pas des découvertes techniques.

Ennio De Giorgi

Il est difficile de parler en cinq minutes de tous les problèmes qu’on a soulevés: la paix, l’éthique scientifique, les applications de la biologie, le développement, l’ecologie. Je pense que sur tous ces sujets peuvent donner une contribution l’Académie Pontificale et les autres Académies du monde avec lesquels nous devons intensifier la collaboration. Aujourd’hui les Académies peuvent être le lieu où est possible une discussion entre scientifiques de spécialités différentes dans un climat d’amitié et de respect de toutes les opinions.

Je trouve que lorsqu’il y a des problèmes comme, par exemple, celui de Chernobyl, l’opinion publique est dérangée par ne pas avoir reçu d’indications claires de la part de la communauté scientifique. Je pense que sur bien de problèmes il ne sera pas possible de parvenir à une opinion unanime des communautés scientifiques, ni même d’une seule Académie. Mais à mon avis il serait important d’exposer et de discuter avec sérénité les opinions diverses et de fournir des indications claires sur des données reconnues par tous, sur les problèmes ouverts qui ont été formulés d’une façon claire, et enfin sur les problèmes mêmes dont on recherche encore la meilleure formulation.

Il me paraît important aussi que le travail des spécialistes de chaque branche soit mieux connu par la communauté scientifique dans son ensemble. C’est pourquoi je suggérerais que lorsque l’Académie Pontificale, comme les autres Académies, organise des réunions spécialisées, soient invités, au côté des spécialistes, quelques étudiants des disciplines diverses qui soient un peu les échantillons du reste de la communauté scientifique. Je crois qu’un tel groupe de non-spécialistes pourrait aider les spécialistes à présenter

les résultats et les problèmes dans une forme accessible pour toute la communauté scientifique et pour l'opinion publique entière, et en particulier pour les responsables politiques et économiques de tous les pays.

Je crois qu'en promouvant la libre discussion dans un climat d'amitié et de respect de toutes les opinions, en favorisant la circulation de l'information dans l'intérieur de la communauté scientifique et la meilleure compréhension entre cette communauté et l'opinion publique du monde entier, les Académies peuvent contribuer grandement à un avenir meilleur de l'humanité entière.

John Carew Eccles

I want to continue on the problems of ethics raised by Professor Polanyi. Usually we talk about ethics for everybody else. We should also talk about ethics for ourselves, inside our laboratories with our associates. I'm speaking about younger associates. Graduate students look to us to be trained for a life in science. Often in these busy days with a high technical level, these graduate students are given problems which they are very expert at. They produce the answers and so on. They get their names on the papers, but often they still don't know what the problems are in the larger sense of the word. They are not given them in the larger context of the field of science they're in, nor are they given any training in the history or in the philosophy of science. I think that we, as scientists who are entrusted with the coming generation of scientists, must try to make creative scientists in the way that we were helped in the past. We should be very careful about that, and not be so overwhelmed by the necessity of getting technical results that we merely use these young students as our very skilled assistants. We must see that they are trained to be our successors in the proper sense of the word. We have the moral obligation to do that, if science is to be kept alive.

En conclusion de ce bref mais intense échange d'idées, le prof. Carlos Chagas a pris de nouveau la parole:

I would like for all of those discussions, first of all to thank you very much, and I think that if the discussion doesn't go on, I would

like very much to have your inputs in writing; send them to me here, they will be sent to Rio if I'm not here. All your information. I think that some of the problems here are very interesting but as you have seen, and as you will see in the document which will be distributed about the activity of the Pontifical Academy of Sciences, which was admirably done by Professor Marini-Bettolo, many of the problems which we are discussing here have already been treated. I think that the idea which was presented here is very important. One I see, I think that to teach the young scientists what are the important aspects of ethics, is something very important because one of the most dangerous aspects of scientific development now is that many of our scientists have created a Faustian complex and they consider themselves above humanity I would say. That's something which really anguishes me.

TABLE RONDE

«OÙ VA LA SCIENCE?»

A 18.30 h, la première chaîne de Télévision Italienne s'est reliée avec la Casina Pie IV au Vatican pour transmettre en direct la Table Ronde qui a marqué la conclusion des travax de la Session Plénière et les célébrations du Cinquantenaire de la fondation de l'Académie.

Le débat, présidé par le prof. Carlos Chagas, a vu les interventions de nombreux Académiciens Pontificaux et a été coordiné par le journaliste Bruno Vespa.

Bruno VESPA

Ceci est la salle où s'est réuni le plenum de l'Académie Pontificale des Sciences. 57 Académiciens sont présents, parmi lesquels se trouvent 19 prix Nobel. 6 prix Nobel sont assis à cette table. Bonsoir, Président, voulez-vous présenter nos invités?

Carlos CHAGAS

With great pleasure. I have on my right here Doctor Rita Levi-Montalcini, who is extremely well known in all the countries in the world by her work, then next to her we have Prof. Menon, who is an extremely good physicist and as a matter of fact he is now the adviser for the Prime Minister of India, but he is also, I think, known and loved by everybody, everywhere in the world. Then we have Professor Arber, very distinguished Swiss scientist, very much responsible for important progress in the field of molecular biology, and then we have Professor Sune Bergström from Sweden, who is a man of many seasons, I would say, because he is not only a vety good biochemist but he is very much interested in the problems of public health all over the world. Then my old friend, probably one

of the oldest friends I have, Sir John Eccles, a very eminent brain physiologist; he has a very interesting approach to problems of the brain. Next we have Professor Manfred Eigen, who has done an extraordinary work in many fields and I think he is one of the outstanding scientists from the Federal Republic of Germany; and then we have Professor Carlo Rubbia whom I don't think I need to introduce. One of my friends said that if the physicists consider that there are four forces in nature, Rubbia is the first one.

Now we are going to put two questions: one question is "Where is science going?" and the second question is "What is the role of science in the development of society?" and I'll ask Professor Levi-Montalcini if she would give an answer to one or the other.

Rita Levi-Montalcini

I thank you, Mr. President, for inviting me to express my viewpoint on one of the two questions that you just raised: "Where is science going?" and "What is the role of science in the development of society?" I shall address myself to the second question and, more specifically, to the role of neuroscience in our society. It has been generally agreed to designate with this term the very broad area of research dealing with the study of the nervous system from the molecular to the behavioral level. The tremendous complexity of this system, which consists of about 100 billion nerve cells interacting with each other through circuits of nerve fibers, evaluated in the order of 10^{15}, defied, until the beginning of the twentieth century, all attempts at gaining an insight into its structural and functional organization. In spite of the fact that this goal has been achieved, at least along its general lines, through the efforts of the past generation of neuroanatomists and neurophysiologists, it was only in the second half of the century that research in this field suddenly blossomed and from the most backward and neglected area of biology, neuroscience became one of the main frontiers of scientific investigation. This most welcome turn took place when experts in genetics, molecular biology, immunology, biochemistry and biophysics joined forces with neurologists to escalade what in biology has been compared to the highest Himalayan peack: the brain. Besides the all too obvious benefit which mankind derived and continues to derive from the heavy investment in research directed towards uncovering the genetic, infectious and vascular

causes of brain disfunctions, another seldom mentioned but most conspicuous advantage will be drawn from the newly acquired knowledge in cognitive and behavioral sciences. As stressed in a series of excellent articles by Roger Sperry (the foremost authority in the study of brain circuits and cerebral functions), experts in these recently developed areas of neuroscience should be given a prominent role in our society. In this way, they could assist political, social and religious leaders in elaborating a new theory of values based on the rigorous scientific principles of brain functions available today, rather than on an empirical subjective value system which served as a guideline for all previous declarations of rights of man.

Govind Kumar M. Menon

Mr. President, I would like first to state that I believe science and technology are the most powerful agents, other than the human spirit, for bringing about social, economic and cultural changes. I therefore believe that scientists have responsibility to insure that science is used in a positive way for the benefit of humankind. Both with respect to insuring peace in the world and, as Pope John Paul II has repeatedly said, peace is something which derives from social justice, indeed it is the social injustice which creates hotbeds of conflict. And therefore it is also important that science and technology are used for development of society in a positive way. Therefore I think, as Professor Rita Levi-Montalcini has just said, scientists must be given a position in society which will enable them to fulfill this role. I also feel that scientists must never feel tired of informing society of the very great developments that have taken place, which many of my colleagues here will certainly speak about, in various fields of physics, in chemistry, in biology, in all the fields of electronics and so on, which can be used in a very positive and spectacular way in human development.

Mr. Chairman, you introduce me as coming from India, and of course I am working in physics but Carlo Rubbia will speak more about that particular field. I'm sure. I don't need to say that when you think of a country like India, which represents a developing country, the problems are large, the problems are complex, the population is 760 millions. We have about 15 millions more every year. One has to provide all the basic needs, water, clothing, shelter, employment, energy for these numbers, and I do not think that

this can be achieved except by making use of science and technology, both existing knowledge as well as new knowledge. A great deal of this development calls for work which is at the frontiers of science and technology, and to enable this to happen there is need for the growth of science, in an organic way in the developing countries, and I think therefore there is the responsibility of all of us, particularly of those of us who are working in the developing countries. But also the colleagues who work in the developed countries, many of whom are sitting around in this hall, can ensure that this happens, and I'm sure that this will certainly take place, and I'm glad that we do discuss at the Pontifical Academy these problems of peace and development and the role of science in them.

Werner Arber

As a microbiologist I have witnessed during the past 30 years a tremendous increase of knowledge on fundamental biological mechanisms. This was largely due to the development of new techniques which are in fact built of and based on each other's knowledge, and these techniques are around us today to reach a better understanding of many different molecular and cellular mechanisms of the fundamentals of life. These however should not be misinterpreted as giving us direct full understanding of the life of a cell or of a multicellular organism. I think it is good to stress that this is much more complex and not yet accessible to a full understanding, although we may understand the function of a particular gene and its products. This is going to lead, I'm sure of that, soon, within the next few years or next decades, to a better understanding of the principles which are relevant for medical cures; in particular I think medicine goes in the direction to strengthen the autodefense mechanisms which we have in our body, and many or several of these, if we understand them better, can, by external action, by natural products probably, be strengthened and in this way we will get less dependent on other unnatural drugs for curing sickness. I just would like to mention a few of these products which are on the market, like the interferon or interleukins, and also many new vaccines, which will be used in future years for prevention and curing of diseases.

Now perhaps just one aspect of the second question on the

responsibility of science with regard to the development of society. I think it is deeply ethically based that we tend to get better medical care, not only for our society in the developed countries but certainly also in the developing countries. However one is faced with the consequences, namely that human beings live longer, live better, and consequently will also grow up to a higher density of population. This gives me some very deep concerns; I think the population density in our society will bring us some problems with regard to the maintenance of the environmental health, not only of humans but of all living beings, and we should really take care that we preserve our ecological richness, that we do not continue to destroy the environment.

There are ways, probably by proper education, and the scientists should contribute to that, to bring these deep understandings, where there are serious problems, into large circles of our population and I think the Academy can contribute to these educational purposes.

Sune Bergström

I'll address myself to the health problems, being a medical man; health is the most basic commodity of every living human. I don't think it is realized that more than half of mankind is living in a health state similar to that we had 150 years ago in Europe. But now we cannot slowly improve it in the coming 50 years, we must speed up the process. What Professor Arber said gives good hope for new possibilities to prevent diseases, rather than cure them.

There are great efforts being made now, by several organisations, especially by the World Health Organisation, to find better cure for the tropical diseases, which is much more difficult than most infections diseases in industrialized countries. At the same time, I think health is the ideal activity to increase cooperation in the world. The best way to bridge the gap between North and South is through cooperation in science, maybe first of all in health, in which I include nutrition and mothers health. I hope that not only the scientists, but the governments should really join forces in aid for the developing world in a more cooperative way. I agree with the earlier speaker here that science is probably the best way to build up trust and cooperation and relieve the tension in the world.

John Carew Eccles

I speak as a brain scientist and I want to tell you that our effort to understand our brains in all of their immense complexity is having unbelievable success, more than we could have anticipated even a few years ago. We now can begin to think how we can carry out planned actions at will. How I can move my finger or do whatever I like. How we can perceive with all our senses in all their wonder, vision, hearing, touch, pain. Immense knowledge is coming from all of that. Everywhere, you might say, it is a success story, with the new techniques giving insight beyond any imagining of a few years ago and this is very important for the treatment of disorders of these various human diseases. How can we think, and then, when involved in all the psychiatry, this great problem of the human psyche: how can we remember? And there's Alzheimer's disease coming before you. All of these are problems for brain scientists and we have, in addition to that, to consider how can our brain, the brain I have here, give me my consciousness of all the immense diversity of happenings that are going on around me in all my waking hours and even in my dreams and give me the feeling of the centrality of myself, unique self, never to be repeated. Each of you is a unique self like I am.

Now, tremendous advances have been made in the understanding of the brain by studies of the communication system in all its diversity. We have wonderful new techniques for doing that and I would say therefore that the attempt to understand where it is going — it's going on forever, expanding, developing — might be, you might say, the last frontier for science.

Now, we can begin to understand the structure of the brain, we have heard that even the cerebral cortex has ten thousand million nerve cells, units all linked together in tremendous complexity, that we have got now great knowledge of, and we can even now, with modern radio techniques, take the conscious subject, put a helmet over his head and see the patches of the brain that are active for one or another thought or imagining and so on. So we are beginning to see how we use our brains in detail, not just as a vague thing but in precise detail, hundreds of little mosaics of operation. This is very important because in diseases this is a must; wonderful insights are given by this technique and as we go down into the finer structure, the microsite, we can begin with new techniques, only in the last

decade, to understand how we may break the barrier between mental events and neural events. How a thought can give rise to an action.

And finally in memory, this is the most wonderful thing. No one can realize what an incredible thing memory is. Imagine from your childhood you can remember, recall things. How can that all be stored and brought out at will? Yet the basic machinery of that is beginning to be understood now in the synaptic microsites. We're getting quite precise statements about this and this again will lead us to, and does lead us to, understanding Alzheimer's disease shall we say. On top of all that we have the whole of neurochemistry, neuropharmacology, we have, you might say, a tremendous operation of science today on the brain.

Manfred Eigen

We are an Academy of Sciences and the basic goal of scientists is fundamental understanding of nature. Therefore let me say a few words on that aspect. A good friend of mine in Israel told me that when he came home from school his mother used to ask him, did you have a good question? She did not ask him whether he knew something in school or whether he was good and I think that is one of the central issues of science, to have the right question, that is 75% at least of the answer to the question and it might be 90% of the understanding of the problem one is working with. So if you ask where is science going, you must be aware that the real new thing is not known. Where we have the good questions, we have soon the solutions. The future of science today is different from the future of science yesterday. So that's why we are doing basic research, not to solve a particular problem but to get a deep understanding from which we can raise new questions, better questions.

Now I am myself working on the borderline between biology, physics and chemistry, so there are many exciting new discoveries in this field concerning the origin of life, concerning the inheritance concerning the differentiation of cells, embryology and, as Sir John said, the exciting developments in understanding the neural network.

Well, what we are doing really is to find out which are the good questions and then solve them step by step. Of course that will lead to applications but the real good applications require a deep understanding. We do not try just to solve a given problem. Society has demands on us, wants us to solve certain problems in order to benefit from applications.

I think everything else has been said by my colleagues. I would completely underline what Prof. Arber said. I would say that we are living in a world almost saturated with people, where the resources are almost exhausted, where all of the sun's energy which gets to earth is required. Of course there are more problems; cancer is the problem to which molecular biology will make great contributions today and tomorrow.

With respect to the ethical aspect, a deep understanding of nature is one of the very human goals, not defined by us, and we wouldn't sit here if we wouldn't have this curiosity for deep understanding. It's part of our coming about, part of our evolution. Of course, another question is how much of our knowledge are we allowed to apply. This cannot be decided by scientists alone. We have to inform the public, the knowlege will finally have to be the basis of all our decisions.

Carlo Rubbia

Bien, étant le dernier de ce groupe de personnes, je voudrais dire avant tout que je suis parfaitement d'accord avec ces considérations de caractère général qui ont été faites par les collègues, surtout sur le rôle de la science et sur les conséquences de la technologie, surtout dans les pays du Tiers Monde et ainsi de suite. Donc, je voudrais utiliser une partie de mon temps, essentiellement pour parler à nouveau de science; en particulier, je voudrais parler de physique, qui est ma spécialité, qui a pour but de donner une meilleure compréhension de la nature du monde qui nous entoure. Je voudrais profiter de l'occasion de cette réunion pour dire que le début de la science physique moderne remonte à Galileo Galilei, qui est le membre le plus illustre de l'Académie dei Lincei dont descend l'Académie présente, l'Académie Pontificale.

Les symboles de l'Académie étaient alors le microscope et le télescope pour observer les objets qui étaient trop petits et ceux qui étaient trop loin pour être étudiés, et aujourd'hui, 350 ans plus tard, les physiciens ont énormément étendu la capacité d'observation mais n'ont pas changé cette problématique fondamentale qui nous vient de cette tradition scientifique d'extrême importance pour le monde entier.

Dans l'étude de l'infiniment petit, aujourd'hui, nous croyons avoir compris, du moins approximativement, la structure plus profonde de la matière, c'est-à-dire que nous savons qu'elle est constituée de particules ou blocs élémentaires en nombre très limité, et tout le monde qui nous entoure, dans sa complexité, peut être construit à partir d'objets élémentaires; nous avons également compris assez bien quel est le mécanisme qui se cache derrière les forces, et à côté des forces traditionnelles, comme la force électromagnétique, il y a deux nouvelles forces qui sont responsables des phénomènes nucléaires et d'interactions faibles et sont mieux comprises aujourd'hui que jadis, et sont surtout imputables au type même de mécanisme, c'est-à-dire l'échange de particules virtuelles qui fait que toutes les forces dérivent fondamentalement d'un principe unique d'égalité, et donc, c'est cette tendance, extrêmement importante, d'unifier tous les phénomènes de force dans un cadre unique de recherches.

Reste le fait que malgré le progrès accompli, qui est extrêmement brillant, la présence de problémes non négligeables rend le progrès dans notre domaine plutôt difficile. Par exemple, je voudrais mentionner l'existence des infinis comme solution de nos équations, qui sont inacceptables, expérimentalement parlant.

Et bien qu'une révolution culturelle de vastes dimensions ne soit pas encore en vue, je crois que nous entrevoyons les signes qui précèdent peut-être des moments de nouvelles crises fécondes de la science.

A mon avis, la possibilité de prédire les phénomènes physiques de notre science physique nous fait oublier l'importance et l'exigence formelle des fondements de la théorie qui semblent ici plutôt faibles.

Et l'infiniment grand?

A cause du temps requis par la lumière pour voyager dans l'espace, les distances de plus en plus croissantes dans l'échelle extragalaxique correspondent à des temps toujours plus éloignés et à

des temps toujours plus proches du début de l'univers tout entier, le dénommé Big-Bang, que nous croyons avoir été produit il y a 12 ou 15 milliards d'années. L'observation du ciel n'a pas encore fini de surprendre l'homme de science: les objets les plus extraordinaires: pulsar, quasar et trous noirs continuent à être découverts. Actuellement, l'intérêt plus profond est tourné vers l'évolution de l'univers dans son ensemble, à partir du moment initial du Big Bang. Et il y a beaucoup de questions qui restent encore ouvertes.

Quel aspect ont pris les lois fondamentales de la physique aux premiers moments de la création?

Comment se sont formées, à partir d'une singularité initiale, les galaxies et tout le reste?

A côté des observations cosmologiques, l'homme s'efforce de s'approcher de ces moments cruciaux étudiant en laboratoire, pour autant qu'il le puisse, et le simulant dans le laboratoire, pour autant qu'il lui soit possible, ce moment extrêmement important dans l'histoire de l'univers qui a été son début.

Un autre grand mystère qui préoccupe notre domaine est celui de la dite matière obscure. Il semble qu'aujourd'hui, nous ne soyons pas en mesure d'observer autre chose qu'une minuscule fraction de ce qui est la matière présente dans l'univers, et il est probable qu'il y ait quelqu'autre forme de matière diverse de celle que nous connaissons qui réprésente la plus grande partie du matériel contenu dans nos galaxies, dans toutes les galaxies.

Donc, nous sommes peut-être au début d'un programme de grandes découvertes; je crois que nous avons découvert beaucoup, mais qu'il y a encore beaucoup à découvrir.

Hector Croxatto

I fully agree with Dr. Menon's and Dr. Arber's words. I want only to emphasize a crucial point for developing countries. Unfortunately, even if for many people it is clear that science is very important for development, I think that public opinion in the III World is not convinced that their own scientific community can be able to cope with the problem of underdevelopment. The people who have to decide, the politicians, and particularly the officers who govern the Country don't believe very much in the potentialities of the indigenous science. That's the point and I think that one important task will be just to inform the public about the impact

and reasons of having a strong basic science and a technological manpower in the country itself, as a necessary requirement to foster the social economical development in order that the society can reach a better way of life.

Alexander RICH

Many of the problems that we now face in society are the outgrowth of the very success of science. This is clearly true in the development of arms in general. Here the scientist has a special role in arms control, as an advisor to the governments to help in the central responsibility that we all have in decreasing the level of nuclear arms so that we can move towards a more stable society.

In other areas, the very success of science and technology has led to the ecological problems that we face. For example, we are losing the tropical rain forests at a rapid rate. We are losing species even before we have had an opportunity to study them. This loss will be irreplaceable because we are losing the heritage of many millions of years of evolution.

These problems arise because of the very rapid growth in population. Here again scientists have a special responsibility in working on problems of population control. We have a finite planet with finite resources. The only way that we can adequately come to a stable and just society, one that will increase the standard of living in the developing countries involves curbing the growth of population. The population problem has grown because of the success of science. I am optimistic that with reasonable, rational application, we will be able to solve these problems.

Walter THIRRING

Mr. Chairman, the other day in his audience, Pope John Paul II encouraged us to look at science from a broader, I should say theological point of view, and let me give some thoughts about connection between science and religion; there is perhaps some interface which may be worthwhile reflecting on and let me formulate it this way: in the old days there was always the question whether we, here on earth, live in a very distinguished position of the universe, and this hypothesis turned out to be wrong. However,

it seems now that we do live in a very distinguished universe, in a universe which is distinguished in the sense that if you change a little bit its laws or its initial conditions, then it will be totally different and in fact there would be not only no life, but the whole cosmos would be completely changed. This is something which you see everywhere in science and, in fact, it has been mentioned quite frequently in our meetings. Even at the very beginning, at the big bang, we see now today a situation which is very astonishing. It seems that the universe was created somehow like the launching of a satellite and you know, if you launch a satellite, if you don't launch it cleverly, it will either fall down because it got too little boost, or it will go off because it got too much, and only if you launch it very cleverly then you see it will stay in orbit for some time. And the universe is in the same position except that it seems to be staying in orbit for an incredibly long time, on the relevant time scale, which is very short indeed.

Secondly, the forces in nature are now believed to be the consequence of some freezing-out procedure and their strength seems to be something which emerged more accidentally. Nevertheless, the ratio between the forces is very important for development of the cosmos, and all the constants regarding masses or strength of the interactions are essential to have the universe function the way we see it today and, if you change them a little bit, then the delicate balance will be destroyed.

So I think we are today in physics in a situation somewhat similar to the situation of mathematics after Goedel's theorem. Goedel told us that in mathematics you cannot have a complete closed rational system, where every truth is proovable. And similarly in physics, we are now in a situation where we don't have a complete rational system in the sense that every important fact can be deduced from the fundamental laws. Quite on the contrary, most of the things which are important for us seem to be of a more accidental nature. Now there are various ways you can think about it. Of course you can say that the Good Lord when He created the universe, He did it very cleverly so that everything functions well. There are some people who want to give a more Darwinistic explanation and say that there have been many attempts to create universes and most of them are failures, therefore we don't see them. In fact we see only the one we live in, which apparently was very successful.

Now this hypothesis may not have much scientific value unless you can see some traces of these abortive universes which never made it and so far there is no indication for that. So I think today we have to be humble and must say that we do not seem to get a completely closed rational system for our universe.

Jérôme Lejeune

Monsieur le Président,
en tant que département du futur de la science, nous avons aussi envisagé la responsabilité des scientifiques; on peut définir la science par une paraphrase très simple en disant qu'elle est l'arbre du bien et du mal; c'est-à-dire que les fruits que porte cet arbre de la science sont également bons ou mauvais et que c'est aux scientifiques d'avertir la société pour qu'elle sache quels sont les fruits bons qui restent à cueillir et quels sont les fruits mauvais qu'il faudrait éviter. Je voudrais prendre un exemple très simple: avec le déchainement de la force atomique on peut faire des bombes ou on peut faire de l'électricité. Au moment où nous parlons actuellement, nous sommes dans une révolution aussi grande que celle que Pasteur a introduite dans la médecine en inventant la bactériologie. Dans quelques années nous aurons une puissance sur les êtres vivants qui sera très difficile, qui est actuellement très difficile, à imaginer. Je pense que nous devons prendre exemple sur ce qu'a fait Pasteur: ayant découvert la bactériologie, il a immédiatement recherché à la mettre au service des hommes. Il n'en a pas fait une arme, ce qui eut été possible; il a, en inventant le vaccin, vacciné l'humanité contre un usage abominable de la biologie. Il nous reste, à nous scientifiques d'aujourd'hui, à suivre un tel exemple, et à ouvrir la voie pour vacciner l'humanité contre les abus qui pourraient venir de notre trop grande connaissance et d'une insuffisante sagesse.

Maxine F. Singer

Professor Eigen talked before about the importance of a question in scientific research. We have the privilege, when we do research, of asking simple and well-defined questions. Therefore

when scientists address themselves to the problems that are set forth by the world, the practical problems, we are faced with the fact that we must deal with very complex issues and we don't have any longer the privilege of asking a simple question and trying to find a simple, straightforward answer. We've spent quite a bit of time this week talking about the problems of ecology and the state of our environment, about the state of health of many people in the world, and about the malnutrition suffered by many people. These all come together as parts of the problem which Professors Rich and Arber mentioned before and which I would like to stress: the problem of dealing with the growing populations of the world and the increased rates of population growth. One of the useful things that we can do in this Academy is to address the problem of population growth in its various aspects, both in terms of modern research that's relevant to family planning, and also in terms of health and food supply.

Anatole ABRAGAM

Monsieur le Président,
A une époque où nos gouvernements exigent de la science qu'elle rapporte de l'argent et qu'elle serve uniquement les buts de l'Etat, vous m'autoriserez à lire toute un passage du discours du Saint Père qui m'est allé droit au coeur. "La recherche fondamentale doit être libre face aux pouvoirs économiques et politiques qui doivent coopérer à son développement sans l'entraver comme toute autre vérité. La vérité scientifique n'a, en effet, des comptes à rendre qu'à elle-meme et à la vérité suprème qui est Dieu créateur de l'homme et de toutes choses."

Bernard PULLMAN

Après les très belles paroles du Saint Père que vient de lire le Professeur Abragam, je me sens embarassé pour ajouter encore quelque chose. Néanmoins, puisque cette session est essentiellement destinée à parler de la science et de la société, il convient de jeter un éclairage equilibré sur ce probleme. En effet, il n'y a aucun doute

que la science contribue, d'une façon prodigieuse, à préparer la société de demain; mais il est certain que les scientifiques ne sont pas les seuls à avoir la responsabilité de l'organisation de l'avenir. Par conséquent, que nous le voulions ou non, il est évident que nous devrions nous mettre en harmonie avec les autres instances qui forment cet avenir et, en particulier, il faut dire le mot, avec les pouvoirs politiques qui ont un rôle important à jouer. Je poserai la question d'une façon un peu différente: est-ce que nous, les scientifiques présents ici, préférerions avoir un gouvernement de scientifiques ou un gouvernement de politiques? Je crois que, quelle que soit l'importance des scientifiques, gouverner un pays, gouverner le monde, exige des qualités particulières que très souvent les scientifiques ne possèdent pas, tout en ayant leurs propres qualités remarquables. Donc je crois que s'il est de notre devoir absolu d'agir en fonction de nos convictions, de rechercher la vérité, comme l'a dit le Saint Père, sans restrictions, néanmoins, nous avons un autre devoir, qui est celui d'essayer d'influer d'une façon constante et positive sur les gens sur lesquels repose finalement le gouvernement de ce monde et les aider. Je pense que la grande majorité d'entre eux ont des bonnes intentions. Ça ne se traduit pas très bien dans les faits, mais, néanmoins, c'est dans cette collaboration, je crois, dans cet effort, que la science produira, en accord avec les autres forces de l'avenir, la solution de nos propres problèmes.

Stanley Keith Runcorn

President, I study the earth. As a geoscientist I am very conscious of the limited resources that we have on our planet and I join very much with what has been said earlier about the importance of not overloading the biosphere. Perhaps one illustration is valuable. We depend for our modern life on energy resources obtained from the earth: coal, oil, gas, and we are using them up at a rate of something like one million times the rate at which they were slowly deposited in geological times. Maybe we shall find other energy sources. Of course we have nuclear power, but nevertheless I think it is essential for scientists to point out these problems and to emphasize that the present rate of population growth will succeed only in making life miserable or even causing a catastrophic breakdown of civilization.

Marcos Moshinsky

Mine is a very simple remark that concerns improving the level of science education in the developing world and I would like to indicate to you that this has been done in the past. For example Japan was completely outside of the Western tradition in science 100 or so years ago and yet now it's one of the leading nations in all the fields. So if we make an effort, and I would like this Academy in particular to make an effort, in studying how to improve the teaching of science in the Third World, I think this would have a very important effect in the long run.

Carlos Chagas

It's my duty now to thank all of you who are here around the table, all the Academicians who have contributed so well to our discussion and particularly the Italian television, RAI, for giving us such a nice occasion to express ourselves, to show what science has to do, how science has developed and also partly to show what our Academy, the Pontifical Academy of Sciences, is doing and how its work develops. I think that from these discussions we can reach a conclusion and this conclusion, I would put it in a very simple way, is that we must be optimists, because without hope and optimism nothing can be done and the world needs very much, humankind needs very much to be helped — to be helped out from the chaos in which strange forces, national egoism, the forces of economics and the military powers (which are in many instances so closely tied up), all those forces have put our society and humankind. I think that in this place, which is guided by the grace of the Divine Spirit, in which we hear the words of John Paul II — as we have heard before, since Pius XI and the other Popes who have reigned in this place of discussion and calm — in this place reflection can be undertaken, and in my modest opinion, reflection is what the world needs more. Reflection in the present to be able to build up the future, Thank you very much.

Bruno VESPA

Président, nous avons encore 5 minutes de transmission, me dit-on, et nous rappelons à qui nous écoute que ceci est une transmission en direct. Un des sujets qui est sorti ce soir est la relation entre les hommes de science et les gouvernements: les savants demandent peut-être de compter davantage?

Me permettez-vous de poser cette question à Mme Lévi-Montalcini?

Rita LEVI-MONTALCINI

Je vous remercie; beaucoup ont déjà traité ce point. Je pense que le scientifique, et pas seulement le scientifique — nous devrions parler également de l'humaniste et du philosophe — devrait avoir du pouvoir dans les futurs gouvernements. Aujourd'hui, le pouvoir, et cela fut particulièrement bien dit par le professeur qui a parlé avant moi, aujourd'hui le pouvoir est entièrement aux mains de celui qui le détient, chefs d'états, du pouvoir militaire, comme l'a dit aussi le Président, et aussi naturellement, des grands industriels. Je demanderais qu'à l'avenir — comme l'à déja fait Sperry dans le passé, le prix Nobel Sperry — soit donnée au scientifique, à l'humaniste, et au philosophe une plus grande importance, une plus grande autorité dans la gestion de nos affaires. D'une décision peut dépendre l'avenir de l'humanité entière, la survie ou la non-survie et il ne semble pas juste que l'on donne au scientifique le pouvoir d'agir, mais d'agir seulement dans sa compétence particulière, sans jamais faire valoir sa capacité de gérer la Société. Je crois que c'est là la plus grande faiblesse de notre société d'aujourd'hui, de dépendre aussi complètement des chefs d'état et des chefs militaires.

Carlo Rubbia

Mais je voudrais ajouter à ce qu'ont dit les collègues un autre point qui me semble important: c'est celui de l'information. Le devoir et la responsabilité du monde scientifique qui a tant de signification dans la société moderne d'aujourd'hui, est d'informer correctement le grand public, l'homme de la rue, de ce que sont les grandes options scientifiques. Je crois que le premier pas vers une meilleure relation entre la science et la communauté dans son ensemble, réside dans un meilleur rapport d'information, afin que l'homme de la rue puisse vraiment comprendre ce que sont les grandes options scientifiques et puisse choisir, en toute liberté, son avenir, car l'avenir de la science est son avenir et non celui des scientifiques seulement.

Bruno Vespa

Merci, Prof. Rubbia. Je remercie l'Académie Pontificale des Sciences de nous avoir donné la possibilité d'ouvrir cette petite brèche vers l'information au public. Nous sommes allés sur les ondes pendant une heure de large audience, et qui a eu l'opportunité de nous suivre au cours de cette heure a eu la possibilité d'entendre de certains parmi les savants les plus influents du monde, ce que seront les projets, les perspectives des différents secteurs de la science dans les prochaines années, mais également de savoir combien sont importants les problèmes moraux, les questions éthiques qui sont à la base des problèmes professionnels du savant. Nous espérons que la télévision, que les organes d'information seront toujours plus proches des savants et que ceux-ci quittent parfois les tribunes des congrès pour parler notre langage, le langage commun, au fond, le langage qui unit l'humanité.

Merci et bonsoir.

APPENDICES

I

LISTE ALPHABÉTIQUE DES ACADÉMICIENS PONTIFICAUX (1936-1986)

* ABDERHALDEN Emil
ABRAGAM Anatole
* ALBAREDA HERRERA Don José Maria
* ALMEIDA (DE) Antonio
* AMALDI Ugo
ANFINSEN Christian B.
* APPLETON Edward Victor
ARBER Werner
* ARMELLINI Giuseppe
BALTIMORE David
* BARROIS Charles
BEKOE Daniel Azei
BERGSTRÖM Sune K.
* BEST Charles Herbert
* BIANCHI Emilio
* BIRKHOFF George David
* BJERKNES Wilhelm Frimann K.
BLANC-LAPIERRE André
* BOHR Aage Niels
BOHR Niels
* BOLDRINI Marcello
* BONINO Giovanni Battista
* BORSUK Karol
* BOTTAZZI Filippo
* BRANLY Edouard
* BROGLIE (DE) Louis
BRÜCK Hermann Alexander
* BULLEN Keith Edward
* BUYTENDIJK Fredrik Jacobus J.
CABIBBO Nicola
* CARATHEODORY Constantin

* *Académiciens décédés.*

* CARDOSO FONTES Antonio
* CARREL Alexis
* CASTELLANI Aldo
* CHADWICK James
CHAGAS Carlos
* CHAUDRON Georges
* COLOMBO Giuseppe
* COLONNETTI Gustavo
* CONWAY Arthur William
* CONWAY Edward Joseph
* CROCCO Gaetano Arturo
CROXATTO Hector R.
* CRUZ COKE Eduardo
* CUNEOT Lucien
* DAINELLI Giotto
* DAL PIAZ Giorgio
* DE BLASI Dante
* DE CASTRO Aloysio
* DE FILIPPI Filippo
DE GIORGI Ennio
* DEBYE Pieter Josef William
* DIRAC Paul Adrien Maurice
DÖBEREINER Johanna
* DOISY Edward Adelbert
DUVE (DE) Christian
ECCLES John Carew
EIGEN Manfred
ESCHENMOSER Albert
* FAUVEL Pierre
* FEIGL Fritz
* FISHER Ronald Aylmer
* FLEMING Alexander
FUKUI Kenichi
* GARCIA OTERO Julio César
* GARCIA SINERIZ José
GARNHAM Percy Cyril Claude
* GEMELLI Agostino
* GENTNER Wolfgang
GERMAIN Paul
* GHERZI Ernesto
* GHIGI Alessandro
* GIACOMELLO Giordano
* GILSON Gustave
* GIORDANI Francesco

* GIORGI Giovanni
* GODLEWSKI Emil
* GOLA Giuseppe
* GREGOIRE Abbé Victor
* GUIDI Camillo
* GUTHNICK Paul
* HAHN Otto
HAWKING Stephen W.
* HEISENBERG Werner Carl
* HEISKANEN Weikko Aleksanteri
HERZBERG Gerhard
* HESS Victor Francis
* HESS Walter Rudolf
* HEVESY (DE) George Charles
* HEYMANS Corneille Jean F.
* HINSHELWOOD Cyril Norman
HODGKIN Alan Lloyd
HÖRSTADIUS Sven
* HOUSSAY Bernard Albert
* HURTADO Alberto
* JOACHIMOGLU Georges
* JULIA Gaston Maurice
* KARMAN (von) Theodore
* KEESOM Wilhelmus Hendrikus
KHORANA H. Gobind
LAMBO Thomas Adeoye
* LANGFELD Herbert Sidney
* LAUE (von) Max Theodor Felix
* LECOMTE Jean
LEJEUNE Jérôme
LELOIR Luis Federico
* LEMAÎTRE Georges
LÉPINE Pierre Raphaël
* LEPRI Giuseppe
LEPRINCE RINGUET Louis
* LEVI CIVITA Tullio
LEVI-MONTALCINI Rita
LICHNEROWICZ André
* LILEY Albert William
LOJASIEWICZ Stanislav
* LOMBARDI Luigi
LORA-TAMAYO Manuel
* LUIGIONI Paolo
* LYNEN Feodor

MALU Wa Kalenga
* MARCONI Guglielmo
MARINI-BETTÒLO Giovanni Battista
* MAROTTA Domenico
* MENDES CORREA Antonio Augusto
MENON M. Govind Kumar
* MICHOTTE VAN DEN BERCK Albert E.
* MILLIKAN Robert Andrews
MINTZ Beatrice
* MIZUSHIMA Sanichiro
* MORGAN Thomas Hunt
* MORGAN William Wilson
* MORUZZI Giuseppe
MÖSSBAUER Rudolf Ludwig
MOSHINSKY Marcos
* NIEHANS Paul
NIRENBERG Marshall Warren
* NOBILE Umberto
* NOYONS Adriaan Karel Marie
OCHOA Severo
* O'CONNELL Daniel Joseph Kelly
ODHIAMBO Thomas Risley
OŁECH Czeslaw
OORT Jan Hendrick
PALADE George Emil
* PANETTI Modesto
* PARRAVANO Nicola
PAVAN Crodowaldo
* PENSA Antonio
PERUTZ Max Ferdinand
* PETRITSCH Ernst Felix
* PICARD Emile
* PICONE Mauro
* PIERANTONI Umberto
* PISTOLESI Enrico
* PLANCK Max
POLANYI John Charles
PORTER George
PRELOG Vladimir
PULLMAN Bernard
PUPPI Giampiero
* QUAGLIARELLO Gaetano
* RAMAN Chandrasekhara V.
RASETTI Franco

RICH Alexander
ROCHE Marcel
* RONDONI Pietro
RUBBIA Carlo
RUNCORN Stanley Keith
* RUTHERFORD OF NELSON Ernest
* RUZICKA Leopold
* RYLE Martin
SALAM Abdus
* SANDOVAL-VALLARTA Manuel
* SCHRÖDINGER Erwin
* SEGRE Beniamino
SELA Michael
* SEVERI Francesco
* SHERRINGTON Charles
SIDDIQUI Salimuzzaman
SIEGBAHN Kai M.
* SIERPINSKI Waclaw
* SILVESTRI Filippo
SINGER Maxine
* SOMIGLIANA Carlo
SPERI SPERTI George
SPERRY Roger
* STONELEY Robert
* STROMGREN Bengt Georg
SZENTAGOTHAI Janos
* SZENT-GYÖRGYI Albert
* TAYLOR Hugh Stott
THIRRING Walter
* TISELIUS Arne Wilhelm Kaurin
* TONELLI Leonida
* TONIOLO Renato Antonio
TOWNES Charles H.
* TSCHERMAK-SEYSENEGG Armin von
TUPPY Hans
UBBELOHDE Alfred René John P.
* ÜRSPRUNG Alfred
* UMEZAWA Hamao
* VALLAURI Giancarlo
* VALLEE POUSSIN (DE LA) Charles Jean
* VENING MEINSZ Felix Andries
* VERCELLI Francesco
* VIRTANEN Artturi Ilmari
* VOLTERRA Vito

WEISSKOPF Victor
* WEYL Hermann
* WHITTAKER Edmund
* WIESNER Karel
* YUKAWA Hideki
* ZEEMAN Pieter

ACADÉMICIENS HONORAIRES

* BISLETI Cardinal Gaetano
* CHIGI ALBANI DELLA ROVERE Ludovico
* CICOGNANI Cardinal Amleto Giovanni
* DE SANCTIS Pietro
* GALEAZZI LISI Riccardo
* MAGLIONE Cardinal Luigi
* MARCHETTI SELVAGGIANI Cardinal Francesco
* PACELLI Cardinal Eugenio
* PASCHINI Mons. Pio
* PIZZARDO Cardinal Giuseppe
RANZI Silvio
ROVASENDA (DI) P. Enrico
* SALVIUCCI Pietro
* TARDINI Cardinal Domenico
* TISSERANT Cardinal Eugenio
* VALLETTA Vittorio

ACADÉMICIENS «PERDURANTE MUNERE»

* ALBAREDA Cardinal Anselmo Maria
BOYLE P. Leonard E.
COYNE P. George, S.J.
* GATTERER P. Aloysius
* GIUSTI S.E. Mons. Martino
* JUNKES P. Joseph
* MERCATI Mons. Angelo
METZLER P. Joseph
* RAES P. Alfonso
* SCHMIDT P. Wilhelm
* SCHULIEN P. Michael
* STEIN P. Johan Wilhelm J.
STICKLER Cardinal Alfons M.
* TREANOR P. Patrick

II

DISTRIBUTION DES ACADÉMICIENS ACTUELS SELON LES NATIONS DE NAISSANCE ET DE RÉSIDENCE

Nation	*Naissance*	*Résidence*
ALLEMAGNE	Brück, Eigen, Herzberg, Metzler, Mössbauer, Polanyi	Eigen, Mössbauer
ARGENTINE		Leloir
AUSTRALIE	Eccles	
AUTRICHE	Perutz, Thirring, Tuppy, Weisskopf	Thirring, Tuppy
BELGIQUE		de Duve, Rasetti
BRÉSIL	Chagas, Pavan	Chagas, Döbereiner, Pavan
CANADA		Herzberg, Polanyi
CHILI	Croxatto	Croxatto
CITÉ DU VATICAN		Boyle, Coyne, Metzler
DANEMARK	Bohr	Bohr

Nation	*Naissance*	*Résidence*
ESPAGNE	Lora-Tamayo, Ochoa	Lora-Tamayo, Ochoa
ÉTATS-UNIS	Anfinsen, Baltimore, Coyne, Mintz, Morgan, Nirenberg, Rich, Singer, Speri-Sperti, Sperry, Townes	Anfinsen, Baltimore, Khorana, Mintz, Morgan, Nirenberg, Palade, Rich, Singer, Speri Sperti, Sperry, Townes, Weisskopf
FRANCE	Blanc-Lapierre, Germain, Lejeune, Leloir, Lépine, Leprince-Ringuet, Lichnerowicz	Abragam, Blanc-Lapierre, Germain, Lejeune, Lépine, Leprince-Ringuet, Lichnerowicz, Pullman, Roche
GHANA	Bekoe	
HOLLANDE	Oort	Oort
HONGRIE	Szentágothai	Szentágothai
INDE	Khorana, Menon	Menon
IRLANDE	Boyle	
ISRAËL		Sela
ITALIE	Cabibbo, De Giorgi, di Rovasenda, Levi-Montalcini, Marini-Bettòlo, Puppi, Ranzi, Rasetti, Rubbia	Cabibbo, De Giorgi, di Rovasenda Levi-Montalcini, Marini-Bettòlo, Puppi, Ranzi, Salam
JAPON	Fukui	Fukui

Nation	*Naissance*	*Résidence*
KENYA	Odhiambo	Bekoe, Odhiambo
MEXIQUE		Moshinsky
NIGÉRIE	Lambo	
PAKISTAN	Siddiqui, Salam	Siddiqui
POLOGNE	Lojasiewicz, Olech, Pullman, Sela	Lojasiewicz, Olech
ROUMANIE	Palade	
ROYAUME-UNI	de Duve, Garnham, Hawking, Hodgkin, Porter, Runcorn, Ubbelohde	Brück, Garnham, Hawking, Hodgkin, Perutz, Porter, Runcorn, Ubbelohde
SUÈDE	Bergström, Hörstadius, Siegbahn	Bergström, Hörstadius, Siegbahn
SUISSE	Arber, Eschenmoser	Arber, Eccles, Eschenmoser, Lambo, Rubbia, Prelog
TCHECOSLOVAQUIE	Döbereiner	
URSS	Abragam, Moshinsky	

Nation	*Naissance*	*Résidence*
VÉNÉZUÉLA	Roche	
YOUGOSLAVIE	Prelog	
ZAÏRE	Malu	Malu

III

PRÉSIDENTS, CHANCELIERS ET MEMBRES DU CONSEIL DE 1936 À 1987

PRÉSIDENTS

P. Agostino GEMELLI o.f.m. (28 Octobre 1936-15 Juillet 1959)
Mons. Georges LEMAITRE (19 Mars 1960 - 20 Juin 1966)
P. Daniel O'CONNELL S.J. (15 Janvier 1968 - 15 Janvier 1972)
Prof. Carlos CHAGAS (3 Novembre 1972-)

CHANCELIERS

Prof. Dr. Pietro SALVIUCCI (28 Octobre 1936 - 31 Décembre 1973) Chancelier
Dr. Francesco SALVIUCCI (8 Février 1948 - 31 Octobre 1972) Assistant
P. Enrico DI ROVASENDA (16 Novembre 1972 - 3 Avril 1974) Co-Directeur; (3 Avril 1974 - 31 Décembre 1986) Directeur
Ing. Don Renato DARDOZZI (5 Juillet 1985 - 31 Décembre 1986) Co-Directeur; (1 Janvier 1987-) Directeur

MEMBRES DU CONSEIL DE L'ACADÉMIE

ARMELLINI G.	1936-1941; 1944-1948
LEPRI G.	1936-1941; 1944-1948

ALBAREDA A.M.	1936-1962
BIANCHI E.	1936-1941
BOTTAZZI F.	1936-1941
AMALDI U.	1940-1944
GIORDANI F.	1940-1961
LOMBARDI L.	1944-1954
SEVERI F.	1944-1961
QUAGLIARIELLO G.	1944-1948
BOLDRINI M.	1958-1969
BONINO G.B.	1958-1980
CROCCO G.A.	1958-1965
PISTOLESI F.	1958-1968
O'CONNELL D.	1962-1982
BRÜCK H.	1965-1986
LEPRINCE-RINGUET L.	1965-1969; 1980-
DE BROGLIE L.	1969-1980
MARINI-BETTÒLO G.B.	1969-
TUPPY H.	1972-
PUPPI G.P.	1980-
COYNE G.	1986-

IV

SEMAINES D'ÉTUDE ORGANISÉES PAR L'ACADÉMIE PONTIFICALE DES SCIENCES 1949-1987

The biological problem of cancer	June 1949
Problem of microseism	November 1951
The problem of oligo-elements in the vegetal and animal life	April 1955
The problem of stellar population	May 1957
The problem of macromolecules of biological interest with special reference to nuclear proteins	October 1961
The problem of cosmic radiation in interplanetary space	October 1962
The econometric approach to development planning	October 1963
Brain and conscious experience	Sept.-Oct. 1964
Molecular forces	April 1966
Organic matter and soil fertility	April 1968
Nuclei of galaxies	April 1970

Use of fertilizers and its effect in increasing yield with particular attention to quality and economy	April 1972
Biological and artificial membranes and desalination of water	April 1975
Natural products and the protection of plants	October 1976
The role of non-specific immunity in the prevention and treatment of cancer	October 1977
Nerve cells, transmitters and behaviour	October 1978
Mankind and energy: needs, resources, hopes	November 1980
Cosmology and fundamental physics	Sept.-Oct. 1981
Modern biological experimentation	October 1982
Pattern recognition mechanisms	April 1983
Chemical events in the atmosphere and their impact on environment	November 1983
Energy for survival and development	June 1984
The impact of space exploration on mankind	October 1984
Interaction of parasitic diseases and nutrition	October 1985
Remote sensing and its impact on developing countries	June 1986
Persistent meteo-oceanographic anomalies and teleconnections	September 1986
A modern approach to the protection of the environment	October 1987
Large-scale motions in the universe	November 1987

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GROUPES DE TRAVAIL ORGANISÉS PAR L'ACADÉMIE PONTIFICALE DES SCIENCES 1974-1987

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The effects of ionizing radiation in man	November 1975
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Perspectives on immunization in parasitic diseases	Sept.-Oct. 1981
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Biological implications of optimization in radiation procedures	May 1983
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The artificial prolongation of life and the determination of the exact moment of death	October 1985
Molecular mechanisms of carcinogenic and antitumor activity	October 1986
Aspects of the uses of genetic engineering	November 1987

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LISTE DES PUBLICATIONS DE L'ACADÉMIE PONTIFICALE DES SCIENCES

SCRIPTA VARIA

001 *Index Général des travaux de l'Académie Pontificale des «Nuovi Lincei», 1847-1935.*

003 *Catalogo dei gasteropodi polmonati della Collezione Coen*, G.S. Coen, 1945.

004 *Funzioni quasi abeliane*, F. Severi, 1947.

005 *La sphygmographie*, L. Dalla Torre, 1946.

006 *L'anemia perniciosa*, M. Torrioli, 1948.

007 *The biological problem of cancer.* Study Week, June 6-13, 1948.

008 *La strutturazione psicologica del linguaggio mediante l'analisi elettroacustica*, A. Gemelli, 1950.

009 *Tendenza aggressiva e accertamento precoce del sesso nel pavoncello*, E. Valentini, 1951.

010 *Studio fisico dell'aorta normale e patologica*, V. Dal Borgo, 1952.

011 *Ein Vorschlag zur empirischen Reduktion von Spektralverteilungen*, S.J.J. Junkes, 1952.

012 *The problem of microseisms*, Study Week, November 19-26, 1951.

013 *Cellule cianofile e cellule mucoidi dell'adenoipofisi*, A. Casarini, N. Rossi, 1958.

014 *The problem of oligoelements in the vegetal and animal life*. Study Week, April 17-24, 1955.

015 *Studio sulle ernie diaframmatiche*, L.V. De Stefano, C. Simonetti, 1957.

016 *The problem of stellar population*. Study Week, May 20-28, 1957.

017 *La vescica artificiale*, V. Russo, F. Salviucci, P. Proietti, 1958.

018 *La rivascolarizzazione del miocardio*, L.V. De Stefano, L.G. Frezza, 1959.

019 *Elastoplasticità, Saggio di interpretazione delle deformazioni plastiche come fenomeni ereditari*, G. Colonnetti, 1960.

020 *Funzioni quasi abeliane*, F. Severi (seconda edizione ampliata), 1961.

021 *Testosterone e patologia epatica, ricerche istologiche e biochimiche*, M. Girolami, 1961.

022 *The problem of macromolecules of biological interest with reference to nuclear proteins*. Study Week, October 23-31, 1961.

023 *Le funzioni e le varietà quasi abeliane dalla teoria del Severi ad oggi*, M. Rosati, 1962.

024 *La prevenzione del cancro*, V. Russo, S. Magalini, F. Salviucci, 1963.

025 *The problem of cosmic radiations in interplanetary space*. Study Week, October 1-6, 1962.

026 *Myasthenia gravis, rivista sintetica e studio patogenetico*, E. Malizia, M. Di Lorenzo, L. Torbidoni, 1963.

027a *Miscellanea Galileiana*, P. Paschini, voll. I-II, 1964.

027b *Miscellanea Galileiana*, P. Paschini, V. Ronchi, F. Soccorsi, vol. III, 1964.

028 *The econometric approach to development planning*, part I-II. Study Week, October 7-13, 1963.

029 *Fisiopatologia dell'annegamento*, C. Manni, V. Russo, F. Salviucci, E. Scrascia, 1970.

030 *Brain and conscious experience*. Study Week, September 28 - October 3, 1964.

031 *Molecular forces*. Study Week, April 18-23, 1966.

032 *Organic matter and soil fertility*. Study Week, April 22-27, 1968.

034 *L'Académie Pontificale des Sciences en mémoire de son premier Président Agostino Gemelli*, G.B. Montini, F. Severi, A. Michotte, G.B. Marini-Bettòlo, 1970.

035 *Nuclei of Galaxies*. Study Week, April 13-18, 1970.

036 *L'Académie Pontificale des Sciences en mémoire de son second Président Georges Lemaître*, C. Manneback, O. Godart, P.A.M. Dirac, G. Lemaître, A.S. Eddington, 1972.

038 *Use of fertilizers and its effect in increasing yield with particular attention to quality and economy*, part I-II. Study Week, April 10-16, 1972.

039 *Pontificiae Academiae Scientiarum Edita Omnia, MCMXXXVI-MCMLXXIII.*

040 *Biological and artificial membranes and desalination of water*. Study Week, April 14-19, 1975.

041 *Natural products and the protection of plants*. Study Week, October 18-23, 1976.

042 *Science and the modern world*. Plenary Session held in March, 1976, Part I.

043 *The role of non-specific immunity in the prevention and treatment of cancer*. Study Week, October 17-21, 1977.

044 *Science and technology for developing countries*. A contribution to the problem by the Pontificia Academia Scientiarum. Report prepared by a special committee of the Pontifical Academy of Sciences composed of C. Chagas (President), G.B. Marini-Bettòlo, G.P. Puppi, Father E. di Rovasenda, together with Prof. P. Bisogno (CNR) and A. Rambelli (University of Rome), 1979.

045 *Nerve cells, transmitters and behaviour*. Study Week, October 9-14, 1978.

046 *Mankind and energy: needs, resources, hopes*. Study Week, November 10-15, 1980.

047a *Mental deficiency*. Working Group, November 3-6, 1980.

047b *Perspectives of immunization in parasitic diseases*. Working Group, September 29-October 2, 1981.

048 *Astrophysical cosmology*. Study Week, September 28-October 2, 1981.

049 *Science and the modern world*. Plenary Session held October 11-13, 1978, Part II.

050 *Recent advances in the evolution of primates*. Working Group, May 24-27, 1982.

051 *Modern biological experimentation*. Study Week, October 18-23, 1982.

052 *Science and the modern world*. Plenary Session held November 11-13, 1979, Part III.

053 *I documenti del processo di Galileo Galilei*, S.M. Pagano, A.G. Luciani, 1984.

054 *Pattern recognition mechanisms*. Study Week, April 25-29, 1983.

055 *Specificity in biological interactions*. Working Group, November 9-11, 1983.

056 *Chemical events in the atmosphere and their impact on the environment*. Study Week, November 7-11, 1983.

057 *Energy for survival and development*. Working Group, June 11-14, 1984.

058 *The impact of space exploration on mankind*. Study Week, October 1-5, 1984.

059 *Developmental Neurobiology of mammals*. Working Group, June 3-7, 1985.

060 *The artificial prolongation of life and the determination of the exact moment of death*. Working Group, October 19-21, 1985.

061 *The interaction of parasitic diseases and nutrition*. Study Week, October 22-26 1985.

062 *Galileo Galilei e gli orientamenti esegetici del suo tempo*. Rinaldo Fabris, 1986.

063 *Federico Cesi nel quarto centenario della nascita*, 1986.

064 *Discorsi indirizzati dai sommi pontefici Pio XI, Pio XII, Giovanni XXIII, Paolo VI e Giovanni Paolo II alla Pontificia Accademia delle Scienze dal 1936 al 1986*, 1986.

065 *Discours Adressés par les Souverains Pontifes Pie XI, Pie XII, Jean XXIII, Paul VI, Jean Paul II à l'Académie Pontificale des Sciences de 1936 à 1986*, 1986.

066 *Discourses of the Popes from Pius XI to Jean Paul II to the Pontifical Academy of Sciences (1936-1986)*, 1986.

067 *The Activity of the Pontifical Academy of Sciences 1936-1986*. G.B. Marini-Bettòlo, 1987.

068 *Remote Sensing and Its Impact on Developing Countries*. Study Week, June 16-21, 1986.

069 *Persistent Meteo-Oceanographic Anomalies and Teleconnections*. Study Week, September 23-27, 1986.

070 *Molecular Mechanisms of Carcinogenic and Antitumor Activity*. Working Group, October 21-25, 1986.

071 *L'Attività della Pontificia Accademia delle Scienze 1936-1986*. G.B. Marini-Bettòlo, 1987.

072 *Immunology, Epidemiology and Social Aspects of Leprosy*. Working Group, May 28-June 1, 1984.

073 *Cinquantenaire de la fondation de l'Académie Pontificale des Sciences*. Compte rendu et Actes de la Session Plénière et des Célébrations, Octobre 27-30, 1986.

074 *Aspects of the uses of Genetic Engineering*. Working Group, October 19-23, 1987.

075 *A Modern Approach to the Protection of the Environment*. Study Week, November, 2-7, 1987.

076 *Large-scale Motions in the Universe*. Study Week, November 9-14, 1987.

HORS DE SÉRIE

Gregorian Reform of the Calendar - Proceedings of the Vatican Conference to commemorate its 400th Anniversary, 1582-1982.

Einstein, Galileo - Commemoration of Albert Einstein, 1979.

La sede (della Pontificia Accademia delle Scienze), G. Delfini Filippi, 1986.

Le Siège. G. Delfini Filippi, 1986.

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La Medaglia d'Oro, 1986.

Annuario degli Accademici Pontifici, 1987.

Allocution de sa Sainteté Jean Paul II et discours de Carlos Chagas président de l'Académie (Audience Pontificale 28 octobre 1986) (texte français, anglais, italien).

COMMENTARII
I série 1961-1966

001 *Panégyriques du Rév.me Père Agostino Gemelli, O.F.M.*, A.M. Michotte van den Berck.

002 *Long term observations on pathogenic fungi cultivated on artificial media for two, three, four and five decades. Permanency and variations of their characters. The «Sterile distilled water method» of cultivation to maintain such fungi in mycological collections and present the development of pleomorphism*, A. Castellani.

003 *Nouvelles observations sur l'identification mycologique du saccharose et de l'insuline, substances non réductrices*, A. Castellani.

004 *Una nuova razza di fagiano dorato doppiamente recessiva*, A. Ghigi.

005 *Modalità di comportamento aggressivo del pavoncello maschio adulto e loro analisi quantitativa*, E. Valentini.

006 *Sulla stereospecificità della biosintesi di alcuni triterpeni*, D. Arrigoni e L. Guglielmetti.

007 Les temples d'Abou-Simbel en danger, G. Colonnetti.

008 *Charles Jean De La Vallée Poussin*, G. Lemaître.

009 *Vers une physiologie anthropologique*, F. J.J. Buytendijk.

010 *Drug resistance of bacteria in relation to general biology*, C.N. Hinshelwood.

011 *The nature of the elementary particles*, W. Heisenberg.

012 *Partition phenomena in two phase polymer systems and their significance for particle separation*, A. Tiselius.

013 *Internal rotation in polymers*, S. Mizushima.

014 *Mechanism of the synthesis of ammonia on iron catalysts*, H.S. Taylor.

015 *Sur les peuplades non bantoues de l'Angola*, A. de Almeida.

016 *La vie et l'oeuvre de Francesco Severi*, G. Julia.

017 *État actuel de nos connaissances des cyclones tropicaux*, E. Gherzi.

018 *Researches on the central nervous system*, J.C. Eccles.

019 *The significance of inorganic levels in the internal medium of higher animals*, E.J. Conway.

020 *On fever, hunger and thirst*, B.E. Andersson.

021 *Historical notes to the discovery of the cosmic radiation*, G. De Hevesy.

022 *Bibliografia dell'Archivio Vaticano*, M. Giusti.

023 *History and clinical value of the ballistocardiogram - A review of clinical and experimental researches*, A. Farulla - E. Castagnetta.

024 *Rilievi batteriologici in corso di rinofaringite acuta - Frequenza dell'isolamento di stafilococchi patogeni dal cavo nasale*, E. Castagnetta.

025 *Rilievi farmacologici sulle alterazioni elettrocardiografiche indotte nel coniglio dalla somministrazione di Stafilolisina Alfa*, E. Castagnetta.

026 *Rilievi elettrocardiografici nel coniglio dopo somministrazione di «O Streptolisina»*, E. Castagnetta.

027 *Anatomical and physiological remarks on right ventricle infarctions*, E. Castagnetta, A. Farulla, G. Naro.

028 *Endocardial fibroelastosis*, E. Castagnetta, A. Farulla, G. Naro.

029 *Observations on pathogenic fungi cultured on artificial media for 2, 3, 4 and 5 decades. Permanency and variations of certain cultural, biochemical and antigenic characters*, A. Castellani.

030 *The cultivation of pathogenic fungi in sterile distilled water*, A. Castellani.

031 *Theodor von Karman*, E. Pistolesi.

032 *Actions pharmacologiques sur le seuil convulsif de l'électrochoc*, C. Heymans, A.F. De Schaepdryver, Y. Piette, A.L. Delaunois.

033 *Aplicaciones científicas y utilitarias de los mapas gravimétricos*, J.G. Siñeriz.

034 *La struttura di una nuova categoria di composti aromatici derivati del tetraazapentalene*, M. Brufani, W. Fedeli, G. Giacomello, A. Vaciago.

035 *On the structure of atomic nuclei*, A. Bohr.

036 *Su la possibilità di sottofondazione del Campanile di Pisa*, G. Colonnetti.

037 *The redox pump in the biological performance of osmotic work*, E.J. Conway.

038 *Changes in reaction pattern accompanying bacterial adaptation*, C.N. Hinshelwood.

039 *Prinzipien cerebraler Organisation*, W.R. Hess.

040 *Appunti sul significato morfologico dell'apparato reticolare interno (Golgi) studiato in cellule nervose di cefalopodi*, P. Graziadei.

041 *The floating zone refining of iron*, S. Mizushima.

042 *Hormonal factors of diabetic ketosis*, B.A. Houssay.

043 *Natural resistance to disease*, G. Speri Sperti.

044 *The effect of an electric field on the critical opalescence*, P. Debye.

045 *Cell regulation*, C.N. Hinshelwood.

046 *Internal rotation and conformation of linear high polymers*, S. Mizushima.

047 *Campo fluido supersonico dietro onda d'urto aderente*, L. Broglio.

048 *Membrane barriers to the entrance of sodium ions into isolated amphibian skeletal muscle*, E.J. Conway.

049 *Analisi elementare continua di composti organici separati mediante cromatografia in fase vapore*, F. Cacace, R. Cipollini, G. Perez.

II série
1967-1972

001 *Note on the reception at Brébeuf College in Montreal of pulses from distant Loran stations on the Atlantic Coast*, E. Gherzi.

002 *Contribution à la synthèse des hétérocycles au moyen des sels de nitrilium*, M. Lora-Tamayo.

003 *Role of liver innervation on fat metabolism*, B.A. Houssay, E. Ashkar, E. Del Castillo, M.E. Galli, A. Roldan, C.T. Rietti, E. Urgoiti.

004 *Copper content of blood plasma*, G.C. De Hevesy.

005 *Milk production on protein-free feed*, A.L. Virtanen.

006 *The active transport of inorganic cations across the yeast cell membrane*, E.J. Conway.

007 *Virus et hérédité*, P. Lépine.

008 *Progrès dans la micromorphologie des sols*, J.M. Albareda Herrera.

009 *Researches on certain long term recurring phenomena exhibited by some bacteria and fungi*, A. Castellani.

010 *Two peculiar pleomorphic slime organisms isolated from human lesions of most difficult classification: myxomicrobium multiplex cast, and myxogeometrichum filarioides cast*, A. Castellani.

011 *The scientific work of Georges Lemaître*, P.A.M. Dirac.

012 *Dérivés hydraziniques d'indols en tant qu'inhibiteurs de la monoamineoxydase*, M. Lora-Tamayo.

013 *The physical interpretation of quantum electrodynamics*, P.A.M. Dirac.

014 *Note on an explanation of crystal structures of elementary substances*, S. Mizushima and I. Ichishima.

015 *Absorption spectra of molecular ions*, G. Herzberg.

016 *Note on the reception at Montreal of a continuous wave radio transmission on 80 kHz from the Defense Research Communications Establishment in Ottawa, Canada*, E. Gherzi.

017 *Long term maintenance and cultivation of the common pathogenic fungi of man in sterile distilled water*, A. Castellani.

018 *La protection de la nature dans la lutte contre la faim*, A. Ghigi.

019 *Le spectre infrarouge - Quelques-unes de ses propriétés et de ses applications*, J. Lecomte.

020 *An improvement of Runge's theorem on diophantine equations*, A. Schinzel.

021 *Production of L.-asparaginase by a strain of «Aspergillus terreus»*, A. Tonolo, L. Carta De Angelis, E. Zurita.

022 *Ricordo del Padre Agostino Gemelli*, G.B. Marini-Bettòlo.

023 *Valutazione statica e dinamica delle strutture istologiche e citologiche*, A. Pensa.

024 *La production de chaleur et les deux facteurs qui la composent: vitesse et rendement*, E. Cruz Coke.

025 *Science and the protection of the environment*, G.B. Marini-Bettòlo.

026 *Priorities in scientific research*, A. Tiselius.

027 *On the substances controlling reproductive phenomena in starfishes*, H. Kanatani.

028 *Les infections virales à évolution lente*, P. Lépine.

029 *Urinary kininogenase and renal hypertension*, H.R. Croxatto and M. San Martin.

030 *Note on the conformation of chain molecules*, S. Mizushima and T. Shimanouchi.

031 *Dolichol monophosphate glucose, an intermediate in glucose transfer in liver*, L.F. Leloir and N.H. Behrens.

032 *A meteorological forecasting puzzle*, E. Gherzi S.J.

033 *Role of the hypophysis on ketonemia and fatty liver of the pancreatectomized dog*, B.A. Houssay, A.G. Roldan, C.T. Rietti, E.J. Del Castillo, M.E. Galli.

034 *Sir Edward Victor Appleton*, H.A. Brück.

035 *L'infrarouge et la météorologie*, J. Lecomte.

036 *Alessandro Ghigi (1875-1970)*, S.O. Hörstadius.

037 *Sur un virus modèle et son évolution: le virus de la rage*, P. Lépine.

038 *Arne Tiselius (1902-1971)*, G.B. Marini-Bettòlo.

039 *The solidity of the Earth's inner core*, K.E. Bullen.

040 *Kallikrein-like enzyme in purified rat renal extracts containing renin*, H.R. Croxatto and G.E. Noe.

041 *A short note on atmospheric pollution and atmospheric electricity*, E. Gherzi S.J.

042 *Dimeric proanthocyanidins: structure and biological activity*, G.B. Marini-Bettòlo and F. Delle Monache.

043 *Reexamination of conformations of some molecules*, S. Mizushima, T. Shimanouchi and I. Harada.

044 *Bat malaria: zoogeography and possible course of evolution*, P.C.C. Garnham.

045 *Aldo Castellani (1877-1971)*, P.C.C. Garnham.

046 *Evolutionary cosmology*, P.A.M. Dirac.

047 *Cell division*, A. Szent-Györgyi.

048 *Les techniques pour obtenir les hautes températures et leurs applications*, G. Chaudron.

049 *Experimental tests of the quantum theory of molecular hydrogen*, G. Herzberg.

050 *Inhibición de la tiroxina*, E. Cruz Coke.

051 *Molecular interactions in hydrogen-bonding solvents*, G. Némethy.

052 *Alcune osservazioni sulle formule di quadratura approssimata*, M.A. Sneider Ludovici.

053 *Contribution à l'étude de l'ascendance des Bochimans Khun*, A. de Almeida.

054 *Synthetic metals*, A.R. Ubbelohde.

055 *On the problem of the origin of spiral structure*, J.H. Oort.

056 *Organic ionic melts. A novel class of liquids*, A.R. Ubbelohde.

057 *The history, the discovery and the present position of insulin*, C.H. Best.

058 *Recientes progresos en el estudio del curare y de los alcaloides de menispermaceae y loganiaceae*, G.B. Marini-Bettòlo.

059 *Productos naturales de origen vegetal de intéres farmacológico en Latino-América*, G.B. Marini-Bettòlo.

060 *Les di- et triazolindiones comme philodienes*, M. Lora-Tamayo.

III série
1974-1988

001 *Le progrès de la science et l'avenir de l'humanité*, C. Chagas.

002 *Le message de vie*, J. Lejeune.

003 *Commémoration de Guglielmo Marconi*, G.B. Marini-Bettòlo.

004 *Gravitational collapse and after*, S.W. Hawking.
005 *Infrared and Raman spectra of 1,2-dichloroethane and its deuterium compound in the gaseous, liquid and solid states*, S. Mizushima.
006 *James Chadwick*, P.A.M. Dirac.
007 *Does the gravitational constant vary?*, P.A.M. Dirac.
008 *Some ethical considerations regarding the use of man and primates in scientific research*, P.C.C. Garnham.
009 *Réflexions sur la débilité de l'intelligence des enfants trisomiques 21*, J. Lejeune.
010 *Remarques sur l'énergie et sur quelques moyens proposés pour remédier a la pénurie actuelle*, J. Lecomte.
011 *La tache pigmentaire congénitale chez des nouveaux-nés du timor portugais*, A. de Almeida.
012 *Domenico Marotta, G.B. Marini-Bettòlo.*
013 *Commemorazione del Padre Giuseppe Gianfranceschi, S.J., Presidente della Pontificia Accademia delle Scienze - Nuovi Lincei*, P.E. di Rovasenda.
014 *Heisenberg's influence on physics*, P.A.M. Dirac.
015 *New developments in neurobiological research*, R. Levi-Montalcini.
016 *A partial survey of mathematical achievements*, B. Segre.
017 *The kidney and its humoral action on arterial hypertension*, H. Croxatto.
018 *Elementary particles*, V. Weisskopf.
019 *Natural products and the protection of plants*. Summary of the Study Week held October 18-23, 1976.
020 *L'évolution des galaxies dans l'Univers en expansion*, B. Strömgren.
021 *Les relations entre la science et la foi chez Georges Lemaître*, O. Godart, M. Heller.
022 *P. Angelo Secchi*, S.J., H.A. Brück.
023 *Cultural and social background of the rapid modernization of Japan*, S. Mizushima.
024 *New ideas about gravitation and cosmology*, P.A.M. Dirac.
025 *Accordion-like vibrations of long chain molecules*, S. Mizushima.
026 *Organic matter in interstellar space*, R.D. Brown.
027 *Mathematics, science and mathematical sciences*, G. Colombo.
028 *Solar photochemistry and water photolysis*, J.M. Lehn.
029 *Understanding elementary particles by Gauge theories*, G. t'Hooft.

030 *The developmental role of sleep: a new hypothesis*. A. Giuditta, M.V. Ambrosini, G. Grassi Zucconi.

DOCUMENTA

001 *Perspectives of immunization in parasitic diseases*, Working Group, September 29 - October 2, 1981 - Conclusions

002 *Allocution de Sa Sainteté Jean Paul II et discours de Carlos Chagas, Président de l'Académie*, Audience Pontificale, 3 Octobre 1981 (Textes français et anglais)

003 *Statement of the consequences of the use of nuclear weapons*, October 7-8, 1981

004 *Declaration on prevention of nuclear war, September 23-24, 1982*

005 *Astrophysical cosmology*. Study Week, September 28-October 2, 1981. Conclusions

006 *Discourse of His Holiness John Paul II and address of Carlos Chagas, President of the Academy*. Papal Audience, October 23, 1982

007 *Rapport sur la International Conference on nuclear power experience*, L. Leprince-Ringuet, Vienne, 13-17 Septembre, 1982

008 *Allocution de Sa Sainteté Jean Paul II et discours de Carlos Chagas, Président de l'Académie*. Audience Pontificale, 12 Novembre 1983 (Textes français, italien et anglais)

009 *Chemical events in the atmosphere and their impact on the environment*. Study Week, November 7-11, 1983, Conclusions

010 *Immunology, epidemiology and social aspects of leprosy*. Working Group, May 28-June 1, 1984, Conclusions

011 *Declaration on nuclear winter*, January 23-24-25, 1984 (English, French and Italian text)

012 *Energy for survival and development*. Study Week, June 11-14, 1984, Conclusions

013 *The impact of space exploration on mankind*. Study Week, October 1-5, 1984, Conclusions

014 *Biological implications of optimization in radiation procedures*, Working Group, May 2-5, 1983, Conclusions

015 *The interaction of parasitic diseases and nutrition*. Study Week, October 22-26, 1985, Conclusions

016 *Remote sensing and its impact on developing countries*. Study Week, June 16-21, 1986, Conclusions

017 *Persistent meteo-oceanographic anomalies and teleconnections*. Study Week, September 23-27, 1986, Conclusions

018 *Molecular mechanisms of carcinogenic and antitumor activity*. Working Group, October 21-25, 1986, Conclusions

019 *Celebration of the anniversary of the restoration of the Academy (1936-1986). Inaugural address of President Carlos Chagas*, October 27, 1986 (English, French and Italian text)

020 *Allocution de Sa Sainteté Jean Paul II et discours de Carlos Chagas President de l'Académie*, Audience Pontificale 28 octobre 1986. (Texte français, anglais, italien)

021 *Historical aspects of the Pontifical Academy of Sciences*, G.B. Marini-Bettòlo. October 28, 1986

022 *Aspetti artistici della Casina Pio IV Sede della Pontificia Accademia delle Scienze*. C. Pietrangeli, October 28, 1986.

023 *A modern approach to the protection of the environment*. Study Week, November 2-7, 1987, Conclusions

VIE ET SYNTHÈSE DE L'OEUVRE SCIENTIFIQUE DES ACADÉMICIENS

001 *Biografia e Pubblicazioni dei 70 Accademici Membri della Pontificia Accademia delle Scienze all'atto della fondazione*, 28 ottobre 1936.

002 *Vie et Synthèse de l'oeuvre scientifique de 20 nouveaux Académiciens nommés par Jean XXIII en 1961* (J. Chadwick, C. Chagas Filho, E.J. Conway, A. De Almeida, G.C. De Hevesy, P.A.M. Dirac, J.C. Eccles, R.A. Fisher, G. Giacomello, V.F. Hess, C.N. Hinshelwood, S. Hörstadius, A. Hurtado, L. Leprince-Riguet, D. Marotta, S.I.P. Mizushima, J.H. Oort, C.V. Raman, M. Sandoval-Vallarta, H. Yukawa)

003 *Vie et Synthèse de l'oeuvre scientifique de 9 nouveaux Académiciens nommés par Paul VI en 1964* (W.A. Heiskanen, G. Herzberg, J. Lecomte, P. Lépine, M. Lora-Tamayo, W.W. Morgan, D.J.K. O'Connell, S. Siddiqui, F.A. Vening Meinsz)

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