PONTIFICIAE ACADEMIAE SCIENTIARVM SCRIPTA VARIA

80

THE RESPONSIBILITY OF SCIENCE

PROCEEDINGS

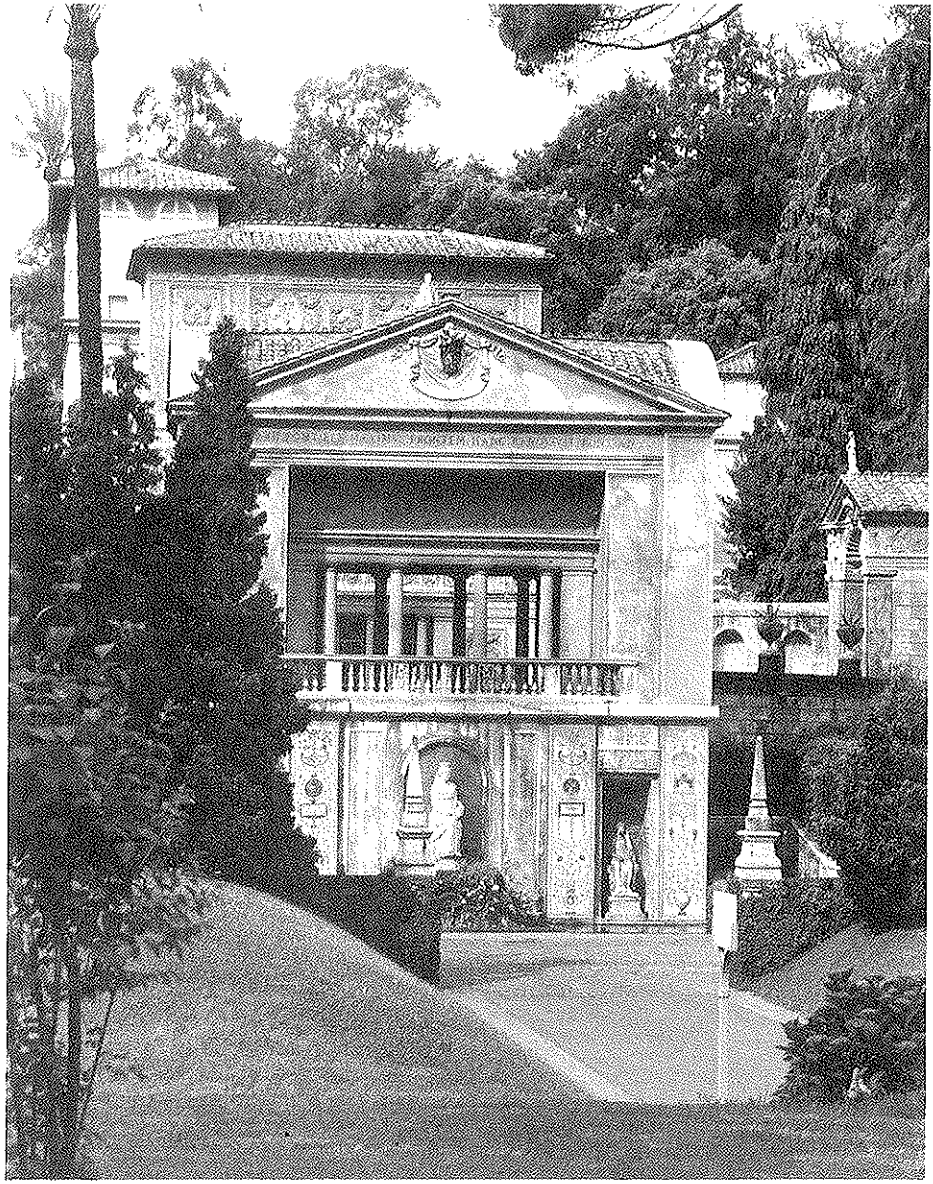
Plenary Session of the Pontifical Academy of Sciences
27-31 October 1988

Pontificia Academia Scientiarvm

1088-1988 Universitatis Bononiensis Secularia Nona

EX AEDIBVS ACADEMICIS IN CIVITATE VATICANA

MCMXC



Casina Pio IV - Vatican Gardens
Seat of the Pontifical Academy of Sciences

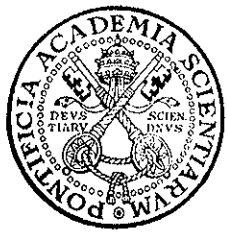
PONTIFICIAE ACADEMIAE SCIENTIARVM SCRIPTA VARIA

80

THE RESPONSIBILITY OF SCIENCE

PROCEEDINGS

Plenary Session of the Pontifical Academy of Sciences
27-31 October 1988



Pontificia Academia Scientiarvm

1088-1988 Universitatis Bononiensis Secularia Nona

EX AEDIBVS ACADEMICIS IN CIVITATE VATICANA

MCMXC

The opinions expressed with absolute freedom during the presentation of the papers and in the subsequent discussions by the participants in the Plenary Session, although published by the Academy, represent only the points of view of the participants and not those of the Academy.

Editorial committee for the preparation of the Proceedings:
GIANFRANCO BASTI
ARDIS GROSJEAN

ISBN 88-7761-040-9

CONTENTS

DAY ONE - 27 OCTOBER 1988

SCIENTIFIC PAPERS

DAY TWO - 28 OCTOBER 1988

DAY THREE - 29 OCTOBER 1988

SPECIAL SESSION HELD IN BOLOGNA AT THE INVITATION OF THE UNIVERSITY OF BOLOGNA TO CELEBRATE THE 900th ANNIVERSARY OF ITS FOUNDING

EXCHANGE OF OFFICIAL GREETINGS IN BOLOGNA

SCIENTIFIC PAPERS PRESENTED IN BOLOGNA

DAY FOUR - 30 OCTOBER 1988

CRITICAL SYNTHESIS

DAY FIVE - 31 OCTOBER 1988

CONCLUDING SESSION

APPENDICES

FOREWORD

When the Pontifical Academy of Sciences celebrated the jubilee of its reconstitution and renewed founding in 1986, it resumed the practice of publishing the Session's Proceedings. Continuing this practice, we present the volume of the Proceedings of the 1988 Plenary session where, meeting in the Seat of the Academy in the Vatican, and also in Bologna, the Pontifical Academicians deliberated on the theme, "The Responsibility of Science".*

In a world where science and technology have an ever increasing impact on all aspects of economic, social and cultural life, it is essential that this growing objective responsibility *of science be accompanied by an at least equal increase in the* subjective responsibility *of the scientists themselves. Indeed, though the final application or end use of the results produced by scientific and technological research does not usually depend on the individual scientists, it is nevertheless clear that the scientific community is capable of exerting an effective control on the entire chain of knowledge, from discovery all the way to application, and that it can greatly influence the education and training of researchers. This increase in moral responsibility requires cooperation of various types among the many institutions on which our society largely depends for its scientific and moral life, so that these institutions may be able to provide the necessary formation in scientific and moral values. Such, then, was the focus of this Plenary Session of the Pontifical Academy of Sciences.*

For the very first time in its history, the Pontifical Academy of Sciences held part of a Plenary Session outside its Seat in Vatican City. This exceptional occurrence was related to an event significant for the entire academic world: the nine-hundredth anniversary of the founding of the University of Bologna, "Alma Mater Studiorum". The Special Session held in Bologna on the third day of the deliberations provided an excellent illustration of the close relationship which exists between the functions performed by the university and the role of the entire scientific sphere in promoting an authentic culture impregnated

---

* *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, Scripta Varia 73,* Pontificia Academia Scientiarum, Vatican 1988. (The Academy has also published the Proceedings of its Plenary Sessions in 1976, 1978 and 1979 as *Science and the modern world, I-III, Scripta Varia* nos. 42, 49 and 52).

with moral responsibility. It is no accident, in fact, that the first theme, discussed at the Seat of the Academy on Day One of the Plenary Session, was precisely The Responsibility of the Universities. *Each of the presentations dealing with this topic stressed the need for promoting, during academic training, all those values which would form the student into a good scientist* in spe, *prepared to serve both scientific progress and the well-being of society. Students need encouragement to fight against the recurrent temptations of science economically enslaved to technological uses. If we want to have good scientists in the future, we must inspire the new generation with the essential theoretical goals of scientific research. If we also want these future scientists to be dedicated to human and social progress, we must educate them in the proper values of humanistic culture.*

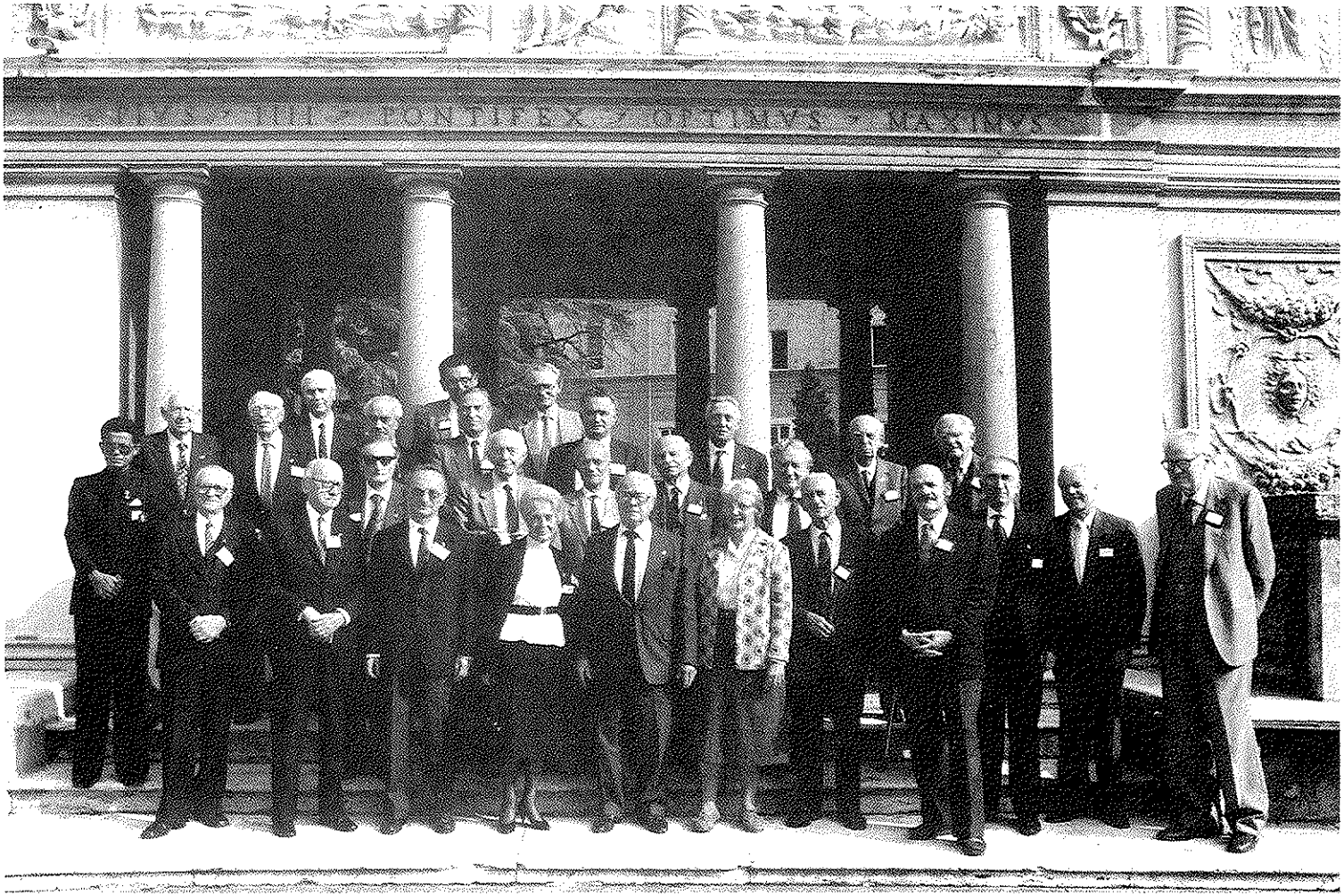
Here lies the true challenge facing both developed and developing countries and their institutions—scientific, cultural, political, moral and religious, all of which are now confronted with the rapid development of scientific knowledge and of its technological applications. The challenge is this: how to overcome the lack of dialogue between the "two cultures", one scientific and one humanistic. The necessity of meeting this challenge has emerged from practically all the contributions made during the Plenary Session, though the points of view and the approaches proposed have differed. Indeed, it is inconceivable that a positive soluton to this situation could depend on the responsible actions of single scientists or single groups of scientists, or on one educational establishment or structure. Nor may we suppose that solutions will come from the political mediation of various governments which are all too often incapable of understanding all the implications of scientific and technological questions, and which are always constrained by economic and national interests.

The problems we are dealing with have, in fact, a universal structure, just as scientific culture and applications have an intrinsic universal value. Some of these complex issues which were raised during the Plenary Session included: a more just distribution of educational, scientific and technological resources in relation to the demographic situation; questions of ecology; military use of our ever increasing knowledge of the inner structure of matter, both inanimate and animate; genetic engineering; ethical questions related to the present development of neuroscience; the improper divulgation of scientific information as a power ploy. All these are problems requiring that give-and-take which we now lack between the two cultures, each having its respective categories and languages. Yet, if we do not want to repeat earlier mistakes, we must work for such an integration through an authentic dialogue, though maintaining the reciprocal distinctions of the two interacting parts.

Finally, it should be noted that these Proceedings are being published as a co-edition between the University of Bologna and the Pontifical Academy of Sciences. Thus this volume constitutes in itself a small but concrete example of the new, open, cooperative and constructive mentality which its contents express.

CARLOS CHAGAS
President (1972-1988)
of the Pontifical Academy of Sciences

FABIO ROVERSI MONACO
Rector Magnificus
University of Bologna



First row, from left to right: Croxatto, Garnham, Thirring, Levi-Montalcini, Chagas, Döbereiner, Leprince-Ringuet, Rich, Blanc-Lapierre, Mössbauer, Marini-Bettòlo.

Second row: Malu, Łojasiewicz, Lichnerowicz, Pullman, Abragam, Runcorn, Weisskopf.

PONTIFICAL ACADEMICIANS PRESENT AT THE 1988 PLENARY SESSION

ABRAGAM Anatole, *(France)*
BERGSTRÖM Sune, *(Sweden)*
BLANC-LAPIERRE André, *(France)*
CHAGAS Carlos, *(Brazil)*
COYNE George V., *(Vatican City State)*
CROXATTO Hector R., *(Chile)*
DE GIORGI Ennio, *(Italy)*
DÖBEREINER Johanna, *(Brazil)*
ECCLES John C., *(Switzerland)*
GARNHAM Percy C.C., *(United Kingdom)*
GERMAIN Paul, *(France)*
LEJEUNE Jérôme, *(France)*
LEPRINCE-RINGUET Louis, *(France)*
LEVI-MONTALCINI Rita, *(Italy)*
LICHNEROWICZ André, *(France)*
ŁOJASIEWICZ Stanisław, *(Poland)*
MALU Wa Kalenga, *(Zaïre)*
MARINI-BETTÒLO G.B., *(Italy)*
MINTZ Beatrice, *(United States of America)*
MOSHINSKY Marcos, *(Mexico)*
MÖSSBAUER Rudolf L., *(Federal Republic of Germany)*
PAVAN Crodowaldo, *(Brazil)*
PULLMAN Bernard, *(France)*
PUPPI Giampietro, *(Italy)*
RANZI Silvio, *(Italy)*
RICH Alexander, *(United States of America)*
RUNCORN S. Keith, *(United Kingdom)*
SIDDIQUI Salimuzzaman, *(Pakistan)*
SZENTÁGOTHAI János, *(Hungary)*
THIRRING Walter, *(Austria)*
TUPPY Hans, *(Austria)*
WEISSKOPF Victor, *(United States of America)*

EDITORIAL NOTE

The structure of this volume reflects the course of events at the Plenary Session of the Pontifical Academy of Sciences which was held at the Seat of the Academy and at the University of Bologna during the period 27-31 October 1988.

Each of the papers presented at the Plenary Session, while sharing the common theme of "The Responsibility of Science", examines a particular aspect or a sub-theme such as The Responsibility of the Universities, *or* Science and Ethics. *The papers are printed in the order in which they were delivered, together with the discussions which followed them.*

The scientific papers are preceded by the Commemorations *which were pronounced in honour of the seven Pontifical Academicians who had died since the previous Plenary Session of 1986, and they are followed by two speeches of hommage addressed to the outgoing President, Carlos Chagas, and by Professor Chagas' response. The first item on the program of the last day of the Proceedings is the address of the young scholar selected to receive the Pius XI Gold Medal Award, Professor Luis A. Caffarelli, who describes his work in mathematics.*

At the conclusion of the Plenary Session the participants adjourned to the Sala Regia in the Apostolica Palace. There the Holy Father pronounced an allocution to the assembled Pontifical Academicians, Cardinals and members of the Diplomatic Corps accredited to the Holy See. Professor Chagas, addressing Pope John Paul II, gave an account of the work of the Pontifical Academy of Sciences. These two discourses appear at the end of this volume. During the solemn audience Professor Caffarelli received the Pius XI Gold Medal from the hands of the Holy Father.

An Appendix contains the Declaration of the Pontifical Academy of Sciences on Chemical Warfare *which was initiated and elaborated by the Pontificial Academicians in the course of the Plenary Session. Also appended is an overview of the activities of the Academy since the previous Plenary Session, and a list of the Academy's principal recent publications.*

THE RESPONSIBILITY OF SCIENCE

DAY ONE
27 OCTOBER 1988

OPENING REMARKS

CARLOS CHAGAS
President, Pontifical Academy of Sciences

Dear Colleagues,

It is truly an honour to open this first meeting of our 1988 Plenary Session. It is an even greater honour in view of the fact that my term of office will come to an end in a few days, and this is therefore the last Academy meeting at which I shall preside.

I have enjoyed every moment of the sixteen years I served here. There have been other moments of great joy, pleasure and honour, but never, in the many other meetings or chairmanships I have known, have my knowledge and my spirit been so enriched as in my collaboration with you, my colleagues here in the Casino Pio IV.

There are few of you, I believe, who were not elected to the Academy during my chairmanship. In my view, the Plenum of the Academy has been very wise in selecting and electing those who now constitute its membership. As for those who were already here before my time of office began, they gave most generously to me of their experience and knowledge.

Therefore I wish to express to all of you my profound thanks for the contributions you have made to the Academy and my own appreciation of the honour, the joy, the experience I have gained in your company. Thank you, my colleagues, very much.

COMMEMORATION OF RECENTLY DECEASED PONTIFICAL ACEDEMICIANS

The first act performed by the 1988 Plenary Session was to honour the memory of those Members who had died in the preceding years: Louis de BROGLIE, Edward DOISY, Luis LELOIR, Bengt STRÖMGREN, Alfred UBBELOHDE, Hamao UMEZAWA and Karel WIESNER.
The commemorations are published here in the order in which they were presented. Hermann Brück, who had prepared the text commemorating Bengt Strömgren, was prevented from being present at the Session. His text was read, therefore, by George Coyne, S.J.

EDWARD A. DOISY (1893-1986)

Born in Hume, Illinois, U.S.A., on 13 November 1893. Professor of Biochemistry at St. Louis University, St. Louis, Missouri. Nobel Laureate in Physiology and Medicine, 1943. Pontifical Academician since 29 May 1948. Died on 23 October 1986.

It is with a great sadness that I have to tell you that our admired colleague Dr. Edward Adelbert Doisy died of heart disease at the Medical Center of the St. Louis University, the University where he spent most of his long and productive life. He was 92 and he passed away a few days before the solemn celebration of the 50th anniversary of this Academy, on 23 October 1986.

Dr. Doisy was one of the most renowned and creative biochemists of that ebullient period of biology history, when in a few decades, a considerable number of biologically active substances, such as hormones, vitamins, bacteriostatics, neurotransmitters, enzymes, etc., were discovered, isolated, and chemically identified.

One of the most vivid emotions I can recall of those years (1939) as a student at the medical school of the University of Chile, was when Dr. Cruz-Coke, Professor of Biochemistry, of fond memories, in the classroom dramatically announced the memorable exploit of Dr. Doisy, who successfully had obtained in crystalline form the estrogen isolated from the urine of pregnant women, the first sex hormone ever to be extracted.

Dr. Doisy will be remembered not only for his numerous scientific accomplishments, but as well for his uncommon dedication, friendliness to his collaborators, graduate students. His generosity to St. Louis University is legendary.

The scientific legacy brought him world-wide acclaim; however, we easily realized that a whole era of science has passed with him. He personifies an age when a great deal of the research work in biochemistry has been done by hand, with a limited budget, with no well prepared technicians always busy, facing much more the working wooden table and the hood than the desk office.

The Spartan virtues of his long life devoted to carry on the projects of his restless mind were deeply rooted in his early life. He was born in Hume (Illinois) a small village of 500 inhabitants, on November 13, 1893, and according to a delightful autobiography written when he was 82 years old, he had learned from his mother that work could be fun. Being a school boy, he sold garden produce, delivered newspapers and saved up enough money to buy a cow, which he milked and distributed the product in the restaurants. He received another kind of joy from his father, who introduced his son to out-of-door activities: fishing, hunting, baseball, tennis; and Edward Doisy gained physical endurance and a love for sports, which he cultivated for long years ahead, and which he shared with his wife, colleagues and particularly with postgraduate students. According to his own report, he had the feeling that «the students keep the impression that no one could receive a degree in biochemistry until he had learned to catch trout».

He graduated from high school when he was 16 and went off to the University of Illinois, in Champaign. He registered as a premedical student, and there he was introduced to the chemistry of the nervous tissue. He earned his master's degree, but later on, 1915, he received a scholarship for graduate study in Harvard Medical School, where he obtained his Ph. D. working with one of the foremost biochemists of the day, Dr. Otto Folin. Under his direction he studied a debatable problem dealing with creatine-creatinine determination, but the first World War changed his plans. In 1917, he was called in the first draft contingent. An order was read directing him to report to the Rockefeller Institute for Medical Research, where he could learn from Dr. Donald D. Van Slyke about determinations of blood gases. After his discharge from the Army, he had already published several papers, and he was offered a position in the Department of Biochemistry in Washington University School of Medicine in St. Louis. In his department he undertook a series of research work on blood gases, uric acid, but one of the most startling was his engagement, in 1920, to prepare insulin from pancreas in collaboration with the well known Philip Schaffer and Michael Somogyi, in a great hurry, because at that time the supply

of that hormone was very scarce and in the hospital there were 2 children in diabetes coma who badly needed it. The purification procedure was quite successful and the children were saved.

One of the reasons why he got along so well was the intimacy of the staff and the intensity of purpose of his incisive mind and the perception of a fascination radiating from his spirit when he was finding out something new. But not everything he could undertake worked out. During the war he was looking intensively for antibiotics, but none of the products isolated turned out to be useful therapeutically.

The Dean of Saint Louis University School of Medicine offered him a professorship in biochemistry, a proposition that appeared to Doisy quite attractive and unusual at that time because, being a Protestant, he was offered a teaching position by a Jewish Dean of the Medical School owned by Jesuits. It was a happy association. Dr. Doisy organized the Department of Biochemistry, and became its first chairman, a post he held until his retirement with no interruption, in 1965, because he never asked for a sabbatical year and day by day he felt more attached to his lab and became intensively affectionate to Saint Louis University.

His most praised achievement started in 1922, when his close friend Edgard Allen, a young biologist of Washington University, asked Dr. Doisy to help solve the riddle about the factors which induce the estrus cycle of the mouse. Dr. Doisy agreed to prepare some extracts of ovarian tissue for him. Allen had noted the development of the ovarian follicle just preceded the appearance of the estrus, and the follicular fluid from saw ovaries in ovariectomized mice produced the typical estrus. Doisy prepared extracts of liquor folliculi, *corporea lutea*, whole ovaries, and placenta, looking for the active substance, but his collaboration for a long time was not very fruitful, until Doisy decided to isolate the estrogenic principle from the urine of pregnant women. As we know, Doisy, was able at the XIII International Physiological Congress, held in Boston in August 1926, to show slides of the pure crystalline compound corresponding to estrone. Thereafter, Dr. Doisy and his associates isolated three female sex hormones. These discoveries stimulated research in reproduction endocrine problems and opened the door to a new field of steroid compounds. Patents granted on the results of these research works were turned over to the University, and royalties from these were used, among other things, to finance another of his most celebrated discoveries: identification and synthesis of vitamin K. He had heard from Ralph McKee, a graduate student, a report about hemorrhagic disease in chicks, and he found so appealing the challenge to identify the chemical factor involved in this trouble that he started, with a team of seven scientists, a research trying to isolate the anti-hemorrhagic factor called vitamin

K, using as starting material putrefied fishmeal and alfalfa, which prevents and cures the chick illness. After an intense activity, one of his collaborators, Stephen Binkley, was able to exhibit proudly a beautiful crystalline product, vitamin K2, on November 13, 1938, as a birthday present for both of them!

A short time later K-1 was crystallized. Both compounds proved to be 2-methyl 1-4 naphtoquinone, substances which stimulate the production of prothrombin, an essential element in blood clotting. For this outstanding achievement he was awarded the 1943 Nobel Prize in Physiology and Medicine jointly with Dr. Henrik Dam of Copenhagen.

In the past 40 years, approximately 70 graduate students working under Dr. Doisy's chairmanship have received the Ph. D. degree. He has received numerous honors including St. Louis University's highest award, the fleur de lis, conferred in 1951. He holds honorary degrees from many of the most prestigious Academies and Universities.

He was one of the founders of the American Society of Biological Chemistry and its president in 1945. He also served as President of the Endocrine Society and the Society for Experimental Biology and Medicine. The Biochemistry Department was named for him in 1965, and in that same year the professorial chair in biochemistry was named in memory of Dr. Doisy's first wife, Alice A. Doisy. Doisy Hall of the School of Medicine was dedicated to him at its completion in 1968 in honor of his being «one of the most distinguished professors ever to hold faculty rank at the University». In 1977, a big center, housing a large auditorium and the medical center library, was dedicated in honor of his second wife, Margaret McCormick. Dr. Doisy justified the great admiration of his followers, not only because of the example he set as a scientist; he also excelled in his proverbial generosity and philanthropy and it is not a surprise that his name is at the top of St. Louis University's all-time list of individual benefactors. In addition to his decision to sign over all the rights and royalties from his works to the Biochemistry Department, a few months before his death Doisy and his wife Margaret had pledged 1 million dollars for the current expansion of the Pius XII library.

Dr. Doisy will be remembered as a paradigmatic scientist for his many distinct traits and qualities of a superior spirit, friendly collaboration with others in the search of new knowledge. He was always ready to invite with optimism to experience the joy of exploring the unknown, capturing the new harmony and beauty bursting out from the mystery, a man who could write in the last days of his fecund life: «I suspect that only few scientists have enjoyed their work as much as I».

(HECTOR R. CROXATTO)

KAREL WIESNER (1919-1986)

Born in Prague, Czechoslovakia on 25 November 1919. Research Professor of Chemistry at the University of New Brunswick, Fredericton, N.B., Canada. Pontifical Academician since 17 April 1978. Died on 28 November 1986.

Ten years ago, just in these days of October, Karel Wiesner rose at that bench on the left, to introduce himself to the Academy.

Karel Wiesner left us two years ago after a long and painful illness which made it impossible for him to attend the Academy's 50 years' celebration.

He represented among us his country of origin, Czechoslovakia, where he was born in 1919 and where he started his scientific career obtaining his first successes, and Canada where he moved in 1948 and where he created, at the University of New Brunswick in Fredericton, a school of natural product chemistry which became famous all over the world.

As a student of the Charles University of Prague he faced the tragic events of the occupation of his country.

He managed anyway to follow the courses of chemistry and to carry out, at the Prague Bulovka Hospital, independent research in the field of polarography, a discipline well established at the Charles University, where Professor J. Heyrovsky, the discoverer of polarography, was the head of the Physical Chemistry Department.

This work, for which Wiesner received in 1945 his doctorate in Physical Chemistry, led him to the innovative discovery of kinetic polarographic currents, the first method which made it possible to determine the reaction rate of very fast chemical reactions, as stated by Professor Heyrovsky himself in his Nobel Lecture.

After World War II he joined Professor Ruzicka's laboratory at the Eidgenössische Technische Hochschule (E.T.H.) in Zürich, where he became a disciple of our colleague and friend Professor V. Prelog.

The atmosphere of the E.T.H., in the forefront of structure elucidation, influenced the future activity of Karel Wiesner.

In fact when in 1948 he moved with his wife Blanka and his young child Charles to New Brunswick, a land of which he would become very fond, he concentrated on the structure elucidation of the aconitum and delphinium alkaloids. Having overcome the difficulties of the first years with the help of the head of the Chemistry Department, Professor F. Toole, Karel Wiesner could assemble a large group of young and enthusiastic people.

Thus he determined the structure of the Garrya and Lycopodium alkaloids and later that of the more complex Aconitum compounds delphinine, the toxic principle of the delphinium plant and, in collaboration with Professor G. Buchi at M.I.T., aconitine, contained in monkshood and to which chemists for more than 100 years had devoted their efforts.

His success in establishing the exact formula of these policyclic and polisubstitute alkaloids, in the pre-N.M.R. era is due to the logical approach followed, which allowed him to select a number of oriented degradative reactions: coupling the information obtained in this way with a perfect knowledge of biogenesis and reaction mechanism, he could then deduce the structure.

The work on structure elucidation was concluded by that on ryanodine, the insecticide principle of Ryania.

In those years he also organized annual Summer Seminars which were held either in Fredericton or on Grand Manan Island in the Bay of Fundy.

In these many leading scientists in the field participated, some of whom, like Professor A. Eschenmoser, are here today.

In the early sixties, he came to spend a sabbatical year in Rome. I was glad for his stimulating presence at the Istituto Superiore di Sanità: during almost one year my coworkers and I could greatly benefit from his stimulating ideas and his teaching.

The sabbatical represented for Karel Wiesner a turning point: after going back to the University of New Brunswick, he decided to concentrate his efforts on the synthesis of the complex natural products of which he had previously solved the structure.

In fact with the advent of the new spectroscopical techniques, structure determination had lost for him most of the challenge it had before.

Since then he was able to develop simple strategies for the synthesis of the alkaloids mentioned above.

The technique he used was based on testing the key reactions of a first generation synthetic design on a model compound and possibly modifying it before carrying out the synthesis proper.

On the basis of the experience gained and accidental discoveries made in the first generation synthesis, a second generation synthetic design was worked out, tested on models and then implemented by a synthesis and so on.

Thus his fourth generation syntheses, among which one should remember that of napelline and 13-desoxydelphonine, attained to a high degree the objectives and the standards of selectivity Karel Wiesner was pursuing.

In 1979, after concluding the synthetic work on the diterpene alkaloids, Karel Wiesner decided to dedicate his efforts to digitalis cardenolides, of which since 1966 he had envisaged the possibility of preparing less toxic analogues.

Though carried out in only a few years, this work was successful both in the chemical and in the pharmaceutical aspect: a new and efficient general synthesis of these compounds was in fact realized and analogues with comparable activity on the heart muscle and reduced toxicity were prepared.

Karel Wiesner was the author of about 200 publications and reviews, which are remembered not only for their high scientific content but also for the personal and fascinating style in which they are written.

For his leading work over about 50 years he was considered among the most distinguished organic chemists of our time.

Although serously ill in the last years, he always continued to follow directly the activity of his students and coworkers.

I admired Karel Wiesner, with whom I was acquainted for a long time, for his bright mind, for his skillfulness in approaching chemical problems and for his straight logic in debating scientific matters.

In his daily hard work he always had the support of his wife Blanka and his family.

During the ten years in the Pontifical Academy of Sciences he always collaborated in its initiatives with great enthusiasm.

It is always sad to commemorate an older colleague, but this is unnatural in the case of a younger one, who could have still contributed to the progress of science.

The sorrow for his departure is therefore even deeper.

(GIOVANNI BATTISTA MARINI-BETTÒLO)

HAMAO UMEZAWA (1914-1986)

Born in Okama, Fukui Prefecture, Japan, on 1 October 1914. Professor of Biochemistry, University of Tokyo. Pontifical Academician since 26 September 1983. Died on 25 December 1986.

Professor Hamao Umezawa — who was a Member of our Academy since 1983 — died December 25th, 1986.

He was born 1914 in Okama City, Japan, and studied medicine at Tokyo University, where he also made his dissertation in 1945.

He remained in Tokyo all his life as Professor and Director of several departments at the University of Tokyo and the Institute of Medical Sciences. He retired in 1975, but until his death remained Director of the Institute of Microbial Chemistry, an Institute that he had been developing and directing since 1962.

Dr. Umezawa was very active in several research fields, especially in isolating physiologically active metabolites from micro-organisms. The most important antibacterial antibiotic is Kanamycin 1956.

He also organized up screening of microbial products for anticancer activity from 1951. Among the identified products several became registered drugs (bleomycin, etc.).

Another field that he pioneered was enzyme inhibitors from micro-organisms, and studies of marine organisms.

Those who had the privilege to know him were also struck by his warm personality and his extensive knowledge and appreciation of western art and music.

Dr. Umezawa was a remarkable creative scientist who inspired and brought up several generations of young Japanese scientists. He has been an important force behind the strong scientific and industrial development in the antibiotic field in Japan.

(SUNE BERGSTRÖM)

LOUIS de BROGLIE (1892-1987)

Né le 15 août 1892 à Dieppe, en France. Professeur honoraire de physique à la Faculté des Sciences, Université de Paris. Secrétaire perpetuel honoraire de l'Académie des Sciences, Paris. Lauréat du prix Nobel en physique, 1929. Académicien pontifical depuis le 5 avril 1955. Décédé le 19 mars 1987.

Louis de Broglie est né le 15 août 1892 à Dieppe. Il était le dernier d'une famille de quatre enfants, ses deux sœurs et son frère, Maurice, étant beaucoup plus âgés que lui. Maurice joua un grand rôle dans l'orientation de son très jeune frère. Il écrivit, lorsqu'en 1945 il le reçut à l'Académie française: «Rien dans l'enfant sociable et turbulent que vous étiez alors n'annonçait le

savant assez austère et même un peu sauvage que vous êtes devenu. Le génie mathématique se révèle généralement de très bonne heure, comme le génie poétique ou musical; vous fîtes à cette règle une assez remarquable exception». Le jeune Louis, brillant élève, sauf en maths et en chimie, fut attiré, après un bachot précoce, par l'histoire, celle du Moyen-Age en particulier. D'où une licence en Sorbonne à 18 ans. Il compléta sa formation par un examen de droit, tout en envisageant un diplôme historique sur la politique du Régent vers 1717. Mais sa réflexion le pousse aussi vers la pensée philosophique orientée par Henri Poincaré. Alors il change de faculté, empoche rapidement une licence de science et se trouve, à 20 ans à peine, avant même son service militaire, attiré par un pôle puissant qui l'entraînera sa vie durant.

Pour comprendre le cours de ces événements, il faut savoir que Maurice, le frère aîné, après quelques années passées comme officier de marine, avait quitté son uniforme pour se consacrer à la physique des rayons X. Dans son hôtel particulier près de la place de l'Etoile à Paris, il avait aménagé un petit laboratoire pour l'étude de la diffraction de ces rayonnements. Progressivement, quelques physiciens, Lucas, Dauvilliers, Thibaud, Trillat, vinrent y travailler et, en 1929, je me joignis à eux pour être l'assistant de Maurice de Broglie dans l'orientation nouvelle qu'il voulait donner à ses recherches en direction des transmutations des noyaux atomiques. Ainsi, dès 1911, Maurice était un jeune physicien estimé, et, au cours de cette année, se tint à Bruxelles le fameux «congrès Solvay» qui réunit pendant une semaine les plus grands physiciens de la planète pour une confrontation sur la science la plus avancée, la plus sujette à discussion, la théorie des quanta. Maurice de Broglie avec Paul Langevin furent les secrétaires de ce congrès et en rédigèrent les comptes rendus. Ainsi, le jeune Louis fut-il passionné par le contenu de ces discussions: il avait trouvé la voie de sa propre réflexion.

Mais vint le service militaire, puis la guerre de 1914. Louis fut mobilisé, affecté comme sapeur télégraphiste au poste de la tour Eiffel. Adjudant à la fin de la guerre, il ne fut démobilisé qu'au milieu de 1919. C'est alors qu'il trouva le chemin du laboratoire de Maurice: il participa aux colloques internes avec les jeunes physiciens attelés aux recherches sur la diffraction des rayons X et sur les faisceaux d'électrons. Les rayons X présentent un aspect ondulatoire avec les phénomènes de diffraction sur les cristaux. Mais l'effet photoélectrique de ces mêmes rayonnements oblige à leur attribuer un aspect corpusculaire, celui des photons. Il est bien difficile pour un esprit rationnel d'admettre que l'on puisse être effectivement une chose et son contraire: c'était pourtant ce qui apparaissait avec les rayons X. De plus, bien des difficultés se présentaient dans l'image que l'on se faisait de l'atome. Le modèle de Bohr-Rutherford n'était pas satisfaisant. Un électron tournant autour du noyau doit, à cause

de son accélération, perdre progressivement son énergie, donc tomber finalement sur le noyau. C'est contraire à la réalité. Et puis, comment admettre facilement qu'un électron puisse changer brusquement d'orbite en émettant un photon et que seules certaines orbites soient autorisées, ce qu'indiquent les raies monochromatiques de l'émission? Car la mécanique classique est une mécanique du continu, et l'interdiction de changements continus d'orbites (avec émission de rayonnements d'énergies variées) est contraire au fondement même de la mécanique.

On le voit, de nombreux problèmes, combien fondamentaux, se posaient alors et l'on comprend que l'esprit curieux de Louis de Broglie se soit passionné à les étudier et à essayer de résoudre les graves contradictions qui se présentaient. Sa thèse de doctorat, quelques dizaines de pages petit format, sera le résultat de ses réflexions. Il pense que, tout comme la lumière, la matière doit aussi présenter, outre l'aspect corpusculaire que l'on connaît bien, un aspect ondulatoire aussi fondamental, et il donne même la formule d'une longueur d'onde associée aux électrons, formule très simple: $\lambda = h/p$, h étant la fameuse constante de Planck, introduite pour la théorie des quanta dès 1905, et p étant l'impulsion (la quantité de mouvement) de l'électron.

Ces idées parurent curieuses et même choquantes. La thèse, soutenue en 1924 devant Jean Perrin et Paul Langevin, contenait les principes d'une nouvelle mécanique, ondulatoire, mais dont les conséquences apparaissaient comme tellement invraisemblables qu'elle fut considérée avec un peu de légèreté. Pensez donc! imaginer qu'une particule soit un «paquet d'ondes», qu'un faisceau d'électrons puisse présenter des phénomènes de diffraction, c'était fort difficile à concevoir. Ainsi, Jean Perrin, qui présidait le jury, confia-t-il à Maurice de Broglie, à propos des conceptions de son jeune frère: «Tout ce que je peux dire, c'est que votre frère est bien intelligent!» Quant à Langevin, il ne croyait pas que la voie que Louis de Broglie pensait ouvrir fût la bonne porte pour sortir de l'impasse où la physique était acculée.

Mais voilà que, trois ans plus tard, en 1927, deux physiciens américains, Davisson et Germer, expérimentant sur la réflexion des électrons rapides par le nickel, trouvent un phénomène inexplicable. Ils ne comprennent pas, vont vers Einstein, qui leur dit après réflexion: «Vous êtes assis sur une mine d'or». C'était la diffraction des électrons, confirmation éclatante de la mécanique ondulatoire et de la longueur d'onde de Louis de Broglie. Alors tout change: on prend ce jeune homme au sérieux, on s'empresse de le nommer maître de conférence à la Sorbonne avec un cours officiel à l'Institut Henri Poincaré. Il était temps car le prix Nobel venait couronner ses réflexions dès 1929.

Ainsi, la mécanique ondulatoire prévoyait la diffraction des faisceaux de particules. Elle fut confirmée non seulement pour les électrons mais aussi, plus

tard, pour les faisceaux de neutrons. Les applications des propriétés ondulatoires des électrons furent considérables. Les ondes associées à leur mouvement permirent de définir le pouvoir séparateur des microscopes électroniques, tout comme la longueur d'onde optique permet de définir celui des microscopes à lumière visible. On peut ainsi réaliser avec les électrons des microscopes extrêmement performants, aux pouvoirs séparateurs plusieurs centaines de fois supérieurs à ceux de l'optique — d'où les admirables photographies de phenomènes cristallins et surtout biologiques, impossibles à déceler avec l'optique ordinaire.

Mais les prolongements de la mécanique ondulatoire furent aussi considérables dans le domaine des concepts fondamentaux. Tandis que la mécanique classique permet, à partir de la position et de la vitesse d'un mobile à un instant donné, de calculer rigoureusement son mouvement ultérieur, la mécanique ondulatoire n'apporte plus une précision aussi definie et se borne à des indications probabilistes. C'est Heisenberg qui formula la relation d'incertitude $\Delta q \cdot \Delta p \geq h$. Impossible de mesurer avec une précision infinie à la fois la position et la quantité de mouvement d'une particule. Plus on resserre la précision sur l'une des deux quantités, plus l'imprécision apparaît sur l'autre, la limite du produit des deux imprécisions étant la fameuse constante de Planck.

Les travaux de Louis de Broglie, d'Heisenberg, de Schrödinger, de Dirac, de Pauli jettant une lumière toute nouvelle et révolutionnaire sur la macrophysique. Ce n'est pas en quelques lignes que l'on peut les développer. Disons seulement que les discussions sur la dualité onde-corpuscule, sur l'assimilation du corpuscule à un paquet d'ondes, sur la probabilité de présence de la particule, définie par le carré de la fonction d'onde, sur une interprétation causale de la mécanique ondulatoire, ne sont pas terminées. Louis de Broglie écrivait récemment: «Malgré tant de succès remportés et tant de chemin parcouru, je ne crois pas que l'énigme ait été vraiment résolue».

Louis de Broglie fut titulaire de la chaire de physique théorique à la faculté des sciences de la Sorbonne, reçut la médaille Henri Poincaré, le prix Albert I^{er} de Monaco, fut élu membre de nombreuses académies dont l'Académie Pontificale des Sciences. Il entra à l'Académie des Sciences en 1933 et en devint le secrétaire perpétuel en 1942. Il fut reçu à l'Académie française en 1945 par son frère Maurice. Il a écrit, en dehors de ses cours, de nombreux ouvrages remarquables à l'usage du grand public cultivé. Ce sont des réflexions profondes sur la physique. En voici les titres: *La physique nouvelle et les quanta, Matière et lumière, Continu et discontinu en physique moderne, Physique et macrophysique, ...*

Louis de Broglie, génie solitaire, penseur audacieux, a ouvert des horizons nouveaux devant les yeux étonnés de ses contemporains.

(Louis Leprince-Ringuet)

BENGT STRÖMGREN (1908-1987)

Born in Göteborg, Sweden, on 21 January 1908. Professor Emeritus of Astronomy. Director of Nordic Institute of Theoretical Atomic Physics, Copenhagen. Pontifical Academician since 2 December 1975. Died on 4 July 1987.

Bengt Strömgren, who died on 4th July 1987, was born in Göteborg in Sweden on 21 January 1908. He was the son of Professor Elis Strömgren, the Director of the Observatory of the University of Copenhagen. Elis Strömgren was a distinguished astronomer of the old school, well versed in celestial mechanics and a great expert in the theory of the orbits of planets and comets in the solar system. Bengt thus learned early from his father the foundations of mathematical astronomy, while in the nearby Institute of Theoretical Physics of Niels Bohr he was introduced to the field of atomic physics and quantum theory.

The close cooperation between father and son resulted in the joint publication of an outstanding Textbook of Astronomy which appeared in German in 1933, when Bengt had been appointed «Lector» in the University of Copenhagen, where his father was Professor. The chapters on celestial mechanics were written by the father while those on astrophysics were the first evidence of Bengt's skill in exposition, which was to show itself in many major contributions to international symposia in later years.

In the early 1930s Bengt Strömgren began his theoretical work on the chemical composition of the interiors of stars and on the abundance of the principal elements hydrogen and helium. In 1936 he joined Professor Otto Struve at Yerkes Observatory in the United States, where a brillant team of astrophysicists, including a member of our Academy, W.W. Morgan, worked on problems of both the physics of stellar atmospheres and the properties of interstellar gas. Strömgren demonstrated that very hot stars are surrounded by regions of ionised hydrogen which can be traced out to clearly determined distances.

For the period of the second World War Strömgren returned to Denmark, where in 1940 he was appointed Director of the Copenhagen Observatory in succession to his father. When the war ended Strömgren went again to the United States, where he was appointed Director of the Yerkes and McDonald Observatories in 1951 and Professor in the Princeton Institute for Advanced Studies in 1957. He returned to Denmark ten years later when he was offered by the Royal Danish Academy the palatial residence at Carlsberg that had been formerly occupied by Niels Bohr.

In these later years Strömgren's interest turned to problems of stellar composition and its correlations with the ages of stars. He developed photoelectric instead of spectroscopic methods using interference filter for narrow-band photometry, which allowed him to embark on large-scale surveys of the sky and on investigations of the chemical and dynamical evolution of the Galaxy. He discussed his ideas more than once at meetings of our Academy, and in the Study Week on «Stellar Populations» in 1957.

Strömgren won a large number of honours in the course of time, including membership in many Academies the world over and four honorary Doctorates. Between 1948 and 1952 he acted as General Secretary of the International Astronomical Union and between 1973 and 1976 he was the Union's President. He was elected a member of our Academy in 1975, an honour he greatly valued.

I knew Strömgren well for more than half a century. Fellow Academicians will agree with me that we have lost a charming, friendly and ever-helpful colleague.

(prepared by HERMANN BRÜCK;
presented al the Plenary Session by GEORGE COYNE, S.J.)

LUIS F. LELOIR (1906-1987)

Born in Paris on 6 September 1906. Professor of Biochemistry, University of Buenos Aires, Argentina. Nobel Laureate in Chemistry, 1970. Pontifical Academician since 22 April 1968. Died on 2 December 1987.

Like the highest peaks of the Cordilleras which run like a vertebral colonnade through South America, Luis Leloir is a landmark in Latin American science. Born in 1906, Luis Leloir — Lucho, an affectionate nickname used by his close friends — graduated in medicine from the Medical School of Buenos Aires, where his scientific formation took place under the guidance of Bernardo Alberto Houssay, a Nobel Prize winner. Houssay was a great scientist who worked in the laboratory until his death. His outstanding work gave him the Nobel Prize in 1947, but he was also a great teacher and a true leader. At the time Leloir began his work in the Physiological Institute at the Medical School in Buenos Aires, Houssay had been able to gather around him a brilliant group

of young scientists which transformed in a few years the condition of biomedical and clinical research not only in his but also in many other Latin American countries. New trends in cardiology, many discoveries in the field of endocrine physiology, the importance of hormone regulation and the discovery of the role played by hormonal and enzymatic factors in renal hypertension were then the subject of study of this group centred around Houssay. The enthusiasm and effervescence of this group can only be compared to the one that fifty-five years earlier surrounded Oswaldo Cruz in Brazil, and produced an everlasting contribution to tropical medicine. To Houssay's group belonged Orías,Foglia, Braun Menéndez, Fasciolo, Tachini, Lanari, among many others. Their scientific work has enriched the Latin American scientific bibliography up to the present.

Having visited this group many times before the Argentinian government expelled them from the University and forced them to look for asylum in private institutions, I am in a position to say how much I admired the group and learned from it how to organize the institution where I work.

When I first met Leloir, he had already stayed for one year in Cambridge and at the biochemical laboratory directed by Sir Frederick Hopkins. This was the beginning of his move towards biochemistry, a move reinforced by his stay with Carl Cori at Washington University in St. Louis, and afterwards with D.E. Green at the College of Physicians and Surgeons, Columbia University, New York.

Up to 1934, Leloir's work is centred mostly on the study of the physiology and biochemistry of adrenals, but his interest in the biosynthesis of hydrocarbons was already present, as can be seen, for instance, in a note published in the C.R. Soc. Biologie in 1934, or in the paper, «Rôle des surrénales dans la resynthèse du glycogène musculaire après la fatigue» published still earlier. From 1936 his work becomes geared to the synthesis of important chemical compounds of biological significance.

As a matter of fact, the time was ripe for the intelligence and investigative power of Leloir. Biochemistry had overcome the great limitations imposed on its experimental approach, which had to allow for assays and determinations which required a special methodology which could deal with micrograms and nanomoles. This lack was a severe handicap in the development of biochemistry. But from 1945 on, differential centrifugation, paper chromatography, radioactive tracers and other methods were produced and were aptly used by Leloir. His work is one of the best examples of modern biochemistry. It shows the interplay of chemistry and biology.

In the early fifties Leloir identified the gluconucleotides, the first being uridine diphosphate glucose (UDPG), and their role in donating the glucose

moiety for biosynthetic reactions. The first syntheses he described were trehalose and sucrose, followed by the biosynthesis of starch, cellulose and last, but not least, glycogen. Although his initial discovery was made working with yeast cells, Leloir promptly enlarged our knowledge, demonstrating the role of UDPG in the synthesis of glycogen by liver cells. Thus the Nobel Prize awarded to him in 1970 came as no a surprise.

Leloir's basic research had an enormous impact on the studies of intermediate metabolism of glycolysis versus gluconeogenesis required for maintaining blood-sugar levels as well as in plant metabolism and agriculture. We have to keep in mind that all plant seeds store starch and sucrose, two saccharides formed through the pathway described by Leloir.

Leloir, a scientific giant, looked like a frail person. Small in height, his face was thin, his profile aquiline, but the strength of his personality could be found in the depths of his dark eyes. If one could overcome his natural self-restraint, Luis Leloir would become one of the most charming and engaging personalities I have ever met. To define Luis Leloir, two words come to my mind, modesty and dignity. Let me quote from his speech during the Nobel banquet in 1970, at which his wife Amelia, the perfect companion, was present, «The prestige of the Nobel Prize is such that one is suddenly promoted to a new status. In this new status I feel rather uneasy on considering that my name will join the list of giants of chemistry such as van't Hoff, Fischer, Arrhenius, Ramsay, von Baeyer, to name only a few. I also feel uneasy when I think of contemporary chemists who have made great contributions, and also when I think of my collaborators who carried out a great part of the work. In spite of this, I am profoundly grateful for having received from your Majesty this great honour, and to the Nobel Committee for Chemistry of the Royal Academy of Science for having selected me. Finally, I might paraphrase Churchill in saying, 'Never have I received so much for so little'.

Luis Federico Leloir, born of Argentinian parents in Paris, where he lived until he was two years old, by his courage, his gentleness, his civic spirit and his *savoir faire* was a typical man from the most scientifically developed country of Latin America. He honoured his country, he honoured Latin America, and he honoured the scientific community as a whole. He was an example to be pointed out to the younger scientists.

His death on the second day of December 1987, opens an irrecoverable void for our Academy and for the scientific community of all the world, but his memory will stay forever in the annals of science.

(CARLOS CHAGAS)

ALFRED R. UBBELOHDE (1907-1988)

Born in Antwerp, Belgium, on 14 December 1907. Professor of Thermodynamics at Imperial College, University of London. Pontifical Academician since 22 April 1968. Died on 7 January 1988.

Professor Alfred R.J.P. Ubbelohde, Academician since 1968, died on 7 January this year. He was one of the most distinguished exponents of the science of thermodynamics, but could well be described as a chemist and engineer.

He was born on 14 December 1907, the third son of F.C. Ubbelohde and A. Verspreeuwen, and received his education at St. Paul's School. From there he went to Oxford University as an undergraduate of Christ Church, where he obtained a degree in chemistry, proceeding in due course to the M.A. degree; later he became D. Sc. of the University. He worked in Göttingen University for a year and often mentioned the stimulus he had received in that great centre of research in the 1930's. His first research was as Dewar Fellow of the Royal Institution of London from 1935 to 1940.

The mobilisation of British scientists for the war effort took him into the Ministry of Supply doing research on explosives. At the end of the war he was appointed Professor of Chemistry at the Queen's University, Belfast, from 1945 to 1954, where he served as Dean of the Faculty of Science for a four-year term from 1947 to 1951. He left Northern Ireland to become Professor of Thermodynamics at Imperial College, University of London, from 1954 until retirement in 1975. From 1961 he undertook the duties of head of the department of Chemical Engineering and Engineering Technology at Imperial College. Imperial College has a distinguished group of Senior Research Fellows, to whose ranks Ubbelohde was appointed in 1975.

He played a full part in science in Britain: President of the Faraday Society 1963-65, Vice-President of the Society of Chemical Industry, Member of the Agricultural Research Council 1966-76, and Chairman of the Science and Engineering Panel of the British Council 1964. As Director of the Salters Institute and Chairman of the Fire Research Board from 1956 to 1961, he reflected his concern for societal questions.

His researches covered a wide range of the profounder applications of thermodynamics to the condensed state of matter, and appeared in the leading scientific journals. He gave full expression to his thought in his well known book, «Modern Thermodynamic Principles», first published in 1937, with a second edition in 1952; and in his later work, «Time and Thermodynamics», 1947, he tackled one of the most fundamental questions of physics still greatly debated today by physicists, cosmologists and philosophers. He wrote the classic work

«Graphite and its Crystal Compounds», Oxford University Press 1960, and in «The Molten State of Matter», 1978, he made great contributions to one of the most difficult fields. He wrote on «Man and Energy», 1954, with a second edition in 1963, an early treatment of issues very much of concern in modern society. One of his most important achievements was in the development of the graphite lattice-based materials, for which he coined the expression «synthetic metals».

He was honoured: the Alfred Egerton Medal, 1970; the Messel Medal, 1972; the George Skakel Award, 1975; the Paul Lebeau Medal, 1975; and universities conferred on him many honours: Hon. Laureate of the University of Padua, 1963; Hon. Doctor, Free University of Brussels; Hon. D. Sc., Queen's University, Belfast; Hon. Doctor of the University of Nancy, 1982. He was President of the Council of the Solvay Institute, 1957-64; he was a Fellow of many British societies: Fellow, Royal Society of Chemistry, Fellow of the Institute of Chemical Engineers, Fellow of the Institute of Physics. He was elected Fellow of the Royal Society in 1951, and to the recently instituted Fellowship of Engineering, established about ten years ago to be similar in status to the Royal Society.

Ubbelohde was a man of wide culture, a collector of antiques, with a remarkable collection of Chinese ceramics, a salmon fisherman and a great farmer, often discoursing to his academic colleagues on pigs, and a great connoisseur of wine.

He frequently attended the Pontifical Academy of Sciences, to which he was elected in 1968, and was able, though in ill health, to attend the 50th Anniversary of the Academy two years ago.

(S. KEITH RUNCORN)

SCIENTIFIC PAPERS

LA RESPONSABILITÉ DE LA SCIENCE RESPONSABILITÉ DES UNIVERSITÉS, DES ACADÉMIES, DE L'INDUSTRE

A. BLANC-LAPIERRE
Académie des Sciences, Paris

I - Remarques générales

1 - *Responsabilité de la Science: vis-à-vis de qui?* vis-à-vis de l'homme et de son plein épanouissement dans l'ensemble de la création, dans l'ensemble du Cosmos. Il s'agit de l'épanouissement de «tout l'homme et de tous les hommes» (cf. la lettre encyclique «Sollicitudo rei socialis» du Souverain Pontife Jean-Paul II, du 30 Décembre 1987). Bien évidemment, cet épanouissement ne concerne pas uniquement la vie matérielle, mais aussi, et pour une part à travers elle, la vie sociale, intellectuelle et spirituelle. Toutes ces dimensions de l'existence humaine sont, comme le disait Sa Sainteté Jean-Paul II dans son discours a l'UNESCO le 2 Juin 1980, intimement liées: elles se conditionnent mutuellement «comme s'il s'agissait d'un vaste système de vases communicants».

2 - *La Science a marqué l'évolution de l'humanité de deux façons:*

— d'une part, en faisant accéder l'homme à une meilleure *connaissance de l'Univers* et a une meilleure *compréhension des mécanismes de ce dernier*;

— d'autre part, en mettant à sa disposition des *moyens* qui ont bouleversé ses conditions de vie.

L'accroissement de la connaissance est un bien sans équivoque qui s'intègre dans le *développement culturel*. Il n'en va pas de même de l'utilisation des moyens qui en résultent. Ceux-ci peuvent être utilisés pour le bien, mais aussi, hélas pour le mal de l'homme.

3 - A l'intérieur du thème extrêmement vaste de la responsabilité de la Science, ce qui suit concerne, plus particulièrement, les *rapports entre la Science*

et le Développement. Dans une première partie, le mot développement sera pris dans son acception la plus large, celle du *développement scientifique et technique en général*. La seconde partie prendra spécialement en compte les *pays en développement*.

4 - *Pourquoi mêler les Universités, l'Industrie et les Académies* (*)? Les *Universités* ont deux rôles essentiels: *formation des hommes* et *action de recherche* (avec, globalement, un accent plus particulier sur la *recerche fondamentale*) et, au titre de cette action de recherche, ce qui sera dit à leur sujet concerne aussi l'ensemble des Centres de recherches. Un enseignement «à jour» implique, nécessairement, une recherche vivante et les résutats de la recherche réagissent sur le contenu de l'enseignement.

L'Industrie a en charge les *applications*, la production, la réalisation des grands projets techniques. Son activité aboutit au *développement technologique*. *L'agriculture* joue un rôle équivalent dans le domaine qui lui est propre. Le *commerce, l'économie* reposent sur les produits de l'industrie, de l'agriculture... L'industrie s'acquitte aussi de *tâches de formation*, surtout dans des domaines spécialisés, elle développe également un important *potentiel de recherche à finalité d'application*.

Un lien étroit existe entre Université et Industrie. Il découle, d'une part, de l'importance, pour l'une et pour l'autre, de tout ce qui touche à la *formation des hommes* et, d'autre part, de *l'unité profonde de la recherche*. On ne peut dissocier la recherche de base de ses applications. Toute connaissance nouvelle donne, tôt ou tard, naissance à des applications. Réciproquement, rares sont les possibilités techniques nouvelles qui ne sont pas utilisées comme moyens dans les laboratoires de recherche fondamentale. D'ailleurs, c'est un souci d'applications ou celui de faire face à des besoins de l'humanité (transports, communications, santé, ...) qui a souvent donné naissance à de grands domaines de recherche, appliquée certes, mais aussi fondamentale.

Le rôle de plus en plus grand joué par la Science et ses Applications dans le monde actuel rend inévitable *une prise de conscience de la «communauté scientifique— sur les conséquences du développement scientifique et technique pour la vie de l'humanité*. C'est dans cette perspective que se situe l'action des *Académies* au regard de la «responsabilité de la Science». Il est de leur dévoir d'attirer l'attention des gouvernements et, plus généralement, des citoyens, sur

(*) Le terme «*Industrie*» ne comporte pas d'ambiguité, ni celui d'«*Universités*» à condition d'adjoindre à ces dernières les Ecoles d'Ingénieurs ou autres cadres supérieurs, qui, dans certains pays, en sont distinctes. Le mot «*Académie*» est pris, ici, dans le sens qu'il a en France: il vise une collectivité de savants cooptés, sans impliquer d'aucune manière la gestion de laboratoires ou de centres de recherche.

ces conséquences. Les Académies ont une indépendance suffisante pour pouvoir le faire sans être contraintes par des groupes de pression. Comme le notait le Pr Pierre JACQUINOT lors de la Séance Solennelle du 6 Novembre 1982 de l'Académie des Sciences (Paris), chaque Académie agit alors, dans sa sphère, comme une «conscience du monde scientifique».

A fortiori, cette mission incombe-t-elle à notre Académie, bien sûr à cause de sa très large ouverture par rapport à la géographie et par rapport aux spécialités, mais, aussi et surtout, parce qu'il s'agit de l'*Académie Pontificale*, ce qui implique une attention particulière aux conséquences générales du développement scientifique pour la vie sociale, culturelle et spirituelle de l'humanité. Etant donné l'importance croissante de ce type de questions, *il me paraît très souhaitable que soit vigoureusement étudiée la possibilité d'une diffusion plus grande des résultats de ses travaux*. Cela pose, sûrement, des problèmes d'organisation, mais aussi implique un effort particulier des Académiciens dans ce sens.

On peut aussi se demander *si les diverses Académies des Sciences ont une connaissance suffisante des résultats de leurs réflexions respectives relatives à la responsabilité de la Science* et si de vastes questions sur ce thème ne pourraient faire l'objet d'*études concertées entre elles*. Ce qui sera dit dans la suite sur la Sécurité et le Contrôle des Armements, va dans ce sens.

II - Responsabilité dans le développement scientifique et technique

Les apports des développements scientifiques et techniques dans les domaines de la *nourriture*, de la *santé*, des *produits nouveaux*, de l'*énergie*, de l'*aide procurée par les machines* (aux niveaux individuel, familial et collectif), des *transports*, des *communications*... constituent des facteurs de libération vis-à-vis de contraintes matérielles et offrent des possibilités croissantes de contacts, d'échanges de connaissances d'entraide. Tout cela est élément de progrès et, globalement, il n'est pas douteux que les conditions de vie des hommes en ont été améliorées. Cependant, il est malheureusement tout aussi clair que la plupart des progrès scientifiques ou techniques peuvent être *détournés de leur potentialités bénéfiques* et utilisés à des *fins de domination et même de destruction*: ainsi la biologie, la chimie, l'énergétique, l'électronique.. peuvent, à côté des bienfaits énumérés ci-dessus, fournir des *armes de guerre ou de terrorisme extrêmement dangereuses: conventionnelles, biologiques, chimiques, nucléaires, ...*

Une attention particulière doit être portée à la nécessité d'un *respect suffisant de l'environnement. Les ressources disponibles sur la Terre sont limitées et il y a des équilibres naturels à respecter*. Par exemple, dans cette perspec-

tive, il est actuellement urgent d'étudier avec soin les problèmes relatifs à la *couche d'ozone* et au *gaz carbonique* autour de la terre, à la *pollution atmosphérique, à celle des océans*, à la *déforestation*.

Il est clair que *les scientifiques sont particulièrement concernés* par les problèmes pris en compte par le présent exposé *puisque le développement dont il est question découle de moyens qui, à des titres divers, résultent de leurs propres travaux*. A ce point, il faut cependant noter que, en tant qu'hommes, les scientifiques ne sont pas uniquement des scientifiques. Ils participent aux activités de la vie humaine et, à ce titre, ont des engagements sociaux, culturels, politiques, religieux, etc. Chacun fait partie d'un pays particulier qui, lui aussi, a ses problèmes sociaux, politiques, économiques... De la même façon, *le développement ne met pas en jeu uniquement des facteurs scientifiques et techniques mais aussi encore, des facteurs économiques, sociologiques, éthiques, ...*Je crois qu'il est très important, pour la clarté de leurs messages, que les scientifiques distinguent avec précision *ce qu'ils énoncent en tant que scientifiques compétents dans tel ou tel domaine de ce qui découle de leurs convictions ou engagements extrascientifiques personnels*.

Ils ont le devoir, *dans le domaine scientifique et technique, de fournir aux gouvernements et aux citoyens l'information nécessaire aux grands choix technologiques. Cette information est, en particulier, capitale pour que puissent être établis les sérieux bilans «bénéfice-risque»* indispensables à toute prise de décision importante.

On doit mentionner ici les développements récents en matière de *Sécurité et de Contrôle des Armements* correspondant à la création, par l'Académie Nationale des Sciences des Etats Unis, du CISAC (Committee on International Security and Arms Control, présidé par Wolfgang K.H. PANOFSKY) et à celle d'une Commission homologue de l'Académie des Sciences de l'Union Soviétique, ces deux groupes ayant entre eux de nombreux contacts. Il faut de plus signaler la réunion qui, sous la présidence du Pr Edoardo AMALDI, s'est tenue à Rome en Juin dernier, à l'Accademia dei Lincei, sur le même sujet avec une participation des Etats-Unis (CISAC) et de l'Europe. Tout ceci cherche à combler le vide qui, à un certain degré, existe entre les perceptions politiques et la réalité scientifique et technique. Nul doute que les responsables politiques et les opinions publiques n'aient besoin d'analyses factuelles, claires, complètes et irrécusables sur l'évaluation des armements, les moyens de contrôle des mesures de désarmement, ... etc.

Les prises de positions de *scientifiques* ou de *groupements de scientifiques s'affirmant comme tels*, doivent rester en accord avec les caractéristiques du travail et du discours scientifique:

— L'*objectivité*, le respect des faits et une grande modestie devant ceux-ci. Ainsi est la recherche de la vérité scientifique. Elle implique, de la part du savant, qu'il admette de se laisser convaincre. Certes, les luttes sont souvent vigoureuses entre tenants de deux explications ou de deux théories opposées; mais les arguments scientifiques, le libre brassage des idées, les faits expérimentaux... permettent normalement d'aboutir à un large consensus. Cette attitude est à l'opposé de celle d'idéologies souvent hostiles à la vérité ou cherchant à la confisquer.

— *La pratique de la discussion ouverte dans le respect mutuel.* La Science se veut *universelle*. Elle implique les contacts et les échanges internationaux. Le respect des *Droits de l'homme* est essentiel à son développement.

— L'*universalité*. En tant que quête de la connaissance, la science ne connaît pas de frontières. Bien au contraire, elle constitue un facteur de rassemblement.

Sous réserve des précautions de clarté mentionnées ci-dessus, il n'y a, bien sûr, aucun inconvénient à ce que des scientifiques s'expriment en tant qu'hommes — et pas seulement en tant que scientifiques — sur les problèmes de l'humanité. Chacun d'eux doit, à des degrés divers, développer l'unité de sa personne et de sa vie. Certains ont eu à s'interroger sur la compatibilité de leurs travaux avec leurs convictions morales, religieuses. Dans tous les cas, leurs témoignages ne peuvent qu'enrichir l'expérience humaine.

Le *développement considérable des media* augmente encore la nécessité d'une *bonne diffusion vers le public des résultats de la Science et de ses Applications*. Ce n'est cependant pas une chose aisée. La recherche par les media du sensationnel et d'une diffusion de plus en plus rapide ne facilite pas ce transfert d'information. Il est malgré tout du devoir des scientifiques de porter la plus grande attention à cette communication avec le public.

III - Le partage du développement a l'échelle de la planète

Une première constatation s'impose; le *fossé* qui sépare les régions dites du *Nord développé* et celles du *Sud en voie de développement* ne s'est pas rétréci, comme diverses initiatives prises au cours des années 60 pouvaient le laisser espérer: il s'est *élargi*. Certes, le développement scientifique et technologique n'est qu'un des aspects de cette évolution; il en constitue cependant une composante essentielle et il y a lieu de s'interroger à son sujet.

Il faut noter la grande importance qui s'attache à une bonne prise en compte des *spécificités*, des *modes de vie*, de la *nature particulière des problèmes* pro-

pres à chaque pays, à chaque région, à chaque collectivité. Illustrons ceci en prenant l'*énergie* comme exemple. Le problème est incontestablement mondial mais il n'est pas moins soumis à de *multiples contraintes locales, nationales, régionales:*

— *Les ressources énergétiques sont intégralement et diversement réparties sur la terre*; ceci condiut les divers pays à des solutions qui diffèrent largement, en particulier pour sauvegarder un *minimum d'indépendance* dont le désir passera au delà des questions de prix.

— *Les conditions d'utilisation de l'énergie varient considérablement selon qu'il s'agit de pays déjà industrialisés, de zones géographiques dont le décollage économique, quoique significatif, reste encore assez faible, ou de zones plus pauvres.*

— Enfin , *les facteurs politiques*, qui conditionnent les possibilités d'échanges ou de transferts, jouent évidemment un grand rôle.

Tout cela fait que des solutions globales, apparemment raisonnables au niveau des bilans mondiaux, peuvent ne pas l'être, en fait, car elles correspondraient, pour de nombreuses régions, à des conditions locales absolument intenables ou totalement irréalistes.

Nous insisterons sur deux points:

Le premier reprend ce qui vient d'être exposé. Il s'agit de la nécessité d'une bonne adaptation des transferts technologiques aux besoins propres de chaque région. Ceci implique des études soigneuses, une grande ouverture d'esprit et une étroite coopération entre nations développées et nations en développement.

Le deuxième point est relatif à l'immense besoin de *formation des hommes.* Il concerne l'Université et l'Industrie. Les Universités des pays développés accueillent actuellement un nombre non négligeable d'étudiants en provenance de pays en développement. Il est important que, leurs études terminées, la majorité de ceux-ci soit en situation de faire effectivement profiter leurs pays de l'expertise qu'ils ont acquise et contribuent ainsi à l'élévation du potentiel scientifique et technologique de ceux-ci. Une telle situation ne serait cependant pas encore satisfaisante. Il faut aider le développement des Universités et Institutions de formation de ces pays, afin qu'ils puissent prendre *en mains* de plus en plus l'élévation du niveau de l'ensemble de leurs populations.

L'Université des Nations Unies, en particulier, a un rôle important à jouer dans les directions correspondant à chacun des deux points mentionnés ci-dessus.

* * *

Les questions soulevées dans cet exposé, qui ne recouvre qu'une petite partie du thème relatif à la responsabilité de la Science, appellent une réponse urgente. Elles mettent en jeu simultanément l'équilibre de l'homme avec son environnement, et aussi, l'équilibre des nations entre elles, donc la paix.

DISCUSSION

MOSHINSKY

I am particularly concerned about the need for formation and training. Anyone who is working in a developing country knows how important this is, but I have a comment here which I think is very relevant. Many students can go out, and be trained outside, but only a small part of them — depending on the country — actually return. Many of them really benefit, which in itself is not a bad thing, but they benefit the developed countries rather than the developing ones. So it's quite important to stress that in the case of students from developing countries, their governments should have the responsibility of providing positions for them when they come back and are properly trained. Also, international cooperation is needed for helping the institutions that train people in developing countries to achieve a higher level. I think that just sending them out is not the solution to the problem. There are a lot of other things that have to complement this action.

BERGSTRÖM

I would like to stress the same issue. Already the Rockefeller Foundation in the '20s and '30s instituted something called «Re-entry grants». They were very modest but they showed the way. In many of the agreements for training, they are now starting to include one or two years of salary if they don't have an agreement with the universities. All the UN agencies now really require that the governments promise to take care of these students when they get home or they will not get the grant. It's the hard way, but maybe it will teach them.

MALU

Le problème n'est pas seulement d'assurer à ceux qui rentrent, après une formation à l'étranger, une position économiquement confortable; le problème,

à mon sens, est avant tout un problème d'adéquation entre la formation reçue à l'étranger et le contexte dans lequel ces étudiants reviennent pour travailler. Le décalage scientifique et technologique entre le Nord industrialisé et le Sud en voie de développement est tel que les étudiants sont formés à des problèmes utilisant des moyens qu'ils ne pourront jamais avoir quand ils seront de retour.

Compte-tenu de ce décalage, les étudiants ont tendance à rester dans le Nord. Ce n'est pas seulement l'aspect économique, il y a aussi simplement l'aspect fonctionnel.

RICH

In this regard I would point out some comments that were made by the president of the Chinese Academy of Science last April when he visited Washington and spoke to the National Academy of Science. He said that they are acutely aware of this problem and their response to it has been to generate a series of centres that have the latest equipment in them, regional centres especially designed to attract and utilize the talents of the Chinese students that are trained abroad and then return. He said of course it is impossible to replicate highly sophisticated equipment in all centres, it's a matter of economics, but by creating regional centres they indeed are reaching a partial solution to this, and I think that is an example of a government aware of this difference and trying to mobilize its resources to address that problem. I agree it's the main problem, namely being able to utilize the sophisticated training that they've received once they've gone abroad.

COYNE

The problem we are addressing is one that has plagued all efforts to assist developing countries to train young people in such a way that they will return after their training and work to the benefit of their native countries. The solution may lie in what I call «responsible assistance». I wish to give a concrete example. At the Vatican Observatory we have twice held Summer Schools in Astronomy and Astrophysics and these schools have now become a permanent part of our activities. Every second summer for one month we invite 25 young scholars (in the American system they would be initiating their program of doctoral studies). Two-thirds of them come from developing countries. They are selected by a committee on the basis of their promise to develop research careers in astronomy and astrophysics. The emphasis is on research careers and not on teaching. We receive about 150 applications for each school. In each

of the two schools that we have held so far the students came from 16 different countries. We provide 75% of the total costs for students from developing countries. We require that 25% of the costs be provided by their home institutions and/or countries. The reason for this is not at all financial but it is a very important one. We wish the native institutions/countries to express in a concrete way their interest in the young student so that she/he senses right from the beginning a bond of loyalty to home. We write personally to each of the ambassadors to the Holy See and to other officials associated with each of the students to explain our procedures and to solicit their help. In most cases the response is very positive and the 25% is found. On the other hand, we have never turned down a student, once accepted, even if funding could not be found. This is the first point I wished to make, namely, that concrete bonds of loyalty must be established from the very beginning.

I would like to make two other points. When a young person from a developing country goes abroad to study, the home institution must maintain a regular contact with her/him. More important still: when, hopefully, after completing their training abroad they return to their native countries, they must be given the opportunity to travel regularly to research centres abroad, especially when the necessary tools for research are lacking in their own countries. Again let me be specific by describing one of the programs of the Vatican Observatory. We are constructing in Arizona, and in collaboration with the University there, the Vatican Advanced Technology Telescope. It is a telescope which will test the new technologies to be used for the construction of the next generation of the world's largest telescopes. It will be completed in December 1989. As part of the staffing of that telescope we are seeking to establish two endowed fellowships for young researchers from developing countries. Each would work in Arizona with the new technology telescopes for a period of two years. The intention is that they would return to their native countries and carry back the excitement for the new technologies, not so that new telescopes would necessarily be built there but that the knowledge would be implanted there. For our part we realize that we have a continuing responsibility, after the two-year tenure of the fellowships, to maintain a productive link with the fellows. My point is that the continuing link is extremely important.

PULLMAN

Une solution partielle à ce problème, en fait au double problème, qui est celui du retour des scientifiques des pays sous-développes dans leur pays, et de l'adaptation de l'enseignement qu'on leur délivre aux besoins du pays, peut être trouvée dans la renversement de la direction de l'opération.

Voilà ce que j'entends par là: quand j'ai été pendant trois ans Président de l'UIPAB, qui est l'Union Internationale de Biophysique pure et appliquée, nous étions en face du problème du développement de la biophysique dans les pays sous-développés. La solution à laquelle nous nous sommes finalement arrêtés, à été plutôt que de drainer des chercheurs ou des candidats de ces pays vers nos universités, d'envoyer des équipes des pays développés vers les pays sous-développés, par exemple vers un continent comme l'Amérique du Sud ou vers un pays vaste comme l'Egypte, avec mission d'y donner des cours, des conférences, des démonstrations, des travaux pratiques, en présence des étudiants et donc à apporter l'éducation, l'instruction sur place, quitte même à transporter pour cela l'appareillage nécessaire comme par exemple les appareils RMN. En même temps, les professeurs, faisant leurs cours sur place, ont une vision beaucoup plus nette des besoins locaux et, par conséquent, peuvent adapter un cours qui, en principe, est très perfectionné, comme un cours de RMN, à certains besoins et possibilités qui apparaissent localement. Je crois que nous avons eu, à ce sujet, dans ce domaine, des succès.

Evidemment, cela ne peut pas remplacer toute l'opération, mais une telle façon de délivrer, sur place, ce qui pourrait contribuer au développement de la science et des besoins me paraît une opération avantageuse, à laquelle nécessairement, alors, sont liés les pays, les gouvernements des pays dans lesquels cette opération a lieu.

DÖBEREINER

I think this was a very important point which Monsieur Pullman made just now which I would like to support, which is the importance of the cooperation between the receiving institution and the Third World institution where the students come from and where they will go back to. I know only cases of success (and a few cases of failure) in such programmes, where the active collaboration between the Third World laboratory and the training place already exists. Now I think in addition to this South-North training we should not forget that there is a very large potential for a South-South exchange in training. We have just this morning heard of two Argentinian Nobel Laureates, and I think there are possibilities in many Third World countries of some centres of excellence where students from other Third World countries can be trained for one-third or one-fifth of the price. Sometimes they would come back with knowledge which is much more immediately applicable to their own country. There are some attempts from the Third World Academy of Sciences in this sense, but there is not, I think, enough support, especially financial support, for this South-South exchange and South-South training.

CHAGAS

I want to make one point, which is that in certain countries it should be established that no-one should have a fellowship abroad if he has not learned everything he can learn in his country. This is an important thing for agriculture, where we are spending large amounts of very difficult foreign currency, and sometimes people go abroad who have not yet been able to absorb the knowledge they could absorb in our country.

ETHICAL RESPONSIBILITIES OF THE MODERN UNIVERSITY

HECTOR R. CROXATTO
Faculty of Biological Sciences
Pontifical Catholic University of Chile, Santiago

A. - The University as the stronghold of moral values

The Universities in every country have been, and still are, among the most respected, influential and durable institutions created by man, because at the very core of their educational undertaking are to be found the supreme ethical values of mankind.

Despite differences in resources and traditions, Universities all over the world, either in developed or in developing countries, show the same fundamental and immovable features: they can outlast the most adverse conditions; throughout history they have endured all kinds of crises; they can survive in a heavily politicized world, in war or in peace, being either detached from the external surroundings in their «ivory tower», or having inside, from time to time, disruptive ferments of iconoclasts. Perhaps, temporarily they have restricted their access; rarely have they closed their door-ways forever, but as institutions — historically — they always grow: they survive and they survive quite well all kinds of upheavals. The interesting question is to know why?

Down through the centuries these outstanding elements of stability and endurance not only reflect their deep involvement in serving society's needs, but mostly are the result of the strength derived from the moral values they venerate and cultivate.

Most of the Universities in the world have evolved from institutions with low student enrollment, with no large endowments, no government's financial help, no foundation grants, with moderate impact on the outside world, into huge institutions growing at a rapid pace, with strong professional and graduate programs. In general, they are today largely capable of serving society in its

cultural needs, contributing, in addition, indirectly but powerfully to economic development. Such a highly utilitarian mission has shaped the academic organization to be the most cogent and influential social body to promote development of the people which it is serving. This outcome is possible because Universities preeminently are, today, institutions in which knowledge is sought, fostered and imparted. On the other hand, knowledge is the most efficient tool by which to introduce innovations, to forge progress and to raise social conditions. Furthermore, by its addiction to moral commitments and its intellectual authority, which should pervade the students, the University is the vehicle for promoting a pluralistic culture that might soften the rough edges of a society absorbed in commerce, industrial and managerial politics, and in other demanding activities of human everyday life. I think there is no question that, although the Universities do not openly express their power, nor dictate rules to society, everyting which is done in the Universities has the potential to shape the national scene.

They are unavoidably deciding to a great extent the future of the nation where they are located, specifically because they have the highest intellectual reserves in their respective countries and can supply the ever-growing knowledge and the trained manpower. For these reasons, in the whole social fabric there is no other institution of the intellect, better equipped to cope with the aim of contributing to economic and social development. The University represents the most effective and far-reaching driving force to raise, in the most ideal sense, the quality of life of society. Few institutions in the history of mankind can claim such national and international scope. In this regard the quality and extension of their impact upon society imposes upon the Universities moral duties and an enormous responsibility. In the first place, from an ethical point of view they must try to define the moral and physical boundaries of the concept of quality of living for the society's members.

Does not this responsibility imply that the University has to mould adequately its programs and curricula to satisfay those aims? It involves the delicate and permanent task: to consider, debate and to decide what kind of country is to be posited as a final goal, and with what values the University should contribute to that aim.

What are the desirable activities to carry out in order to facilitate national progress and to bring up to an ideal level the standard of living of the citizens? In which way should their students be trained to be the bearers of knowledge and of the humanistic values the University is striving for?

The issues are crucial questions, particularly in developing countries which face a world confronted by quick changes resulting from the overwhelming influence of science and technology. The universities experience the tension of

practical demands, which compel them to re-examine their social responsibilities. They have to be attentive to social evolution if they wish to acquire an adequate understanding of their proper role and purpose in present-day society, and to avoid the risks associated with the idea that education is becoming synonymous with the acquisition of normal expertise, a goal considered necessary and even the only valuable requisite to successfully compete in a predominantly technological age.

Should they respond to these practical demands or should they act according to traditional values? What are the most compelling needs of society and how can the University make best use of its resources to encourage constructive change?

Before answering the question let us just look at the:

B - Basic and traditional values of the University

One of the first values which transcends the objectives of the University is its faithful attachment to the concept that genuine knowledge is good in an ethical sense. Following Socrates', ideal, knowledge is virtue, ignorance is an evil. Objective knowledge is superior to ignorance under all circumstances or boundary conditions and this implies that there is no code of forbidden knowledge (Mohr). Such intimate conviction which permeates the academic community has prevailed during centuries, as a sovereign value in all intellectual institutions, particularly in the Universities. The incontestable sovereignty of knowledge arises from the awareness that it is one of the greatest gifts which dignifies man as an intelligent creature, as a person. Since the first Universities, the world was always regarded and examined from the perspective that human dignity is a supreme value. In the Universities the commitment to revere knowledge was favored by other important values: academic freedom, university autonomy and institutional neutrality. Academic freedom has been the result of a long struggle and it dates back to the last century, when German universities became worthy examples to be followed in the Old and the New World. Academic freedom warrants that every member is free to learn, to search for knowledge, to express his own individual beliefs and opinions, to extend the right of free criticism and inquiry. Any internal and external attempt to control the interplay of ideas is unacceptable. Autonomy is the right to decide independently of any external power academic affairs, to set academic requirements, to shape standards for students' admission, to appoint professors, to fix the content of the curricula, etc. Academic freedom and autonomy are essential to the aims of the University. Any from of censorship hampering the

right of its members to write or to speak will undermine the search for knowledge.

Institutional neutrality is the factor which prevents the University from being involved in social and political adventures that could imperil their intellectual virtues or the furthering of knowledge. If the University, as a body, takes official positions on controversial issues, it opens itself to political attack that could obstruct the quality of its mission. However, this does not imply that since Universities cannot solve all the problems affecting the surrounding society, they can afford to be indifferent to those problems. Universities should have absolute freedom to pose all the relevant questions.

Even if academic fredom is an ideal not fully attained, it has to be reaffirmed; its survival is the survival of the University itself. On the other hand, institutional neutrality in an era when the University has grown so deeply involved in the life and affairs of the Society, appears more and more difficult to keep.

C - The establishment of scientific research in the Universities

One of the most remarkable events which happened in the history of the Universities was the introduction into their educational province of scientific research, which became an activity of the highest intellectual prestige, seen basically as the search in the physical world for objective knowledge through experimental procedures in laboratories. Following the model developed in the last century in German universities, most of the universities of the New and Old World, sooner or later, adopted or attempted to adopt such a model. In the leading institutions, research became of primary interest, and the quality of their scientific productivity is, at present, a seal of prestige on their institutional status. This activity, conducted by specialized professors, allowed their student-apprentices to become independent research workers in strictly defined fields of the natural sciences. As we know, they formed or form today the ever-growing contingent of professionals working either in the universities or in the private productive sector. They and their expertise and inquiry prepared and built to its highest peak scientific knowledge and brought about the dominant technological revolution which charecterizes our modern era.

The insertion of research into the Universities was in harmonious line with their most cherished and ennobled traditions: the search for truth, goodness and beauty. They set up laboratories to incorporate scientific research as an essential part of teaching functions.

Hardly can any institution be called a University today if it does not have on its staff active trained researchers. In the beginning the tendency, motivated by a deep interest in how Nature works, embraced the venture to seek knowledge for the sake of knowledge, not for the purpose of achieving practical rewards. As academic institutions, the Universities were still standing aloof from their surrounding societies and had a precarious support from the public.

Nevertheless, in our century many universities have converted into major generators of the tremendous strides of Science that have resulted in astonishing and vast technological applications, benefitting human beings, changing lifestyles and mental climates all over the world. Science has superimposed its own cognitive brand of global domination: its applications have become enmeshed with the whole fabric of our lives and thoughts, and it continues to be spurred on by hopes of ever greater discoveries in its awesome advance.

The impressive achievements have also fostered the equally strong belief that the objectivism, rationality and moral neutrality of Science are the prime conditions for knowing. Accordingly, scientifically acquired knowledge was regarded as the most valid and correct apprehension of Nature's cosmic reality, and the University was seen as the best-suited intellectual institution to cope with the task of looking for truth in the physical world. But science and its technical accomplishments have become in the last decades such a productive force with such an overwhelming impact on social development, that society has started gradually to press on Universities, demanding expertise, capacities for research and manpower which cannot readily be furnished by other institutions. Science, which was enclosed for years in its ivory tower, owing to economic adjustments and social requirements gradually tended to lose freedom and to be put in danger, to become enslaved. Today, increasingly research is depending on heavy support from public funds. Universities have to reconcile their long-term mission as academic institutions, engaged in the preservation of their prerogatives and values in teaching and research at the highest attainable quality, with the public's urgent and practical demands for professional assistance in many enlarging areas. To bolster their competitive position, industries are sponsoring research and graduate education in the University's campuses. Furthermore the University's validity in the society to which it belongs is usually measured by the relevance of its assistance to the needs of the society itself, and because the University is providing or generating useful technologies, higher education is exposed to pressure and temptations that can act as a threat to the preservation of moral values. Interests from the productive industrial sector can interfere as insidious agents which tend to corrupt academic life. The prospect of gathering financial rewards may subtly influence a professor's choice of what to investigate, leaving aside other problems which are more intellectually challenging.

D - Moral responsibilities derived from scientific activity (Research)

The impact of scientific activity on the University's ethical and philosophical realm can be complex and of far-reaching implications. In this regard, there is a deep moral concern: the enlarging gap between the rationality, objectivity and agnosticism of science on one hand and the ethical values of humanism, on the other. Equally important is the need to highlight the moral responsibility of man as professor and as scientist, and also to point out the harmful effects on human social life and on the environment caused by some of the technological applications of scientific enterprise endorsed by the Universities.

Most people would agree that humanity stands at the threshold of a new age and that our present society is based materially on an enormously successful technology. Although scientifically acquired knowledge, in the eyes of society, is mostly a venture of high integrity and the most truthful revelation of the nature of reality and, in many ways, has provided basic prosperity and ameliorated the human condition, there is a growing concern, that science and technology have contributed to enhancing materialism, *consumerism*: that they have privileged the «having» and deteriorated the «being», that «science is not creating a biosphere of wise, happy human beings living harmoniously with each other and with the non-human constituents of their environment». Actually, many people are living in a heavily polluted world and, even worse, are under the fearful shadow of a nuclear holocaust. Pope Paul VI said, not long ago: «Never has humanity had as today so much fear of the things man is manufacturing».

Modern science is capable of producing knowledge that can be used to alter society in frightening ways. The two main discoveries of our age: the structure of the atomic nucleus and the genetic code, which provided the deepest information about matter-energy and the core of life, respectively, are also the source of major worries about their impact on man's future. The first, the atomic bomb, threatens to wipe out mankind from his lovely little globe, and the second raises moral issues which put human dignity and values in the center of the ethical stage. Attempts to manipulate DNA in human eggs: the case of women who hire themselves out as host mother to bear embryos from other couples, providing wombs for rent; the transplantation of human fetal tissues (thymus, liver) into mice to develop in them human immune systems and to produce specialized white blood cells, etc., is causing fierce moral conflicts and religious protest which deeply involve our conscience.

It is also true that it is easy to blame science and technology for the ills of contemporary society, but the fault does not lie in them, but in man himself

by his use of a demanding technology and in his motivations to promote material gains, because he disregards or ignores moral values. The evil is in man's behaviour. The application of technologies is an ethical and political problem and it is outside the domain of science. Science can tell us «how» but not «why»; it can show us how to achieve defined goals, but not which are the right ones. In other words, science describes but does not prescribe, telling us «what is», but not what «ought to be» and as a body of knowledge, or by its methods, can neither formulate value standards nor resolve issues in the realm of subjective norms. Unlike other expressions of human creativity, knowledge can be used, therefore it can be used for good or for bad ends.

According to Gotterer, what we take as the power of technology is plainly the power of the value system of the society which develops, owns and uses technologies. Ethics is concerned with action, is concerned with modern technology because, by its ever deeper penetration into Nature, sometimes, particularly when it is propelled by forces of the market, politics, bellicism, etc, its power is enhanced beyond anything dreamed before. Another basis of moral worry regarding the application of technology is the gap between the ability to foretell its remote dangerous effects and the power to act, the former being superior to the latter.

E - The University as a mansion of human culture

The University is or should be the indisputably staunchest bastion for the synthesis of knowledge and of human culture sustained by the two pillars: humanism and science. Inside the University's walls, the world of self-knowing is cultivated as well as the physical world which is known by scientific methods. Science answers the need for understanding, piercing the veil to perceive physical truth, opening enlarging vistas of the stupendous complexities and beauty of the created universe, but it does by itself help to give meaning to the most basic motivational force. In this regard humanism, which seeks in the intimacy of the self or in religious faith, in philosophy or in theology, will never cease offering answers. Although science appears amoral, there is no science without scientists and the question of good and evil, even if it lies outside the province of science, cannot be considered to lie outside the province of scientists. Science can be viewed not only as a professional training ground, but above all as an education of the mind, particularly for the scientist, because his eagerness for unbiased observation and objectivity can bring him to be rather indifferent to the deep penetration of moral questions. This attitude is, unfortunately, facilitated by a situation common to many universities of the Third World,

where the fields of studies have become so differentiated and specialized that it is considered enough for their fulfillment to provide only the specific professional skill. Although the vast majority of scientists are aware of their responsibility to society, «the qualitatively novel nature of scientific works has opened up new dimensions in ethical relevance for which there were no precedents in the standards and canons of traditional ethics» (Jonas). Values are and will be, of course, determinants of human decisions, they have a considerable influential power and a key role in shaping our acts. Religious faith illuminates the mind to believe that man is not merely an accidental product of evolution, a sophisticated servo-mechanism.If that were the case, there would be no need for him to talk about moral responsibilities. The scope of science is inadequate to answer questions concerning the ultimate goals of existence with which religion, theology, moral philosophy deal, and to set the basic parameters for social values. The University as a mansion of culture should be free of dogmatism or religious pressures, but it has to provide to all its students, particularly to those enrolled in scientific areas, in addition to guidelines for objectivity, a more holistic view, and philosophical and moral perspectives in order that they be confronted with the question of the meaning and purpose of life, giving them opportunities for a wider and deeper understanding and discussion of the natural world, including man. This is one of the paramount and best ways to appreciate the wonder of humanity's uniqueness, the strangeness of how it could have happened that the big-bang created a situation such that a thousand million years later, a part of the universe could study the rest of itself. Scientific knowledge must be linked with ethics to reach wisdom. For scientists this means caring for the future of mankind as an overruling duty to be accepted as an obligation, plus informing the public about the possible misuse of their discoveries.

The Universities, as already said, have greater responsibilities than in the past. In biological research the public concern has largely been in the welfare and dignity of human subjects, and there have been pressures on scientists not to undertake certain studies. The issue at stake is neither trivial nor easy to solve. We cannot forget that if knowledge is a sovereign value for the University's commitment, objective knowledge is good, and superior to ignorance in any circumstance, «neither law, nor tradition confers an absolute right to freedom from all restraints». Nevertheless, we need to accept no constraints other than those essential to protect other values that we cherish (Handler). The society that provides support for the scientific endeavor, has the right to limit the application of knowledge in order to avoid harmful results either in the physical or in moral realms.

I agree with Sinsheimer's statement: «The coupling of inquiry with wisdom is certainly a very high energy bond. The conditions for its formation are ill-

defined, but the conditions for its cleavage obviously abound»... «I certainly would not wish to truncate our Science. We do not want the bonds of responsibility to become the shackles of inquiry». The University should give students the chance to confront the goals of science with the highest ethical ideas of humanism. It should provide them with the means to apply our ever-widening understanding and the increasingly sophisticated technologies with wisdom and charity.

I fully share the thinking of our late and famous colleague Dr. Albert Szent-Györgyi: «Science is the study of the work of the Creator, a kind of divine service, a search for truth, sought with uncompromising honesty». In the University the love of truth, honesty, and human dignity are moral values, which cannot be separated from the values of science.

REFERENCES

— GOTTERER, J.N. MAHMOOD, O.N. *Some commands on Technology and values in a changing world.* Proc. of the Sixth International Conference on the Unity of Sciences, San Francisco. Vol. II, page 1052 (1977).

— HANDLER, PHILIP. *When Science becomes a public venture, to whom is the scientist accountable?* The Chronicle of Higher Education. Page 64. March (1980).

— JONAS, HANS. *The Imperative of Responsibility in search of an Ethics for the Technological Age.* University of Chicago Press, Chicago (1984).

— MOHR, HANS. *The Ethics of Science.* Interdisciplinary Science Reviews. Vol. 4:45, (1979).

— SINSHEIMER, ROBERT. *On coupling inquiry and wisdom.* The future of biomedical Sciences. Federation Proceedings. 35:2537 (1976).

— SZENT-GIÖRGYI, ALBERT. *Knowledge versus wisdom.* Proc. of the Fourth Int. Conf. on the Unity of the Sciences. New York. Vol. II, page 1088 (1975).

DISCUSSION

RICH

I concur with you fully that many of the developments in science bring problems, mostly associated with how this knowledge is applied. In the field of modifying the human genome, we are now within a few years, and possibly even one, of developing the technique of gene therapy, that is, modifying genes in human cells and using those for therapeutic purposes. This is an area of considerable technical challenge but considerable promise. However, at the

same time there is a very strong counter, almost anti-science attitude that has developed. A number of organizations are raising the spectre of, as it were, portraying the scientist as a kind of modern Frankenstein in a most distorted way. In the United States, at any rate, these people have developed a certain following and the consequences of that can be quite severe. The feeling that one must not tamper with the human genome is the same feeling as that which used to be expressed in ways such as: one must not tamper with the nucleus or one must not tamper with whatever the status quo is. I think there is no question at all that all of the applications of science must be associated with very careful thinking about their consequences, and this is especially true in the field of human genetics. This is a subject that has a very long history. The medical physicians have been coping and are coping with this problem, acknowledging its ethical consequences on a steady basis. I think we should not minimize, however, the forces that are, as it were, opposed to the use of science because often they have gained some adherence in the government. There is in the field of microorganisms a law which is now being considered which would set up a special regulatory apparatus for the release of an organism, a microorganism, in which the genetic organization has been modified by recombinant DNA activities. That same organism can be created of course by selection, and no one is suggesting that that be regulated. It's as if the legislators think there's a difference between organisms depending on how they were made, whether by selection, which mankind has been doing for almost ten thousand years — at least in larger organisms, or through recombinant DNA activity which may be faster but the end result is very much the same. But, on the other side of the coin, one also has a great responsibility to educate society, to let people understand the nature of the changes and to give some perspective about the role of these changes relative to what has existed in the past and what may exist in the future.

CROXATTO

Thanks, Dr. Rich. I agree with your comments. It is not only necessary to eradicate public misconceptions about science, but also universities should provide in their curricula for the future science practitioners, broader opportunities to face and discuss the ethical responsibilities of doing science and the moral consequences which can derive from technical applications.

RESPONSIBILITY OF THE UNIVERSITIES TO SOCIETY AS WE APPROACH THE TWENTY-FIRST CENTURY

S. KEITH RUNCORN
Newcastle upon Tyne, England

In addressing this theme, it is well to reflect on what a university professor might have said one century ago had he been so bold — or foolish — as to agree to speculate on the role of universities and their development in the 20th century. It is surely probable that he would have missed all the main developments which have transformed universities in this century: the great increase — logarithmic — of student populations, the doubling or trebling of universities in the western world and the establishment of autonomous universities in the developing world, and above all the commitment to research.

The development in universities of properly organized research schools has been a feature of the last hundred years that has greatly expanded the idea of the university. From being communities of scholars and students concerned with the conservation of knowledge and its transmission, taking in new discoveries into the corpus of what was taught — sometimes with reluctance — they became actively engaged in the active pursuit of knowledge.

The new idea came largely from Germany: for example, the first real research school in England was set up in Manchester University by a German: Schorlemann, who became professor of organic chemistry. Similarly, in North America the idea was planted and Johns Hopkins University towards the end of the last century pioneered research in the universities there. The idea of awarding a degree for supervised research was also a recent development in the English university system: the Ph. D. degree was only instituted in Cambridge in 1919, the first recipient being a member of this Academy, Sir James Chadwick. Postgraduates taking work for a Master's degree or following a course of research for the Ph. D. have now become a key element in a university: in North America organized into graduate schools with a Dean to look after their interests. Ronald Fisher, also a member of this Academy, used to call them the

most important group in a university as they link the research and teaching roles of the modern university in a very explicit way.

I therefore take up my topic recognizing that the universities will develop in the next century in directions which cannot be predicted.

It is perhaps significant that there are very few books that have been written about the idea of the university, about these institutions' role in society and in the development of the individual. The most famous one is by Cardinal John H. Newman, born from his frustrating experience in founding a Catholic University of Ireland (not realised until the National University of Ireland late in the last century). He makes a classic statement of the lasting benefits to the individual in receiving his education within a community of scholars, dedicated to learning and to the pursuit of truth. Few other notable attempts have been made, at least in the Anglo-Saxon world, to define the purpose of the university, although Sr. Walter Moberley's book, born out of his experience as Chairman of the University Grants Committee and Vice Chancellor of Manchester University, was influential in the expansion of higher education in the United Kingdom.

Perhaps the best attempt to describe the 20th century idea was Clark Kerr's «Uses of the University». From his vantage point as President of the University of California, he gave an account of the American experiment in extending the idea of the university. In its great diversity of subjects taught, in the opening up of higher education to a much greater proportion of the age group, in its many-sided research and relations with industry, the community and government, he produced a picture of the expansion of higher education which has great influence in Europe. He coined the rather inelegant but useful term «multiversity» to describe these developments.

Of course I do not wish to decry the value of the very many, often attractive, accounts of individual universities, but they do not help to see the university in its universal role. But from them one can be made aware of the great part played by far-sighted individuals — and by accidental circumstances — in expanding the university idea. I illustrate this by reference to my own Universities of Cambridge and Manchester. My college, Gonville and Cains, has the only complete account of all the students who entered the college since its foundation in 1348 — the many-volumed biographical history — from which the students' curricula vitae are a fascinating study. The college was founded by the generosity of a country clergyman of Norfolk, Edmund Gonville, who left money in his will for the purpose. He showed some lack of judgment in appointing his bishop, Bateman, as his executor, for he promptly expropriated half the money to found his own college, Trinity Hall!

Manchester University for its centenary published a lively account of its history by H.B. Charleton, the Professor of English Literature. It began as

Owen's College, which was also the result of a will: Owen had made a fortune among «the dark satanic mills of Lancashire» and he was neither a prominent citizen nor a patron of the arts and sciences, nor was he in his life a philanthropist. Yet in his will he outlines the purposes of the college that he wished to found with a clarity and a liberality which would today be regarded as an enlightened statement of the purposes of a university. My conclusion is that even in the vast edifice of higher education today we should not discount the role of accident and personality in developing the idea of the university into new directions.

What are then the strengths of the universities as they face the 21st century? *Firstly*, one is struck, in examining their history, by the fact that, in spite of periods of chaos and great destruction in society around them, they have been remarkably durable social institutions. Tenacious in their privileges, they have not been easy to destroy. Only a few have been established and later gone out of existence. One is Harderwijk in Holland (opened in 1648, closed in 1811), where Linnaeus taught as professor for a while. Some have had to be refounded: Cologne in 1919 and Mainz in 1945. They have also weathered the perhaps more serious threats of luxury and ease. The sorry state of Oxford and Cambridge in the 18th century, where most professors did not teach, is unforgettably described by Edward Gibbon, and Winstanley's history is hardly less scathing—at once amusing and sad that such possibilities could be so wasted. My own college has the dubious distinction of having ruined one of the greatest mathematicians: a fellow of Cains chanced to discover Green working as a farm boy — Green's mill near Nottingham has recently been restored — and brought him back to Cambridge, where he succumbed to the excesses of high table life.

Secondly, universities are generally perceived in society to have a unique value in standing apart from the state and church and other institutions, upholding in a disinterested way truth about the world and mankind. The public may only poorly understand them, politicians may frequently be displeased by them, but the fact is that they are independent sources of information, useful and trustworthy. How often are we rung up by the press or TV wishing to provide information to the public about some topical issue, in my case usually about earthquakes, planetary exploration or volcanos!

We have recently had an interesting example when the Church turned to three university laboratories to determine the date, by the C_{14} method, of the Turin Shroud, and the result was at once accepted by the very large numbers of those interested in the matter.

Thirdly, universities have managed on the whole to maintain their independence. I do not underestimate the limitations put on this by pressures

in totalitarian regimes. But it has been significant that totalitarian rulers have feared universities. This year in England we are celebrating the tercentenary of the Glorious Revolution of 1688, which, in spite of some historians' reassessments, marked a significant step in the establishment of our parliamentary democracy. In the events which led up to this the resistance of the universities was influential. At Oxford the Fellows of Magdalen College resisted King James II's attempt to impose a President on them, and in Cambridge there was also opposition, in which I saw Newton was a leader (he later took a seat in the Convention Parliament).

Independence has come under attack from various directions in recent decades in the U.S.A. — seriously during Senator McCarthy's investigations in the 1950s. Recently in certain parts religious fundamentalism has posed a threat to scholarship, and though it may have passed its peak, well financed «Creationism» remains a danger to the teaching of geology and biology. Certain leading geologists have felt that scientific academies, including this one, ought to do more to combat such irrationality and to support more publicly their efforts to place before the young the opportunity to understand, and critically evaluate, one of the great triumphs of the human mind, the theory of evolution.

The challenges to mankind as the 21st century approaches are well recognized, but their interrelation less so. They are:

Firstly, world peace must be preserved and local conflicts more quickly extinguished;

Secondly, the living standards of the Third World must be brought up to a level at which the potential of every human being can be realized, even in small measure. This is a challenge for humanity as crucial as that presented by slavery in the last century.

Thirdly, the biosphere must be conserved for future generations. It is increasingly recognized that the environment is being despoiled to a most alarming degree. Technology has developed so far that mankind has embarked for the first time on an experiment of changing the environment on a planetary scale rather than on local scales as we have been doing since the dawn of civilisation. This experiment is being carried out with an inadequate understanding of atmospheric or oceanic processes.

Fourthly, the Earth's non-renewable resources must be more carefully conserved. To support the high standards of life made possible in the last century by technological advance, fossil fuels are being used up at a rate one million times greater than they were laid down by geological processes. Less than a

decade ago, by taxonomic studies of insect life in the canopy of the rain forests the number of living species has now been estimated at 30 to 50 million rather than 1.5 million. To provide land for agriculture, the rain forests are disappearing at present at a rate of an area equal to that of Manhattan each day, and a sizeable proportion of living creatures will become extinct by the end of the century, even before proper study can be made.

These objectives are all impossible to attain if the growth of world population remains unchecked.

Universities have a key role to play in helping mankind to solve these problems.

Firstly, universities must be the centres of accurate and relevant information and dispassionate thinking about society's problems, on which decision makers can draw. P.M.S. Blackett, referring to the success of operational research in the last war, said that «wars could not be fought on gusts of emotion». Further research is required on the environmental problems about which we have been alerted, especially the gradual rise in global temperatures resulting from the «greenhouse» effect due to the increase of CO_2 in the atmosphere. The «ozone hole» due to release of certain chemicals, the discovery of which is directly the result of basic research, reinforces the need for extending research in environmental physics.

Secondly, universities in continuing their age-old responsibility in training leaders for society, industry, the churches, trade unions, etc., are uniquely able to provide the breadth of training to equip them for a world in which interrelations between economic, technological, ethical and social issues are of extreme importance. Their graduates must understand how their expertise relates to the broad purposes of mankind.

Thirdly, it is clear that the right decision can only be taken by governments if the general understanding of their public is greatly improved. It is perhaps an over-harsh saying that people get the governments they deserve. Abraham Lincoln said that «democracy is the worst form of government except for all the others». In enhancing the understanding and improving of the educational standard, universities have a leading role. To reconcile mass higher education with maintaining the highest standards in scholarship and research is both a challenge to and an opportunity for universities in the coming decades.

Universities will face increasing threats both externally and internally. They will increasingly come under governmental influence. Even when this is benign, it will be a threat to their independence. «He who is piper calls the tune».

Demands upon the university to produce «relevant» research, research directed to the solution of urgent problems, even research that will have the prospect of a quick commercial return are understandable, as much of the general income of most universities comes from the government. But universities must give the highest priority to basic research for that is their most enduring contribution to society, one they are uniquely fitted to make.

In my country it is curious that one has to defend fundamental research when the country was saved during the last war by radar, developed from the work of Balfour-Stewart, first professor of physics at Manchester, who was curious about the origin of the daily variations of the geomagnetic field and was led to the conclusion that there is an electrically conducting layer in the atmosphere, a hypothesis which invited testing by Breit and Tuve's and Appleton's method of reflection of radio waves.

Internationally, universities will be menaced by increasing bureaucracy. Attempts to monitor performance are understandable; in my country ministers repeatedly demand that universities demonstrate that «their standards of teaching and research are of the highest» and that «the public is getting value for its money». Inevitably forms must be filled in by staff, listing numbers of papers written, conferences attended, etc. Quantity is being assessed, quality is not quantifiable—exactly what universities are not about.

Finally, although basic scientific research needs the fullest support, research in the humanities must not be neglected because it attracts, and needs, less financial support. As early as the development of scientific research in the last century in Germany, critical methods were being applied to the Bible, at first by the great school in Tübingen University, and scientific methods applied to historical research searching for truth in historical events have made a great contribution to man's understanding. It is worth reflecting on how great a contribution to the cause of world peace has come in the last fifty years by the objective studies of historians of world events which have influenced the teaching of tomorrow's citizens.

DISCUSSION

WEISSKOPF

I would like to mention a problem of the universities that is perhaps more characteristic of the United States, though I am not sure, and that is the quality of the students. The students of today are much less interested not only in

science but also in other fields. They would like to get an education or a training for making money. Now I am speaking of course of the average. There are always wonderful students around. Now it is interesting that in the United States we have another phenomenon, namely the influx of the East Asian students who are of an incredibly high quality. We once had a discussion on this in the National Academy and there was one member who said, "You know, this influx is not a problem. It is the solution, and in particular for the United States, where immigration has always had a very positive influence on the development of intellectual life, in particular in science. This influx of eastern students is just another example of how to solve that problem". But of course it is a problem. For example, at MIT in a study of the graduate students in physics, we have found that the upper third of achievement is almost 70% East Asian and the lowest third of achievement is 70% native American, (by native of course I don't mean the Indians). So there is here a threatening problem of a psychology which is anti-learning and anti-enthusiasm for intellectual achievement, and I am sure this is not only in the United States.

RUNCORN

I'd just like to say a word in connection with what Professor Weisskopf said. I think it is worrying; the motivation of students in universities is often less than one would wish. I wonder a little bit whether, particularly in subjects like physics, we have made the courses too hard for them.

WEISSKOPF

This is certainly the belief of the students although I do not believe it is really so. I don't think the courses are harder. Indeed I think that many universities, including my own, are making the courses easier in order to get more students in. I think it is the general belief that the hard sciences are difficult, and therefore it is much easier to chose something which is deprecatingly called "soft sciences". I think it's the belief of the students, if not the real situation.

MOSHINSKY

I think it's a problem of social mobility. When I was a graduate student in the United States, a high proportion of the students was Jewish. I think that

at that time, that was the avenue that they had for social mobility. That was one of the reasons for going to the university. Today, maybe Jewish students and other native American students have other avenues for social mobility and they prefer them. I think this fact is reflected here, and when the Asian students achieve a certain level, maybe it will be the turn of other groups to come in.

CHAGAS

I see that some of the problems of bureaucracy which we have in Brazil, you have in England too. I can give you the example of Joanna Döbereiner. She has mountains of reports and summaries of projects and so on to do. There is very little time left for her laboratory work. It is quite interesting for us to learn that this also happens in England.

I would agree with many points of your presentation. I think that if the universities are to face the problems of the next century, a change in their curricula should be established. A much larger approach to the world of knowledge should be found. Also an interchange between the two fields of knowledge should be very much stressed. This is the way in which humankind can face the societal problems which we have and are going to have.

THE RESPONSIBILITY OF SCIENCE IN RESEARCH COOPERATION TO PROMOTE HEALTH IN THE DEVELPING WORLD

SUNE BERGSTRÖM
Karolinska Institutet, Stockholm

The excellent talks this morning on the responsibility of science and on the strength of universities prompt me to add a few comments.

Science — as one of many human activities — certainly has to be conducted in a responsible way in relation not only to personal and national viewpoints but often to international or global aspects, as many problems transcend national boundaries.

However, it must not be forgotten that "Society" also has a responsibility to support science and its activities that are fundamental to solving many serious problems facing mankind.

The Universities play a fundamental role in this process. Their strength depends mainly on the activity of their scientists and groups of students.

Universities are training people that have a high proportion of intellectually independent, forceful personalities. In their research work they are using scientific methods, i.e., they are openly and honestly reporting and interpreting facts obtained when using defined scientific methods. I don't think this way of working in any way threatens any other activities of the human mind, be they artistic or religious.

Health is of prime concern to every human being. Health is of fundamental importance for development. Furthermore, the increasing number of individuals in the world is of critical importance for the future environment of the world, and thus for health.

There is a glaring inequality of the health situation in the world today. The health situation in Sweden, about a quarter of a millenium ago is illustrated in Fig. 1. The age of those dying about 1750 are registered; 50 per cent of the

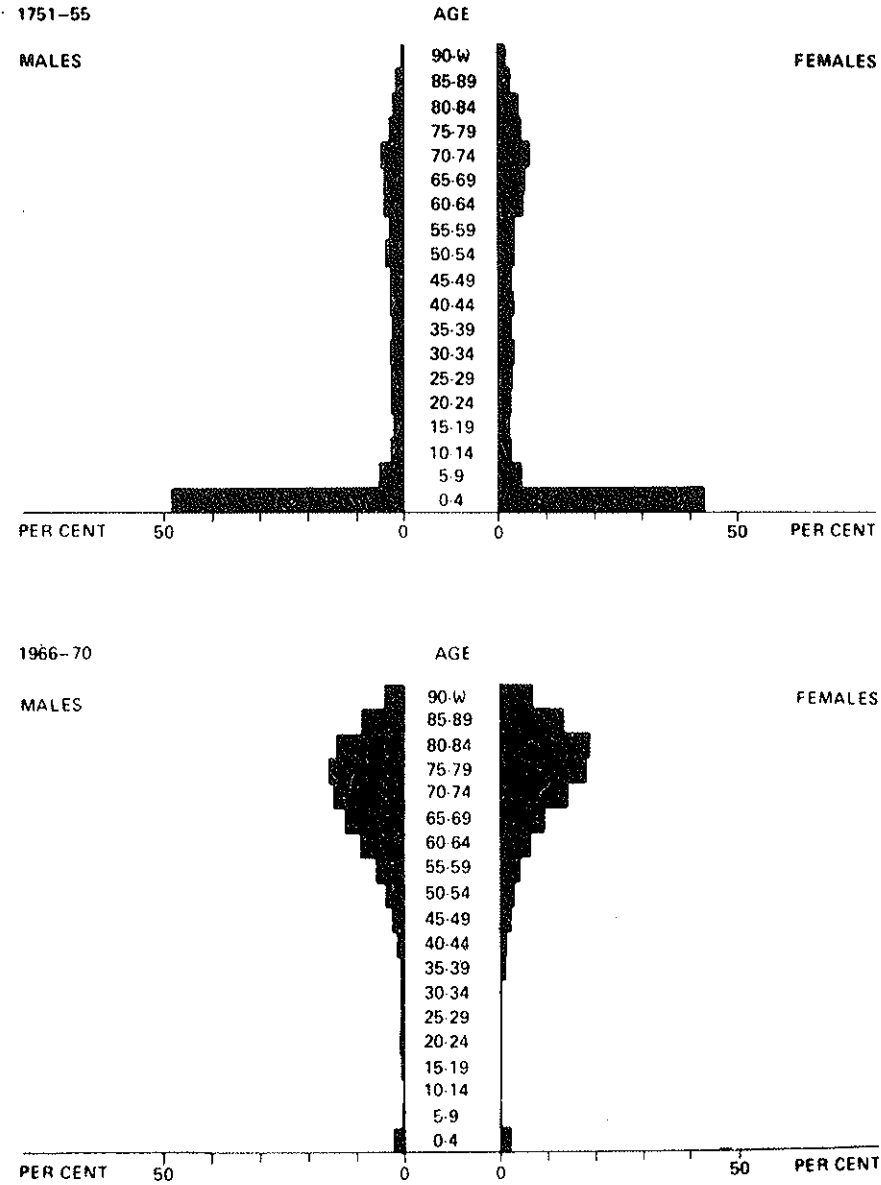


Fig. 1. Age and mortality in Sweden: 1751-55 and 1966-70.

dead were less than 5 years old. Then there is a random distribution of the age of the dead up to 90 years of age. In 1960 there were very few dying at low age, and the dead had mostly lived a long life.

Now one might wonder if this was something peculiar to this poor developing Northern country. In a book, "How to save the life of babies in London", published in 1792, the number of births and of deaths before 5 years of age are recorded from 1762 to 1771 in the London area: out of 162,000 born, 101,000 were dead before five years of age. The situation was thus even worse in London than in Scandinavia from this point of view.

This terrible health condition didn't inhibit scientific activity. I am just giving one example from Sweden. Linneaus, the famous botanist, was Professor at Upsala university in the latter part of the 18th century. He had more than 100 graduate students, as we would call them now, from different parts of the world. He sent many of them out on botanical expeditions all around the world. Two of them accompanied Cook on his voyages. Others did the basic work on the floras of South Africa, Australia, New Zealand, Japan, part of India, South and North America.

A strong scientific personality can usually get through even under adverse conditions, something we must remember when we strive to strengthen research in developing countries.

Coming back to child mortality in Sweden, Fig. 2 illustrates how it has decreased from about 20 per cent in 1750. It didn't decrease much the first hundred years, and it is only in the last decades that it has really gone down to the very low level of about 0.1 per cent.

However, the tragedy is that the situation today in many parts of the world is as bad as it was in England and Sweden in the 1750's. That is certainly one of the serious problems facing the global society and science today.

In large areas of the world life expectancy is still less than 45 years, in others less than 55.

At the same time longevity for those surviving early childhood is increasing very rapidly in many developing countries. In Europe, the USA and Japan, it's well over 70. In India, Columbia, Chile, Brazil, Mexico, life expectancy is rapidly increasing, even if in these cases child mortality still is fairly high.

What does that mean? In the European countries the crude death rate has been slowly decreasing through the last 250 years and the birth rate has followed it but with some delay. In the case of many industrial countries the curves now coincide so that a steady state has been reached. But in developing countries, the death rate has been falling rapidly since the war, whereas the birth rate remains high and only now is beginning to go down. The difference between the curves represents a growth rate of 2 to 3 per cent in these countries, whereas

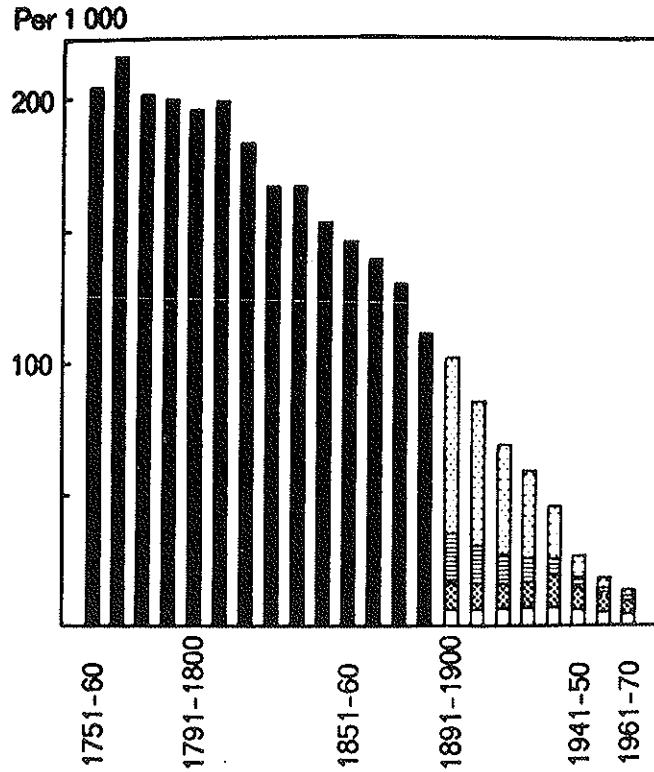


Figure 2. Child mortality during the first year in Sweden.

most industrial countries are now approaching zero growth. Improved education and socio-economic progress are prerequisites for a decreasing birth rate.

It is estimated that the population in the industrialized countries will only increase from 1.1 to 1.3 billions by the year 2000, whereas in the developing world there is projected a tremendous increase from 3.3 to 4.8. There is thus an enormous increase in the younger age groups in the latter countries whereas there is more increase in the older age groups in the industrial countries. Where will this end — will the world's population stabilize at 8, 10 or 12 billions or more?

The population growth is undoubtedly the main problem facing the environment of the world because eventually all people will rightly demand a

similar standard as today's industrialised countries. The mass media will not let them forget the situation.

If you only look at the need for energy of these masses of people, you will realize what a serious problem has to be faced. This and other problems can only be solved by increased research and development efforts.

The present health situation in the developing countries is very bad, mainly due to the parasitic and infectious diseases, malnutrition, adverse socio-economic conditions combined with inadequate education especially of the women.

An encouraging example of what society and science can do is the new «special» research and training programmes in WHO. They are focusing on tropical diseases like malaria, sleeping sickness, Chagas' disease and leprosy (TDR), on diarrhoeal disease (CDD) and on human reproduction (HRP). These programmes represent a new and important development for the subject we discuss today.

These programmes are truly international research councils that are run by scientists from the whole world in the same way as national research councils are managed, with circulation of members and so on. Their highest authority are boards in which government representatives from developing countries are in the majority. They have complete sovereignty over how their funds are used and the UN-agency (WHO) is serving as a secretariat for these scientific groups.

Society in the form of the WHO member countries has responded fairly positively by voluntary contributions from more than twenty countries. For the human reproduction programme the annual budget is now 22 million dollars, tropical diseases 25, and diarrhoea diseases about 10, and an AIDS research programme is being added to these programmes. Table I gives an outline of some of their activities.

Table I.

Human reproduction (HRP) 1972-87

Total contributions	~ $ 220 mill
~ 120 collaborating clinics & laboratories	
~ 200 clinical trials involving ~ 200,000 patients in 50 countries	

Tropical diseases (TDR) 1976-89

Total contributions	$ 250 mill
Active collaboration with ~ 3,000 scientists in 120 countries on ~ 2,000 projects	

How do the different WHO member countries respond? Surprisingly, Denmark has been the largest donor to TDR, followed by the US, Sweden, Norway and many other countries. WHO, the World Bank and UNDP are also participating, thereby adding stability. Of course these contributions are really minuscule for large countries.

Table II.

WHO's Special Research Programme for Tropical Diseases (TDR)
Contributions of selected donors
and research support in respective country in millions of dollars

	contributed	**received back**
Denmark	32.0	0.5
Sweden	24.2	1.1
USA	27.8	35.9
UK	6.6	17.4

It is interesting to see where these contributions end up (Table II). Denmark during a certain period contributed 32 million dollars to the tropical disease programme and got half a million back for research in Denmark. Sweden gave 24 and got one million back. US gave 27 and got 35 back. UK gave 6 and got 17 back for research in the UK. Since colonial times the latter country has institutions that are strong in the field of tropical diseases. It is therefore natural at this point in time to utilize these strong institutions, to get projects going quickly. However, more than half of the total budget is going straight to developing countries for institution strengthening and for joint projects in these countries.

If science and scientists should have responsibility, they must be in responsible positions and they are slowly getting there in research council organizations. They must also have resources, in this case especially for working on problems of the developing countries. Figure 3 illustrates the percentage of the GNP of certain countries used for foreign aid. Norway, the Netherlands, Denmark, Sweden are at the top at 0.8-1 per cent. Japan gives 0.3 per cent and the US 0.2 per cent of the GNP in foreign aid. But of course the latter countries have large GNP's so they are at the top in absolute amounts. Our hope must be that their contributions go up. The Japanese government has decided to double the Japanese aid during the next five years. Then there could really be a revolution in the impact of research and development on the developing world.

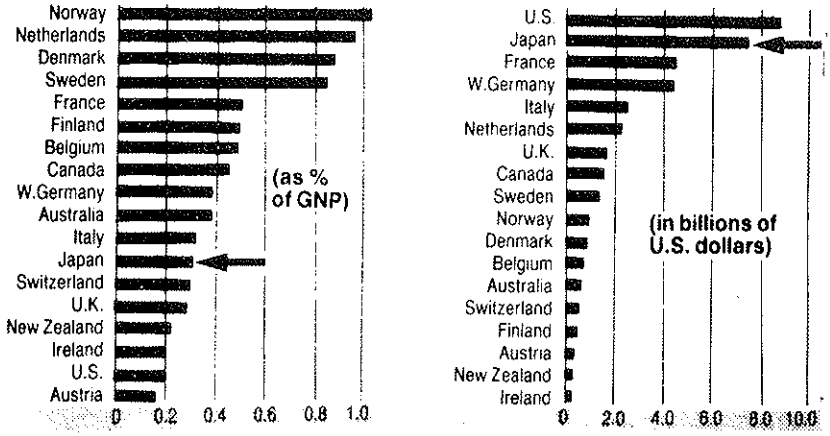


Figure 3. How aid disbursements compare.

Figure 4 illustrates what a contribution of 1 per cent would yield in foreign aid!

It is also necessary that an increasing number of today's scientists get involved in problems of the developing countries and that increased efforts be

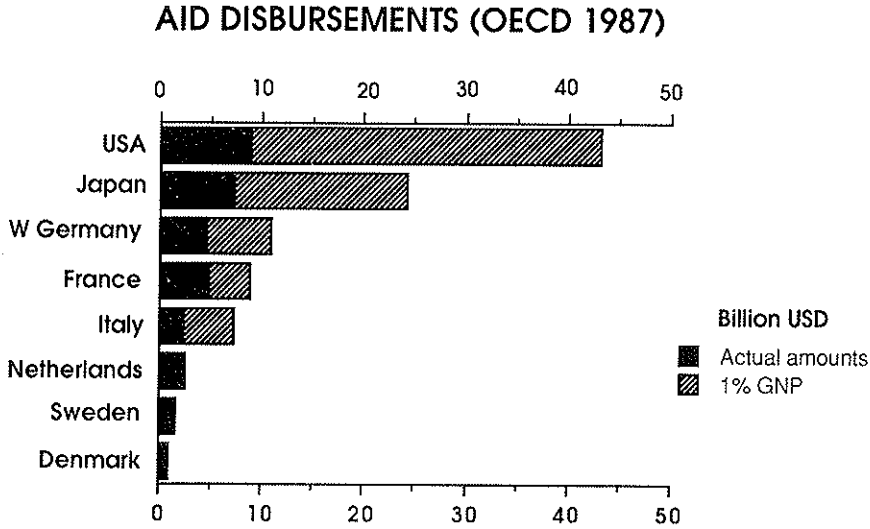


Figure 4.Aid disbursements (OECD 1987)

directed to research and research training in developing countries. I have therefore been proposing that the aid agencies in industrial countries add 5 per cent or more to the budget of every research council in their respective countries (health, agriculture, natural science, humanities etc.). These funds should be earmarked for projects of benefit for and in collaboration with scientists in developing countries. They would amount to a total of hundreds of millions of dollars and it could involve many thousands of scientists. It could unleash a lot of scientific imagination and activity — something which might add greatly to the efforts and efficiency of the aid organizations of the world.

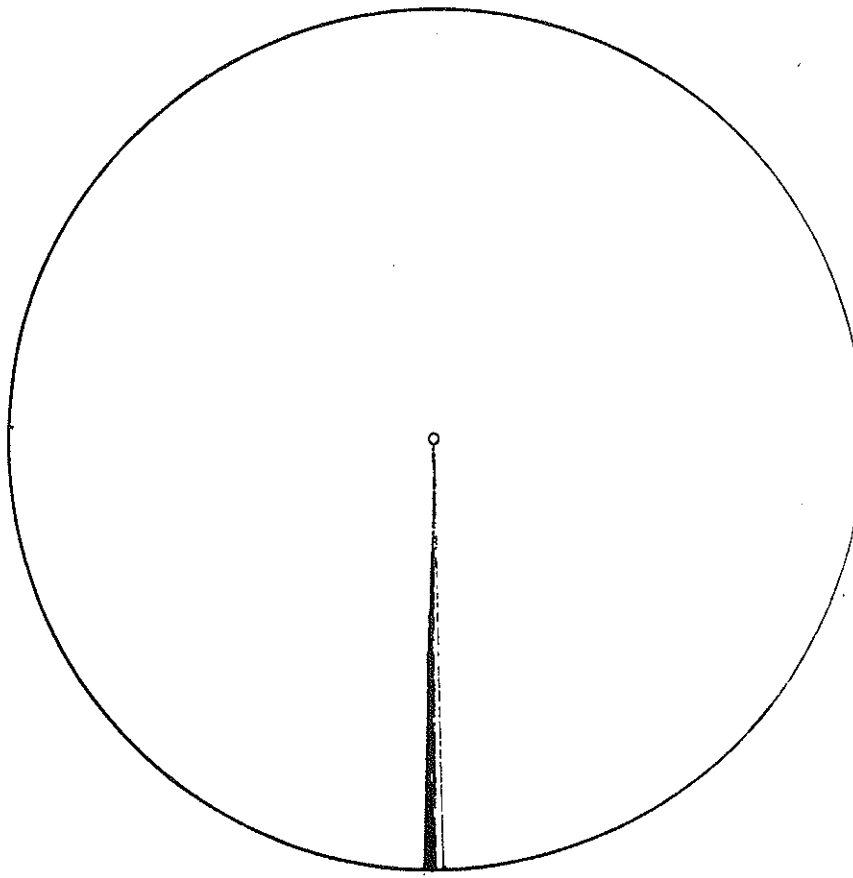


Figure 5. Nuclear arsenals. If the small circle (Radius 1.4mm) represented all the explosives used in the Second World War, the large circle (radius 100mm) would represent the size of present-day nuclear arsenals.
(Figure slightly enlarged.)

As mentioned in earlier discussions in this academy, the largest threat to the health of mankind has been the threat of atomic warfare. The little circle in the centre of Fig. 5 corresponds to all the explosives used in the Second World War. The big circle corresponds to the explosive power of the present store of atomic weapons. You should notice that the atomic weapons corresponding to 1 per cent of this big circle, if aimed at population centres, might kill 143 million people in one go in an exchange between the US and the USSR. What has been accomplished now in the agreement between the US and the USSR is the elimination of roughly 2 per cent.

The important thing of course is that the trend is changing. We have finally arrived close to the point that Alfred Nobel visualized 100 years ago. He was supporting a peace conference in Vienna and he wrote to the lady who organized it saying approximately: "I don't believe that your peace conferences will do much to lessen the threat of war. I think that my explosives are more effective when they are perfected and can annihilate an army in a few seconds. Then people will stop making war".

We are finally getting close to such a point.

Even the transfer of a minuscule percentage of today's military budgets estimated to be $ 120 billions to foreign aid for research and development in developing countries could mean the difference between stagnation and progress, between despair and hope.

DISCUSSION

MALU

Monsieur le Président, c'est une présentaton intéressante, mais je me permets d'attirer l'attention de l'audience sur le fait qu'en Afrique, en particulier, on rencontre beaucoup de cercles vicieux. Et ici nous voyons un exemple de cercle vicieux.

De faibles progrès medicaux, simplement une bonne hygiène, ou la vaccination des enfants contre les cinq maladies infantiles, permettent d'augmenter assez fortement l'espérance de vie de la population. Cette augmentation de la population dans un environnement technologiquement assez peu avancé induit une surcharge des ressources disponibles, des ressources pour la production alimentaire. Et du fait que cette population a moins à manger, vous augmentez la mortalité de la population. D'où vous voyez que, en partant, en se basant uniquement sur l'amélioration de la recherche médicale sans améliorer la recher-

che agronomique et autre, vous revenez à un point de depart qui n'améliore pas beaucoup la situation générale de la population. Il y aura simplement, si vous voulez, un retard.

Ça, c'est un des cercles vicieux. Je peux vous en citer d'autres qui montrent bien qu'on ne doit pas concevoir le développement comme du salami, en petites tranches. Il faut nécessairement considérer l'ensemble et attaquer simultanément les différents aspects qui importent, pour assurer réellement une croissance des populations africaines qui soit harmonieuse.

Le procesus de développement est un processus complexe; on ne peut pas le résoudre uniquement en ne regardant qu'un aspect de la question.

BERGSTRÖM

I am sorry, I think you have misunderstood me slightly. First of all, I said all the research councils, not only the health one, should be supported, and that a minor percent, maybe a tenth of a percent of the aid money should go to the research council. All the rest should go to the developmental effort as before. But one crucial thing is that unless you improve the health status, you can never limit population growth.

WEISSKOPF

Is it always the money that counts? For example, there are problems, (maybe AIDS is such a problem), where the progress is not proportional to the support. I am aware that the support is too low, but I would like your opinion as to whether one could measure the progress in health solely in dollars.

BERGSTRÖM

Well, other people can answer this at least as well as I can. Money is a prerequisite to a certain level, but it takes time for it to have an impact. If you look at AIDS, it is really not realized what fantastic progress has been made there. Had this disease been rampant ten years earlier, it would have been a real catastrophe and if you wait five years more, I am sure there will be great progress thanks to the money. If you look at American science, of course there is a delay but it is very heartening to see how, with liberal funding and reasonable organization, in one generation you are in the forefront of science.

THIRRING

You don't have the figures of the ratio between the money spent on public health and the money spent on armaments in the various countries, but can one see a systematic trend? Is it proportional, inversely proportional, or how is it distributed over the world?

BERGSTRÖM

In the Western countries the proportion spent on health care is about equal to armaments I believe, but if you go into research, health research is minuscule compared to military research in the big countries.

SIDDIQUI

I believe in India the money spent on research is about one percent and in Pakistan 0.14%.

BERGSTRÖM

Yes, I know, that's the situation, but in the Western countries, especially because of health care, taxation is often by districts. It's an important point in the political propaganda to promote health.

CHAGAS

I would agree with what was said here, in the sense that in many developing countries the amount of money that is spent for defence is at least one hundred times the money which is spent on research and health problems. And this is not only for defence against possible aggressions by neighbouring countries, but also military expenditures to keep military governments in power.

There is one point you made which I think should be stressed: the fact that if basic research did not exist, the work on AIDS would be much less developed than it is. However, I think that the problem you have presented here is a very complex one. For instance, I am completely in favour of research for a vaccine for Chagas' disease. It is important that this research go on, because it would help very much toward understanding problems of the biology of protozoa. But the problem of Chagas' disease is not only that of vaccina-

tions; it is also a socio-economic problem — to provide good dwelling houses for the people so that the vector will disappear.

I would also like to point out that what pleases me in the WHO Special Research Programme for Tropical Diseases is that it is being increasingly undertaken in developing countries. This is due, I think, mostly to Prof. Bergström's influence, and it is a very important development. It will not only create the knowledge which developing countries need, but it will provide a climate for furthering the growth of science. In this way we may be able to convince the governments that much more money should be allocated for those problems which are capital in the development of the Third World. I feel, as you do, that much more could be done than is done now — first, through efforts in the educational system, and second in the financial sphere.

BERGSTRÖM

I might add that there are few things that upset me more than when representatives of aid agencies ask: How long do we need these health research programmes? Five years more or ten years more? Then I usually ask them, when do you propose to close down the research councils in your own country?

THE RESPONSIBILITY OF DEVELOPING BASIC SCIENCE

VICTOR F. WEISSKOPF
Massachussets Institute of Technology, Cambridge MA, USA

Most of our discussions dealt with the responsibility of scientists in respect to the effects of their work on environment and on society. It is the duty and responsibility of the scientific community to draw the attention of governments, of the people and their elected representatives to the detrimental effects of scientific and technical innovations, and the possible use of them for destructive purposes.

I am going to speak about a different responsibility: the continuation of pure basic research. There are strong tendencies today to direct the restricted financial support towards applied science, that kind of scientific research which promises immediate returns in the form of technical applications of all kinds, including applications to study and to counteract the deterioration of the environment. Certainly such research is called for and should be supported even more than it is at present. But it should not be done at the expense of basic science.

Another opposition to basic science originates in anti-intellectual tendencies, which make science responsible for negative effects of many of its applications, overlooking the numerous beneficial applications, and argue for an end of further basic research.

What are the aims of basic science? We can distinguish three important points:

1. The search for the fundamental laws explaining why nature behaves the way it does.

2. The discovery of new processes and behavior patterns in nature that had not been recognized before because they were hidden or occurring only under special circumstances.

3. The development of instrumentation that allows us to find the new processes and behavior patterns by refining our means of observation and by creating conditions in the laboratory that do not exist in our natural environment.

All these activities are needed for practical purposes. In particular, the second and the third point are of great importance for applied science. New processes and new natural phenomena can be of practical use, the refined means of observation are most helpful in many respects. A good example occurred recently when a radiometer of very high sensitivity was developed at CERN for improved observations in particle physics. It turned out that it will be of major importanc in biology and medicine, and in studies of atmospheric pollution.

Such applications are often called by the pejorative name «spin-off» from basic science. But they are more than that. Basic science needs increased knowledge of natural phenomena, and requires a constant improvement of our means of observation, without which no progress is possible. The finding of new ways of dealing with nature is the result of basic science, of equal importance as the discovery of new laws of nature or any other discovery.

It is often maintained that such advances could be obtained directly when solving problems of applied character. This may happen but, in general, it is not the case. M. Polanyi has expressed it most lucidly:

«The scientific method was devised precisely for the purpose of elucidating the nature of things under more carefully controlled conditions and by more rigorous criteria than are present in situations created by practical problems. These conditions and criteria can be discovered only by taking a purely scientific interest in the matter, which again can exist only in minds educated in the appreciation of scientific value. Such sensibility cannot be switched on at will for purposes alien to its inherent passion».*

Indeed, history has shown that the scientific discoveries that led to the most important technical applications were made without any thought of their practical use. H.B. Casimir mentioned a few typical examples:

«I have heard statements that the role of basic research in innovation is slight. It is about the most blatant piece of nonsense it has been my fortune to stumble upon.

«Certainly, one might speculate idly whether transistors might have been discovered by people who had not been trained in and had not contributed to wave mechanics of the theory of electrons in solids. It so happened that inventors of transistors were versed in and contributed to the quantum theory of solids.

* M. Polanyi, *Personal Knowledge* (University of Chicago Press, 1958, p. 182).

«One might ask whether basic circuits in computers might have been found by people who wanted to build computers. As it happens, they were discovered in the thirties by physicists dealing with the counting of nuclear particles because they were interested in nuclear physics.

«One might ask whether there would be nuclear power because people wanted new power sources or whether the urge to have new power would have led to the discovery of the nucleus. Perhaps—only it didn't happen that way, and there were the Curies and Rutherford and Fermi and a few others.

«One might ask whether an electronic industry could exist without the previous discovery of electrons by people like Thomson and H.A. Lorentz. Again, it didn't happen that way.

«Or whether, in an urge to provide better communication, one might have found electromagnetic waves. They weren't found that way. They were found by Hertz, who emphasized the beauty of physics and who based his work on the theoretical considerations of Maxwell. I think there is hardly any example of twentieth century innovation which is not indebted in this way to basic scientific thought»*.

These are all examples in physics. The same is true in other sciences. Let me quote W.A. Blattner in the October 1988 issue of *Scientific American*, p. 149:

«...Were it not for the fundamental investment in basic research over the past 20 years, the discovery of the cause of AIDS might still elude us today. The success of science in unravelling AIDS is a stark testimony to the importance of society's investment in the curiosity of scientists. That instinct is crucial to our ability to address this or any other threat to survival».

There are two sides to the argument: One concerns the analysis of a situation, and the other concerns the search for ways to improve it. The attitude engendered by pure science is most conducive to getting a clearer picture of the facts and the problems that may have to be faced in a given problem, such as air pollution, the population explosion, or the effects of technical innovations upon our environment. In basic science the search is for phenomena and connections in all possible directions, while in applied science the search is directed toward a specific goal. Furthermore, when new technical ideas are needed — and they will be needed — the attitude of basic science looks more toward innovative ideas and less toward the application of known devices, because the problems at the frontier are exactly those that cannot be solved with established methods. In basic research a pool is formed of young men and women who are accustomed to tackling unexplained phenomena and who are ready

* Symposium on Technology and World Trade (National Bureau of Standards, November, 1966).

to find new ways to deal with them. They are trained to work under the most exacting conditions in open competition with the scientific world community. Instead of «environmentalists» we should train physicists, chemists, geologists, and biologists capable of dealing with the problems of environment.

Two qualifications are in order: Today's problems certainly require the methods and results of natural science, but they cannot be solved by these methods alone. The problems are to a great extent social and political, dealing with the behavior of man in complicated and rapidly evolving situations. These are aspects of human experience to which today's methods of natural science are not applicable. Seen within the framework of that science, these phenomena exhibit a degree of instability, a multidimensionality, for which our present scientific thinking is inadequate and to which thinking must be applied with circumspection. There is a great temptation to transfer the methods that were so successful in natural science directly to social or political problems. But this is not possible for the most important problems. Adequate methods may be developed in the future. The social scientists are working at the task.

The second qualification concerns the need for scientists trained in basic science. We do not argue that *only* those trained in basic science to the exclusion of others can solve our problems. Far from it; a collaboration between all kinds of people is needed, basic and applied scientists, engineers, physicians, social scientistis, psychologists, lawyers, and even politicians. The argument submits that people trained in basic science will play an important and irreplaceable role. They are necessary but not sufficient. But their necessity emphasizes the importance of keeping basic science activities alive.

Today to keep basic science vigorous is much harder than it was in the past; it would be harder even if the financial support were as generous as before. The reason is quite natural. The world situation has become so serious that many scientists or potential scientists find it difficult to worry about some unexplained natural phenomena or undiscovered law of nature when there are more immediate things to worry about. Some scientists feel that we are in an emergency situation and that we should stop basic science for the duration as we did during the Second World War. But the war lasted only four years for the United States, while the present crisis will endure for at least two decades. If we cripple basic science today, it will not be long before there will be no new generations of devoted young scientists for the tests that mankind must face in the future.

It is difficult to distinguish clearly between fundamental and applied science; any consideration of this kind can lead to dangerous oversimplifications. The success of basic research derives to a large extent from a close cooperation of basic and applied science. This close relation — often within

the same scientist — provided tools of high quality, without which many fundamental discoveries could not have been made.

We have stressed the necessity of basic science for progress in applied science and technology. This is only a part of its significance. Perhaps the most important value lies in the intrinsic character of scientific research. It is an essential part of human culture, in particular, of the culture of today. What is culture? It is most difficult to define, but it certainly encompasses the thoughts, activities, and ideals that people value most and are most proud.of. What is science? There is a quote of Sir Richard Gregory, the late editor of *Nature*:

> «Science is one of the great human endeavours to be ranked with art and religion as the guide and expression of man's fearless quests for truth».

Science is the organized expression of the human trend to penetrate, clarify, and understand the world around us. But it is more. It has a universality and a validity independent of the individual's language in which it is expressed or created. Hence, it has a special human significance. It is a creation of mankind as a whole.

Furthermore, the search for truth in basic science is free from any ulterior motive apart from personal ambitions of the scientists. In this respect it also acts as an example of high moral standards.

In many respects, the last 300 years of man were not so different from any other 300 years; there were wars, empires rose and fell, masterpieces of art and literature were created. But in one respect this period was different. It saw the development of science. Somehow men found the right approach, and suddenly within only ten or so generations an edifice of human understanding of the mysteries of nature was developed, which has shed light into dark abysses of guesswork and superstition. It created new insights, great perspectives, and all-embracing ideas, such as concepts like Darwin's evolutionary theory, like the electromagnetic field, which is the basis of all electric, magnetic, and optical phenomena; the mechanism of genetics, which explains the constancy of variety in the living world; Einstein's relativity theory; the intricate web of ideas in quantum theory, which gives a fundamental understanding of almost all properties of matter on the basis of electromagnetic forces within the atom. These concepts give us a much more profound view of certain aspects of our world than we ever had before. We quote from a speech of Sir Edward Appleton:

> «So far from reducing life to something cold and mechanical, modern science in its explorations ranges from the heart of the atom to the frontiers of the universe, and, like poetry, reveals the depths and mysteries beyond and quite different from the ordinary matter-of-fact world to which we are accustomed».

Here we come to another responsibility of the scientist engaged in fundamental science. He ought to convey the aspects that Sir Appleton has expressed to the non-scientific public. Actually, the public is not so far from this point of view as one might think. Why is the science of astronomy so popular among laymen, and wherefrom does astronomy get its large support in this country? Perhaps it is just the aspect of a starry sky on a moonless night that urges everybody to investigate and to find out what it is and how it works, just for the sake of knowledge. The answers to these questions never will give us better bombs or better toothpaste; nevertheless, we build big and expensive telescopes with popular support. This is the true scientific spirit.

It has been said many times that modern science is too complicated, too intricate for the layman; hence they cannot appreciate its cultural values. This argument is disproved by the great demand for popular science books and magazines. The success of magazines like *The Scientific American* or the *New Scientist* proves that the real values of scientific ideas can be transmitted to the educated layman.

Of course, there will be many facets of scientific development that cannot be explained in full to the layman. To use an analogy from the art of music: many fine contrapuntal structures in a symphony are understandable only to the trained musician; nevertheless, symphony concerts are very popular and appreciated by people who do not follow all the intricate structures of each instrumental part.

Of course there are excellent books and articles presenting scientific ideas to the public in a clear and simple way. But their number is insufficient. More collaboration is necessary between scientists and science reporters of our large newspapers. Educational television is now at the disposal of science. How many of our scientists are thinking about what is the best way to present the great insights and their new discoveries on the television screen? Far too few! It needs much more effort than heretofore on the part of scientists and educators in order to get science into the correct position which it deserves as the pillar of our contemporary culture. This would help to rectify the present situation, where ample support can be received only when one stresses the importance of science for military security and immediate practical applications.

When studying the development of industrial nations, one cannot fail to make the following observations: in the first half of the nineteenth century, England was the great industrial nation and, at the same time, England produced the great names in fundamental research: Maxwell, Young, Faraday, etc. Then, in the second half of the nineteenth century and at the beginning of the twentieth, Germany began to play a leading part. It is then that one finds a galaxy of German physicists: Helmholtz, Nernst, Röntgen, Planck, Som-

merfeld, Heisenberg, etc. Later in the twentieth century, as America became the leading industrial nation, fundamental science blossomed out in America. Fermi, Oppenheimer, Lawrence, Rabi, McMillan, Alvarez, Schwinger, Feynman are only a few names illustrating this. In the last few decades Germany and Japan emerged as industrial leaders; at the same time much new fundamental science came from these countries. There is a clear connection: where there is basic science there is industrial growth.

The value of fundamental research does not lie only in the ideas it produces. There is more to it. It affects the whole intellectual life of a nation by determining its way of thinking and the standards by which actions and intellectual production are judged. If science is highly regarded and if the importance of being concerned with the most up-to-date problems of fundamental research is recognized, then a spiritual climate is created which influences all other activities. An atmosphere of creativity is established which penetrates to every cultural frontier. Applied sciences and technology are forced to adjust themselves to the highest intellectual standards which are developed in the basic sciences. This influence works in many ways: some fundamental-research students go into industry; the techniques which are applied to meet the stringent requirements of fundamental research serve to create new technological methods — in particular, methods to avoid the detrimental effects of industry upon the environment. The style, the scale and the level of scientific and technical work are determined in pure research; that is what attracts productive people and what brings productive scientists to those countries where science is at its highest level. This is why so many good scientists have moved to America from Europe after World War II.

Therefore, it is the responsibility of scientists not to weaken or abandon fundamental research because of the need for putting science into the service of solving immediate problems of our society. The short-term gain will be offset by the long-term loss of the innovative ideas that spring from basic science. Basic science is the most vital part of our intellectual activities and should remain so. It is the part which we should regard with pride as one of the highest achievements of our century.

But there are growing trends to weaken fundamental science all over the world. I would like to propose that the Pontifical Academy of Sciences take a lead in warning the nations of the world of the dangers for human civilisation and even for human survival inherent in this trend. Six years ago our Academy took the lead in bringing the Academies of Science together and in issuing a strong statement about the dangers of a nuclear war. Would it not be appropriate to make use of the supernational character and the moral standards of our Academy in order to work out a statement signed by a worldwide

group of Academies as to the importance of basic science? It certainly would have an influence on world opinion and on the science policies of the various governments. It would be in line with the aim of our Academy to insure that science contributes most effectively to human culture and to human welfare.

DISCUSSION

MALU

I agree with what Prof. Weisskopf said about stressing basic science. I think everybody around this table agrees. But I have two remarks. For me the most pressing need today is to stress basic science and social science because the discrepancy between social science and natural science is becoming so wide that we are getting a lot of problems. This was the first remark.

The second was that basic science is costing so much today that it is becoming exceedingly difficult to stress very good research in basic science. This is becoming a serious problem.

WEISSKOPF

I have some doubts to what extent social science could influence the situation, although I said in my presentation that social sciences are needed for the solution of the problems. So I am a little pessimistic especally about whether more money, for example, in social sciences would help, but I may be wrong.

The second point about the cost. That is always a relative matter. At present the cost of basic research is less than 10% (I am speaking for the United States) of the total of applied research. That is not a very great amount because applied research is also supported insufficiently. It is true that basic research is more expensive now than it was, and one has to be a little selective, but that doesn't mean that one should neglect the essential role of basic research for education, for the culture of today, and for the solution of our problems.

ECCLES

I want to congratulate Professor Weisskopf on what I think is a most important contribution because he understands science very well and sees the problems of the future and I want to go on with what he said. What we need is

underestimated because of the great prestige, or whatever it is, that comes from instrumentation and equipment, and from immense sums of money. What we need is creative imagination. That is to say, thinking beyond the knowledge we have, and that is of course what you were asking for. We need the generation of hypotheses, taking cognizance of all our present knowledge and daring to predict beyond. That can be quite cheap. It isn't that you just have to get more, and that the only way to advance is to have more and more expensive equipment. On the contrary, I think, it may be better if we took thought about these creative minds giving more insights and knowledge about what the future problems are. Certainly that is true of the brain. We need far more insights, creative imagination, in this tremendous problem of the brain, and I assume that's true in physics and elsewhere. Therefore, I agree with Professor Weisskopf completely.

MOSHINSKY

I would like to stress one point that concerns the developing countries. You see, in the problems that Professor Weisskopf mentioned, although for a moment he also spoke about developing countries, he was thinking mainly of the developed ones. However, in developing countries we are facing such critical economic situations that even our small scientific establishments are in danger of disappearing, especially of not reproducing themselves, because we cannot get young people. There are no positions for them, there are no possibilities. So I think that the remark Professor Weisskopf made about a declaration of this Academy concerning the importance of basic research should also stress the fact that basic research is fundamental for the developing countries. It's fundamental for them just as much as for the developed ones. One should stress this point because of the great danger that we in developing countries are now facing.

WEISSKOPF

Of course I agree with Professor Moshinsky. I just wanted to say one thing. I think this Academy should not only make a statement. This Academy should ask, as it did before, all or most of the Academies of Sciences of the world to come together and make a common statement. This may perhaps have some effect.

ABRAGAM

As Professor Weisskopf has said, we are all convinced here, and I would just like to add one little formulation to the distinction between applied science and technology on the one hand and basic science on the other. I could formulate it in the following way: the applied science approach, if it works I don't care why; and the basic science approach, I don't care if it doesn't work, as long as I know why; because then I'll fix it.

SIDDIQUI

My whole life has been spent in basic and applied research. You can't separate the two. But so far as medical uses are concerned, nothing can go through here unless it has the stamp of some foreign pharmaceutical firm. That is how and why, for instance, ajmaline hydrochloride is being prepared by Kali Chemie as a drug of choice in the treatment of cardiac arrhythmia. It would not be employed in this, but so far as other uses are concerned, pesticides and so on and so forth they have been employed in India and Pakistan, and they can be employed a lot more if they are widely studied enough. That is what I hope the fundamental science people can do. We have established an Institute in which most graduate work is being carried out by over one hundred students after they have taken their Master's degree. There are about 12 to 15 doctoral degrees produced by this Institution every year. It is most important to emphasize the fundamental aspects of scientific research, particularly for the developing countries.

ABRAGAM

Like everybody, I fully agree with the suggestion of Professor Weisskopf. I want to say that I slightly disagree with the first comment of Professor Malu. I think that the basic sciences in all science — classical science, art science — have not the same epistemological foundation as the social sciences, and I think we must keep that in mind. The social sciences lack the objectivity which is one of the great characteristics which Professor Weisskopf has stressed. They are not completely independent of their philosophical, religious or political environment. So I don't want to talk against what is called the social sciences, but I think that we have to make the difference and the distinction because if we don't, we will lose the force of the arguments which were so well stated by Professor Weisskopf.

WEISSKOPF

I agree, of course, with what you say, but there is one point where I am a little hesitant to contradict Malu completely because, as I said myself, natural science is necessary but not sufficient. There are problems, psychological, social and others concerning which we do not yet have the scientific means, but that doesn't mean that we can forget about them. In this sense I think social science is important.

MALU

Le professeur Weisskopf a répondu un tout petit peu à l'objection qui a été faite. Je n'identifie pas du tout, bien entendu, "social science" et "natural science". Je n'en suis pas à ce point... Le professeur Weisskopf a souligné l'importance de pousser les sciences de base pour le développement.

Mais le problème du développement demande une contribution tout aussi efficace des sciences sociales. Si les sciences sociales continuent à avoir le retard qu'elles accusent actuellement, le développement ne sera jamais le développement de l'homme intégral. C'est cela le point important.

Il faut appuyer, bien entendu, les sciences de base qui ont leur critère de vérité, qui est différent du critère de vérité des sciences. En fait, même la complexité est différente, parce que, en sciences sociales, l'observateur, par exemple, est associé à la chose observée; en sciences de base comme l'entend Weisskopf — en principe, on dissocie. Donc, les sciences sociales sont plus complexes que les sciences naturelles. Mais c'est très important qu'on puisse appuyer les sciences sociales pour pouvoir en effet rendre même plus efficaces les sciences de base, puisque c'est quand même un individu qui travaille dans toute science, toute activité scientifique. Il faut que l'homme puisse comprendre comment, par exemple, la culture a été élargie avec son effort scientifique. Comme vous le savez, les paradigmes dominant en sciences sont souvent tributaires du paradigme politique et culturel de la période où ces théories scientifiques se sont développées.

Donc, il y a toujours une interconnection entre les sciences sociales et les sciences de base. Alors, mon point de vue était uniquement qu'il faudrait pousser les sciences sociales, parce qu'elles accusent un retard qui devient absolument préoccupant par rapport aux sciences de base. Mais ce n'est pas du tout pour vous dire qu'on a les mêmes critères de vérité, bien entendu.

THIRRING

I wanted to make a remark on the second point which Professor Malu made, namely about the high costs of science, too high for developing coun-

tries. Now it is true that some fields of modern science are far too expensive for developing countries, such as high energy physics or space research, but I don't think that's all of modern science. In fact, I think we have a somewhat distorted view of modern science because the ones which cost most are the most glorious ones. By a kind of natural selection, they have the most money to make propaganda, and of course to justify the work, there has to be a lot of noise about it. But that is certainly not all of science and there is some science research which doesn't cost so much money and which certainly could be done anywhere provided you have the correct environment. As Sir John said before, I think just to have new ideas is perhaps the best thing. This you cannot stimulate by money, just by the atmosphere which you have.

ABRAGAM

I don't want to pursue this debate too much but I think that the argument that the money which goes to pure science is taken from developing countries is untenable. I mean we know very well the conflict is not between money being spent on developing countries and being spent on pure science. The conflict is between money being spent on pure science (and here I will not speak about money spent on defence, although that's a very big piece) and money being spent on nonsense. You have only to turn on your TV set and you will see what countries, Western countries, spend their money on, all kinds of ridiculous and harmful things.

MÖSSBAUER

I would like to emphasize one point which Professor Weisskopf already made. He made the suggestion, which is a very good one, to unite the various academies all over the world to support the case of basic science. But I would like to stress that there is a lot of animosity developing against basic science in all areas now. Basic science is getting to be blamed for many of the faults which we have in our society these days. It's very easy to have a guinea pig to be blamed, but basic science is really getting a concentration of the blame, and two of the reasons for this are the ever-increasing means of communication in the world and the monopoly which the media get in controlling public opinion. Much of the animosity against basic science is being artificially created by the media. If one wants to do something about this, one has to do something about the media. Partially, this comes about because, in my view, the media lack trained scientists who can really represent scientists in a fair way. There

are many people employed these days in the media who are not really well trained and it's always very easy to attack in an unqualified way—much easier than to do a qualified presentation. So I think one should not overlook the very great power which the media have and one should do something in order to straighten out the media situation.

RICH

I would like to reinforce the preceding speaker. A study was done in the United States of movies, including television movies, concerning the role that the scientists play in these movies. It turns out that the vast majority of them have scientists portrayed as either mad or Frankenstein or basically evil people. We are educating a whole generation of people with this as a kind of stock attitude, so this contributes very much to the anti-science attitude in society, and the problem of course spills over into the media as well. There is very little countervailing pressure; that is, very little is being done to educate young people in the opposite direction.

ECCLES

I want to come in on that same theme. Why do the media win? They win because they are presenting stuff to a public that is ignorant of almost everything, wanting to be entertained, so science fiction is the best-selling thing, not science; and science fiction is, I think, very dangerous to science because it gives a distorted view of what we are trying to do as scientists. It's magic, not science, that they get on the TV. So if we are going to really begin to get somewhere, we have to have a more educated public. That is, we have to start with the young. Our whole educational system needs overhauling in order to get the young now coming up, in order to cope with the problems of the age they'll be in. For example, we had this big event where a lot of Nobel prize winners got together in Paris with the President of France. Not one of the presentations concerned education and the future. We were going into the 21st century, that was what the programme was, but no one thought of who was going to live in the 21st century. We dealt with all the subsidiary things, energy, power, AIDS, you name it, but not the people. So we are overlooking the problems that are most urgent such as enlightened education of the young. They should know much more about science, much more about their bodies, so they wouldn't be a prey to all of this irrationality which is pervading everything.

PULLMAN

Je ne voudrais pas donner aujourd'hui la conférence que j'ai l'intention de donner demain, mais je voudrais seulement dire que, dans la conclusion de ma propre conférence, je vais plus loin, nettement plus loin, que Monsieur Weisskopf dans l'extension de nos activités, surtout à l'aurore du XXIeme siecle.

En effet, je ne crois pas que ça ait réellement enormément de sens — ça en a, mais peut-être pas trop — de faire une réunion sur la responsabilité de la science uniquement entre les scientifiques. Même si c'est uniquement notre Académie, ou une asemblée d'académies. Ainsi, par exemple, Monsieur Weisskopf nous a donné un plaidoyer pour la recherche, pour la science fondamentale, qui était certainement un des plaidoyers les plus brillants que j'aie jamais entendus, mais tout le monde ici a remarqué immédiatement qu'il prêchait devant des convaincus.

Evidemment, il est très agréable d'entendre développer un plaidoyer aussi brillant devant nous, mais la portée en est faible. Et ce que j'essaierai de défendre demain, c'est que nous devrions, en fait, étendre notre activité de façon a impliquer dans nos discussions — surtout les discussions sur des thèmes tels que la responsabilité de la science — d'autres catégories de citoyens, de représentants de l'économie, du gouvernement, même de l'armée, et faire des réunions communes (sélectives, mais communes), avec des représentants très haut placés des institutions et essayer de les persuader, de leur expliquer ce qu'est la science, ce qu'elle peut faire, quelle est la relation entre la science fondamentale, la science appliquée, etc.

Aussi longtemps que nous en parlerons entre nous, nous serons plus ou moins d'accord, et la portée sera très limitée, parce que, même si nous écrivons un document, il n'aura pas la même influence que si nous avions ici, disons, un général très important, très influent aux Etats-Unis, qui rentrerait chez lui en disant: "Oui, ils m'ont persuadé, c'est très important que nous aidions à developper la science fondamentale".

GERMAIN

Il y a beaucoup de niveaux auxquels des hommes de science donnent des conseils au gouvernement. D'abord, les Agences gouvernementales. Il arrive souvent, qu'à la tête d'une Agence, soit appelé un scientifique; ce dernier agit en tenant compte, naturellement, des intérêts de l'Agence. Deuxièmement, un ministre peut appeler une personnalité ou une commission pour le conseiller; les avis donnés le sont dans un cadre donné; dans des perspectives imposées. Il y a encore le cas de nos Académies nationales. Leurs avis sont formulés en

toute indépendance et avec le souci du long terme; et souvent à leur propre initiative et non à la suite d'une question posée per le gouvernement. Est-il souhaitable ou non d'avoir un scientifique comme ministre, ce n'est pas évident. Mais l'expérience que nous avons actuellement en France montre qu'il n'y a pas lieu d'y être systématiquement opposé.

Le professeur Weisskopf a souligné le trouble créé dans la population lorsque des scientifiques émettent des idées différentes. C'est pourquoi les Académies peuvent jouer un grand rôle. L'expérience de la nôtre est assez remarquable. Sur des questions délicates, donnant lieu au départ à des opinions opposées, nous avons toujours, après bien des discussions, réussi à obtenir, sur un rapport transmis au gouvernement, une approbation à soixante-quinze ou quatre-vingt pour cent. A ce moment-là, l'avis donné a une valeur certaine.

Il y a donc bien des manières pour les scientifiques d'intervenir et je crois que c'est une bonne chose. On ne peut imposer à un scientifique qui est ministre de se comporter comme un scientifique qui est Président de l'Académie des Sciences. Chacun doit faire son travail du lieu où il se trouve. Au total les scientifiques peuvent avoir un très grand poids.

CHAGAS

In discussing the need for the sciences here, I would say that the basic sciences which are not interested in their own application are needed. They are so much needed that I would add that in my country, when a scientist does mathematics or something which it seems will have no application at all, he is called a poet. But the poet is extremely necessary to our society. So pure or basic science is also something which is necessary to society. Then comes the man who does science in a certain applied way. (I must say that I belong to the category of poets. I have never tried to see how I could produce electricity industrially, from the knowledge I had from the electric eel. I was just curious to know how nature worked. But there was one particular American technologist who used to come to my laboratory to see if he could take out a patent on the work done on the electric eel.) Then we have the technologists, and also the industrial sector. But what is quite clear to me, and I think that Victor Weisskopf will agree with me, is that the gap between the developed and the developing countries is due mostly, if not principally, to the gap in basic sciences. Every time I come to Europe, every time I have a meeting here or in another part, I see how difficult it is to cope with this gap because we don't have the necessary development of our basic science institutes. Why? Because it was said here and probably it's true for all former colonies, the col-

onialist spirit still pervades the country, a spirit which wants to have immediate results and cannot invest in something for the future.

This I think is an important fact and every day it is driving the developing countries more into what is certainly the new colonialism, which is not only industrial but is even intellectual. We have to fight it resolutely because our traditions and our cultures are the facts that produce the image of our country, the culture of our country, and we should avoid in every way a world of a single culture which would be a terrible world to live in.

I was just a bit concerned when Victor Weisskopf said, in one phrase, that science is responsible for the destruction of nature. I think it's technology, and not only technology but mostly the industries. I see for instance the ravages in parts of my country which are caused by this terrible need to industrialize and to make money—not for the comfort of the people of the country, but to enrich those who are already rich, and this is a very difficult question.

Recently I was in a meeting where there were some very interesting new biological tools to be used in research, and this goes also in part for DNA recombination. All of them were patented and are very expensive. They cannot be used in developing countries, and if a general agreement is not established so that those patents can be used at least at a minimum for research in developing countries, it will be very hard for us to follow, even at a certain distance, the progress which is being made and which is being accompanied, I would say, by the heroic "poets" of science which we have in developing countries.

WEISSKOPF

I would just like to add that I am of course in complete agreement with you, and I think perhaps I may not have expressed myself clearly enough. Of course it is the applications of science that are detrimental and not basic science itself.

LA SCIENCE EST-ELLE TOTALITAIRE?

PAUL GERMAIN
Académie des Sciences, Paris

Il convient tout d'abord de commenter le titre de cette communication. On aurait pu l'intituler «quelques aspects de la responsabilité scientifique». En fait, les réflexions qui suivent portent plus précisément sur «la Science et les Cultures». Mais choisir cette dernière formulation serait prétentieux. Je n'ai ni le temps, ni surtout les connaissances nécessaires pour traiter un sujet aussi vaste. C'est pourquoi le titre choisi est une question qui restera ouverte; une question à laquelle seule, je pense, l'histoire du prochain siècle apportera un commencement de résponse.

Balisons dès maintenant les principales étapes de l'analyse qui va être présentée pour que le lectur ou l'auditeur s'y retrouve plus aisément. Le point de départ, c'est la constatation indiscutable de l'universalité des connaissances scientifiques. Les cultures, elles, sont diverses; la pluralité des cultures avec leurs différences représente, aux yeux de beaucoup de nos contemporains, une richesse d'humanité précieuse pour faire face aux incertitudes de l'aventure humaine. L'expérience historique montre que des interactions du développement scientifique avec une culture sont non seulement nécessaires et inévitables, mais encore souhaitables. Comment vont jouer ces interactions? Ce qui se présente au titre de l'universel n'est-il pas porté à exercer une certaine violence sur ce qui met en valeur la particularité? La Science qui a commencé à affronter les cultures va-t-elle nécessairement les uniformiser? Ou, au contraire, les cultures peuvent-elles s'ouvrir au dynamisme scientifique, se laisser pénétrer par lui, s'en trouver certes modifiées et muries, sans pour autant perdre leur spécificité et leur personnalité? A quelles conditions la diversité des cultures peut-elle être préservée et quelles pourraient être, pour y parvenir, les responsabilités nouvelles des hommes de science? Telles sont les questions que nous tenterons de poser et sur lesquelles nous chercherons à ouvrir quelques pistes de réflexion.

1. L'universalité des connaissances scientifiques

Nul ne peut mettre en doute le caractère universel des connaissances élaborées par les disciplines scientifiques. Les résultats et les relations que ces dernières établissent, les énoncés qu'elles formulent ont une validité reconnue par tous ceux capables de les comprendre et de contrôler ou de répéter les démarches qui y conduisent. Ces disciplines, en effet, élaborent des modèles construits avec les ressources de la méthode scientifique qui fait appel exclusivement aux résultats des expériences et au développement de raisonnements satisfaisant aux exigences de la causalité et excluant toute considération d'ordre politique, religieux, philosophique ou moral. C'est ce qui fonde l'objectivité des connaissances scientifiques, qui n'est ici qu'un autre mot pour traduire leur universalité. Ce qui fait leur valeur, c'est le caractère opératoire des modèles élaborés par les disciplines scientifiques qui permettent des prédictions vérifiées avec une précision sans cesse croissante expérimentalement, souvent à un point tel qu'on peut pratiquement admettre qu'elles sont objectives en ce sens qu'elles atteignent la réalité de l'objet auquel elles s'appliquent.

Cette méthode scientifique, qui dans son exercice exclut toute motivation et tout argument relevant de considérations mettant en jeu l'homme dans sa spécificité et ses particularités, induit chez les hommes de science une dimension très spéciale de l'universel, qui marque leurs relations remarquablement ouvertes et chaleureuses et les conduit tout naturellement à former des communautés qui s'organisent à l'échelle mondiale, en principe tout au moins, indépendamment des gouvernements ou des systèmes politiques dont ils relèvent. Les Unions scientifiques internationales sont, à cet égard fort remarquables et le Conseil qu'elles forment — l'ICSU — représente en quelque sorte la communauté scientifique mondiale. Non seulement ces structures internationales organisent les travaux des scientifiques à l'échelle mondiale, mais elles constituent aussi un lieu où s'exerce une certaine responsabilité scientifique. On voit apparaître, en effet, au sein même de l'organisation ayant pour objet premier le développement des connaissances scientifiques, des préoccupations qui la font nécessairement sortir du cadre très strict où s'élaborent ces connaissances. C'est ainsi que l'ICSU et ses Unions imposent aux instances nationales adhérentes — les Comités Nationaux — l'obligation de garantir la libre circulation des hommes de science si elles veulent organiser une réunion internationale au nom de l'Union, de l'ICSU ou de l'un de ses Comités. Il est interdit aux Comités Nationaux d'introduire dans leur statut ou dans leur comportement des discriminations, comme celles pouvant porter sur les opinions politiques, les appartenenaces raciales ou religieuses, le sexe.

De plus, l'ICSU, ses Unions, ses Comités horizontaux, mettent en oeuvre de grands programmes globaux auxquels sont appelés à travailler les savants

du monde entier, consacrés au développement de connaissances certes, mais aussi, et de plus en plus souvent, aux données et aux évolutions ayant une incidence directe sur les conditions d'existence de l'humanité d'aujourd'hui et surtout de demain. Il s'agit, par exemple, avec le Programme International Géosphère-Biosphère (IGBP), d'observer les changements globaux des climats, de l'atmosphère, des radiations, d'analyser les facteurs décisifs d'évolution, de prévoir les évolutions futures. L'ICSU entend aussi participer activement aux travaux de la Décennie internationale pour la réduction des catastrophes naturelles décidée à l'initiative des Nations Unies. Le Comité SCOPE vient de clore une étude sur les conséquences sur l'environnement d'une guerre nucléaire. Il s'agit bien, avec ces exemples,[1] de l'exercice d'une responsabilité scientifique à l'échelle mondiale. Il faut encore noter l'attention très particulière portée aux problèmes du Tiers-Monde et très spécialement aux problèmes de formation et d'éducation. L'ICSU cherche à mobiliser les scientifiques du monde entier pour assurer, souvent sous l'égide de l'UNESCO, les actions de solidarité envers les régions du globe les moins favorisées.

Ainsi, au niveau même de l'organisation internationale des disciplines scientifiques, la responsabilité scientifique apparaît comme un fait irrécusable. Le concept est relativement neuf. Il y a un siècle, la Science n'avait d'autre responsabilité que d'assurer son développement; celui-ci entraînerait par lui-même le progrès de l'homme et de l'humanité. Aujourd'hui, l'affaire apparaît moins évidente. Le développement scientifique et le développement technique posent de multiples problèmes; les hommes de science ne peuvent s'en désintéresser et doivent apporter leur concours aux solutions de ces questions et de ces situations nouvelles que, directement ou indirectment, ils ont contribué à faire émerger.

2. La Science et les cultures

Les interactions du développement scientifique avec les cultures sont donc bien réelles. Les hommes de science sont les premiers à réclamer que les sciences soient considérées comme faisant partie intégrante de toute culture. De fait, en pratique, dès que se pose à la Société une question nouvelle, c'est au sein de chaque culture, marquée par une tradition nationale, que s'instaure la réflexion qui prépare les décisions pour y faire face. Le Comité National d'Ethique, en France, ainsi que des institutions analogues dans d'autres pays, en constituent des exemples remarquables. Souvent même, c'est à une échelle plus petite — celle d'un grand hôpital par exemple — qu'apparaissent ces cellules de réflexion. Quand une décision immédiate est requise qui touche directement

l'homme, est-il possible d'y répondre sans tenir compte en tout premier lieu de l'environnement social et culturel dans lequel elle doit s'appliquer? Ce qui doit être souligné, c'est le rôle primordial que jouent dans ces Comités les scientifiques et les experts — ici les médecins — directement associés aux scientifiques, tant par le nombre que par l'influence incomparable que leur donne leur compétence. Dans les cas qui viennent d'être évoqués, la responsabilité s'exerce manifestement à l'intériur de chaque culture.

La question posée dans cette communication se situe au niveau intermédiaire, entre l'universel et le quasi-intemporel du domaine des disciplines d'une part, et le local et l'immédiat de leurs applications d'autre part, celui des cultures elles-mêmes. Laissons pour le moment le cas de la culture occidentale, avec ses racines gréco-latines et judéo-chrétiennes au sein de laquelle la science moderne a émergé il y a quelques siècles. J'avoue ignorer quelles ont été, au Japon, les influences de l'ouverture sur les sciences et les techniques en œuvre depuis plus d'un siècle. Qu'en sera-t-il demain pour les cultures de la Chine et des pays du Sud-est asiatique qui manifestent tant d'ardeur et tant de talents pour assimiler les connaissances scientifiques et qui, sans aucun doute, seront très bientôt au premier rang de la recherche mondiale? Comment en seront affectées les sagesses ancestrales bouddhique et confucéenne? Que va-t-il advenir de la mystique hindoue lorsqu'une forte majorité des habitants de la République de l'Inde aura reçu une éducation intégrant les disciplines scientifiques? Les pays qui se situent dans la mouvance de l'Islam, en dépit du rôle historique indéniable joué par certains d'entre eux dans la naissance de la science moderne, peuvent aussi être l'objet d'interrogations légitimes. La vague intégriste d'aujourd'hui n'est-elle pas une réaction fondamentale à l'encontre de la civilisation scientifique et technique qui, indiscutablement, véhicule un certain matérialisme jugé incompatible avec les valeurs culturelles et religieuses qui sont les racines même de l'identité des peuples marqués par l'Islam? Les tentatives d'Ataturk en Turquie, du Shah en Iran pour faire rapidement accéder leur pays aux sciences et aux techniques modernes semblent bien avoir fait l'objet de rejets, au moins pour l'instant. En Amérique du Sud, malgré la forte pression culturelle exercée longtemps par les colonisateurs, dans la mouvance des théologies dites de la libération qui représentent indéniablement une prise de conscience culturelle typiquement latino-américaine, se formulent des réserves très fortes, non certes sur l'intérêt et la valeur des connaissances scientifiques, mais sur les conceptions en honneur en Occident et qui semblement véhiculées avec elles, la philosophie des Lumières et le progressisme par exemple. Quant aux cultures africaines, fondées essentiellement jusq'à une date récente sur des traditions purement orales, il semble prématuré d'envisager comment elles réagiront demain.

L'intérêt des questions ainsi soulevées n'est pas de chercher à y apporter une réponse, tâche évidemment impossible, mais de délimiter, autant que faire se peut, les frontières des possibles et de voir comment les conceptions que nous avons de la Science et du rôle — éminent de tout évidence — qu'elle a joué, joue et jouera dans l'aventure humaine ne sont pas sans influence sur la réponse que les siècles à venir donneront à ces questions. La Science, soulignons-le, c'est autre chose et plus que l'ensemble des connaissances scientifiques; c'est précisément l'ensemble des disciplines scientifiques et tout le sillage culturel créé par leur évolution.

Une première frontière du domaine des possibles à venir évoqué plus haut est celle de l'émergence d'une culture essentiellement universelle atteinte, asymptotiquement, par une uniformisation des cultures sous l'influence décisive de la Science. Cette option a pour elle des arguments très forts; elle avait la faveur de la majorité des hommes de science au début de ce siécle et elle l'a peut-être toujours encore aujord'hui. La pratique des sciences et les modèles qu'elles élaborent peuvent s'exprimer dans le cadre d'une certaine philosophie pragmatique, la philosophie naturelle d'autrefois ou plutôt son héritière aujourd'hui. Penser qu'avec l'extension des domaines où s'appliquent les sciences, cette philosophie tendra demain à être la philosophie sous-jacente de l'humanité entière constitue une généralisation bien tentante. Toutefois, il faut bien voir, à la lumière de l'expérience des sociétés occidentales qui n'ont jusq'ici opposé qu'une faible résistance à cette tentation, comment ont joué les influences de la Science.[2] Deux traits parmi d'autres peuvent être évoqués, et qui montrent l'effet corrosif, pour ne pas dire destructeur, qu'elles peuvent avoir sur les fondements d'une culture: la dévaluation de tout ce qui relève de la subjectivité inhérente à l'identification du réel avec sa représentation, objet exclusif de l'étude scientifique; la rupture avec la tradition, conséquence de la remise en question permanente qui est le cœur même de la démarche scientifique. Et de fait, l'on a vu se dissoudre successivement dans les consciences occidentales les conceptions chrétiennes, le déisme des Lumières, la pertinence des grands concepts comme la Raison et la Conscience, ou comme la lutte des classes et le sens de l'Histoire qui animaient en grande majorité nos ancêtres, il n'y a pas si longtemps, et qui fondaient leur identité. Dans notre modernité en effet, aujourd'hui est un jour neuf où les individualités livrées à leur libre arbitre ont la possibilité d'inventer le sens de leur action, sans référence au passé, à une norme ou à une fidélité! Si, dans l'avenir, sous l'influence de la Science, une uniformisation des cultures devait se produire dans le sens de notre modernité, alors c'est que la Science se révèlerait comme vraiment totalitaire et à double sens: en prétendant régir la totalité de l'expérience humaine, et en s'apprêtant à s'attaquer aux cultures existantes pour réduire leur diversité en exerçant sur elle sa violence.

Mais ce n'est là, répétons, qu'une des frontières des possibles, l'autre étant atteinte si l'on décide de s'en tenir strictement aux conditions de l'exercice des disciplines: elles n'ont rien à attendre des conceptions religieuses, philosophiques, politiques, morales; elles n'ont donc, en théorie, aucun droit à intervenir dans ces domaines, pourvu que soient préservées les conditions permettant leur pratique et leur développement. Dans cette hypothèse, aussi limitée que la précédente reconnaissons-le, la Science apporterait aux hommes et aux sociétés qu'ils constituent des pouvoirs leur offrant, sans contrepartie, de possibilités sans cesse grandissantes d'exercer leur liberté.[3]

3. De nouveaux champs d'exercice de la responsabilité scientifique

Les deux frontières très sommairement décrites à l'intérieur desquelles a toutes les chances de s'inscrire l'évolution à venir des interactions de la Science avec les cultures n'ont été évoquées ici que pour souligner une évidence trop souvent, à mes yeux, oubliée: l'avenir de la Science au sein de l'aventure humaine dépend en premier lieu des hommes de science, c'est l'idée de la science qu'ils vivent, incarnent dans leur existence et transmettent à leurs contemporains qui en est sans doute le facteur primordial. C'est là, à mes yeux, leur responsabilité majeure. C'est autre chose que l'action indispensable, rappelée plus haut, pour pallier les conséquences écologiques ou sociales des innovations techniques: la responsabilité scientifique ne peut se réduire à celle d'un pompier qui ne serait pas totalement innocent de l'incendie qu'il combat. Pour éviter les réactions de rejet dangereuses que pourrait provoquer une conception ou un exercice pas trop totalitaires de la science, et faire advenir une pratique de la science au service des hommes, les scientifiques doivent faire preuve d'une certaine vigilance. Nous mentionnons ici trois occasions où cette dernière peut s'exercer.

En premier lieu, face à l'idéologie d'un développement technologique sans frein. L'enthousiasme que soulève la perspective des pouvoirs et des capacités que peuvent offrir les innovations techniques s'exprime chez certains dans un contexte d'innocence qui ne doit pas cacher la violence que ces innovations, développées pour manifester une volonté de puissance, ne peuvent manquer d'exercer sur les sociétés. Certains chercheurs et enseignants universitaires ne parlent plus de sciences, mais de techno-sciences et étudient comment adapter les comportements des acteurs sociaux pour augmenter les capacités innovatrices, la production de nouveaux objets et leur consommation, objectifs premiers de tous leurs soins. Sans insister ici sur les éventuels dégâts sociaux et humains d'une telle passion de puissance technique,[4] comment ne pas voir que la Science

s'en trouverait défigurée, son idéal méconnu et son image faussée. Ne pourrait-on craindre que la Science ne soit bientôt plus que l'idéologie qui soutiendra la recherche-développement?

En second lieu, face aux Pouvoirs, tous les pouvoirs. A cet égard, la conception qui réduit la responsabilité scientifique à un simple devoir d'information et qui laisse alors au couple opinion publique-décideurs la totale resonsabilité des orientations retenues a certes l'avantage de donner à peu de frais bonne conscience aux hommes de science, mais me paraît tout à fait insuffisante aujourd'hui. Le poids des facteurs scientifiques et techniques est tel que l'avis des experts consultés est souvent déterminant et cet avis intègre inévitablement dans sa formulation des aspects éthiques ou sociaux qui dépassent le cadre strict de la compétence scientifique. Il est donc, me semble-t-il, de la responsabilité des scientifiques qui sont consultés de prendre en compte dans la formulation de leurs recommandations le contexte culturel et social dans lequel elles peuvent être appelées à s'appliquer.

Un dernier domaine où doit s'exercer la vigilance des hommes de science est celui de l'éducation et de l'information. Il est bon, il est indispensable que les scientifiques fassent connaître les acquis des disciplines scientifiques, les méthodes qu'elles utilisent, la nature de leur travail de recherche. Il est normal qu'ils essaient da faire partager leur enthousiasme. Mais il me paraît encore plus important de ne pas donner des idées fausses ou, tout au moins, qui risquent d'être comprises de travers. Il me paraît capital de bien faire comprendre que la démarche scientifique construit des modèles opératoires portant sur des représentations, par nature même provisoires, qui ne peuvent prétendre — et qui de fait ne prétendent pas — épuiser la totalité du réel et qui ignorent en particulier tout ce qui relève de la subjectivité. L'homme de science devrait, dans l'exercice de cette fonction si importante — car elle détermine chez ceux auxquels il s'adresse l'image de la science — observer une rigueur extrême et bien préciser le lieu dont il parle: comme expert des connaissances scientifiques ou comme homme qui fait connaître ses opinions et sa vision personnelle des choses. Le cléricalisme est la grande tentation des hommes de science et très souvent il joue en faveur d'une conception totalitaire de la Science.

L'option totalitaire ne peut être évitée, répétons le, que par l'exercice d'une certaine vigilance, à laquelle, certes, les sociétés entières sont conviées; mais ces dernières ne pourront y parvenir raisonnablement si elles ne sont pas éclairées et entraînées par les hommes de science prenant en compte leurs convictions et leurs aspirations. A défaut de cette vigilance, l'évolution naturelle semble bien conduire à la technocratie par idolâtrie de la technique et à la sociobiologie par négation des dimensions de la subjectivité: technocratie et sociobiologie sont sans doute les voies principales qu'emprunterait un éventuel impérialisme de la Science.

Une telle vigilance requiert d'abord un effort de réflexion: il faut «penser» la technique,[5] «penser» la science dans le contexte humain où elles doivent être vécues. Il faudra aussi aller plus loin: «maîtriser» la technique non seulement par souci écologique et pour éviter des catastrophes, mais encore par respect des hommes et sans doute également «maîtriser» la science.[6] Les scientifiques, certes, répugnent à envisager une telle éventualité. Mais au nom de quoi les droits de la Science primeraient-ils les droits de l'Homme?

Conclusion

L'aventure scientifique représente une étape significative de l'aventure humaine. Les cultures sont les formes diversifiées de cette aventure; ce sont elles qui donnent aux hommes les fondements de leur identité et leur cadre de référence durant les quelques décennies de leur existence. Comment vont jouer les interactions de la Science marchant d'un pas accéléré avec les cultures; dans le sens d'une destruction ou dans le sens d'une inculturation?[7] Car, bien sûr, il apparaît à la fois nécessaire et souhaitable de faire pénétrer l'esprit de recherche de la Science dans chaque culture qui doit s'en trouver fécondée par lui.

La communauté scientifique, si elle veut s'engager dans cette voie, doit inventer les modalités de son action. Les Académies me paraissent des institutions particulièrement bien placées pour s'y essayer. Les Académies nationales; mais également des Académies ayant une emprise géographique plus large que celle d'une nation. L'Académie du Tiers-Monde, par exemple, pourrait peut-être à cet égard jouer un rôle de tout premier plan. De plus, des rencontres interacadémiques telles que celles organisées par l'Académie Pontificale des Sciences en 1982 ou par l'Académie Nationale dei Lincei en juin dernier permettent, dans un climat de respect mutuel, de débattre de questions majeures pour notre avenir. On se demande parfois, à l'heure où les états ou les groupes d'états se dotent d'organisations puissantes pour développer leur politique scientifique et technique, si les Académies des Sciences auront encore demain quelque utilité. Des réflexions aussi sommaries que celles qui ont été présentées ici sur Science et Cultures soulignent à mes yeux, une fois de plus, la pertinence du jugement de notre ancien Président de l'Académie des Sciences de l'Institut de France, Pierre Jacquinot, qui voyait dans l'Académie, l'un des lieux privilégiés de la conscience du monde scientifique, et pourquoi pas, de la conscience scientifique du monde.

(1) On peut suivre le développement de ces actions dans «Science International», Newsletter of International Council of Scientific Unions.

(2) P. GERMAIN. Dimensions nouvelles de la responsabilité scientifique. Colloque Académie des Sciences—Académie des Sciences Morales et Politiques. Publication de l'Institut, Mai 1984.
(3) P. GERMAIN. La signification culturelle du développement des sciences et ses implications dans les sociétés contemporaines. Comptes rendus Ac. Sc. — Vie Académique — tome 293, p. 129-151, 1981.
(4) Les réactions à cette civilisation scientifico-technique peuvent être très brutales. A titre d'exemple: Michel HENRY. La Barbarie. GRASSET 1987.
(5) Philippe ROQUEPLO: Penser la Technique. SEUIL 1984.
(6) «Maîtriser la Science». Manifeste d'un certain nombre d'hommes de science paru dans le journal «Le Monde» du 19 mars 1988.
(7) Sur les mots inculturation, acculturation, voir par exemple le texte adressé par Jean-Paul II à la Commission biblique romaine. Documentation catholique n° 1764, pp. 450-456, 1979, où la question des rapports entre le message de la foi catholique, fondamentalement universel, avec la diversité des cultures est l'objet d'une analyse pénétrante.

DISCUSSION

MALU

Monsieur le Président, j'ai été très heureux du discours du professeur Germain, parce que je suis entièrement d'accord sur l'importance du contexte social et culturel. Je peux même citer une phrase où vous évoquez, me semble-t-il, la responsabilité des scientifiques de tenir compte du contexte culturel et social dans les recommandations qu'ils peuvent être appelés à formuler. Voilà l'importance de l'aspect social des sciences sociales que je faisais ressortir il y a un instant.

Où prendre un exemple? J'ai terminé, monsieur le Président, un livre sur l'histoire des activités scientifiques et technologiques en Afrique depuis 1935. Quand on étudie les statistiques de ces développements, on voit l'importance de la culture en positif comme en négatif. Ainsi, quand un malade se présente chez un médecin occidental, se plaignant de diarrhées, on va lui prescrire un anti-diarrhéique, peut-être en faisant des examens microbiologiques. Pour un médecin traditionnel africain, il y aura aussi un diarrhéique, mais il posera des questions sur la famille, le comportement, et même éventuellement sur les croyances du malade. En d'autres mots, l'approche africaine est plus syncrétique que l'approche occidentale. A mon avis, une approche plus totalisante, je ne dis pas totalitaire mais totalisante. Il faut tenir compte de la mentalité africaine, non seulement d'ailleurs pour les perspectives de développement, mais aussi pour promouvoir les sciences de base. Comme je le ferai ressortir dans

mon papier, il est absolument indispensable que les sciences de base, les sciences naturelles et sciences sociales, puissent coopérer plus étroitement qu'elles ne le font actuellement.

ABRAGAM

Je voudrais dire que nous venons d'assister à un exemple d'un certain totalitarisme qui vient d'être vaincu ici. Nous avons entendu le discours de Monsieur Paul Germain, un discours exprimant de belles idées dans une belle langue et de sa belle voix. Je ne veux pas discuter sur le fond. Il y a des choses avec lesquelles je suis entièrement d'accord, il y en a d'autres sur lesquelles je ferais des réserves — j'aurais besoin d'y réfléchir avant de faire un commentaire sensé. Mais il faut bien dire qu'il existe parmi nous le totalitarisme de la langue anglaise qui exerce sur nous tous sa tyrannie, et à tel point que ce n'est même pas une belle langue anglaise que nous parlons tous, ou presque tous. Nous sommes forcés de parler une espèce de charabia; et c'est certainement là un aspect de ce totalitarisme linguistique dont nos cultures sont atteintes.

THIRRING

Sometimes scientists make statements which not only concern their own field of work (where they can certainly give an authoritative answer), but which may touch on other questions where their knowledge is more limited. Great scientists, in particular, are opinionated people. In fact, you have to have a strong conviction to make a great discovery. However, they may also express strong views which can be totally wrong because they are in fields where they are not really so knowledgeable. Now if they would make a clear distinction between when they are speaking *ex cathedra* and when they are giving their private opinion, this would be perfectly legitimate. Unfortunately, they don't always distinguish, or if they do, in the media this is never mentioned. There we only hear that this scientist says such and such, and another says quite the contrary, and in this way the value of what scientists say has become discredited in public opinion.

ANNOUNCEMENT BY PROFESSOR CHAGAS OF THE BEATIFICATION OF THE DANISH SCIENTIST, NIELS STENSEN

An event happened here in the Vatican last Sunday which I think is of great interest to the Academy. On that day the Pope beatified in a solemn way at a mass at St. Peter's the Danish scientist and later priest, Niels Stensen, who lived from 1638 to 1686. Stensen was a very good anatomist, and all of those who have studied the parotid gland know about the stenonianus ducts. In the domain of anatomy he did a lot of interesting work. For instance, it was he who was really the first one to prove that the heart was only a muscle, and not the seat of the soul. During his stay in Paris, he gave a famous lecture on the anatomy of the brain. In one of his speeches he made a wonderful statement: "Beautiful are the things that we see, more beautiful still are the things that we are able to know, but still more beautiful are the things that we will never know", which I think is an interesting thought for a scientist.

In the fields of philosophy and anatomy he had some disagreements with Descartes, but this shows that even in the 17th century scientists could differ with one another, and sometimes in very strong terms. After going to Florence, Stensen became a Roman Catholic, and then a priest. He went to Germany, where he did wonderful pastoral work which exhausted him, and he died very early, only about fifty years old.

This is the first time a scientist has been beatified. I was present at the beatification, which was a very beautiful ceremony. During December, a plaque will be put here at the Academy, offered by a Danish memorial committee which includes the University of Copenhagen.

Note: Blessed Niels STENSEN (STENO/STENONE/STENONIUS/STENONIS) 1638-1686, who began his scientific studies in his native Denmark, went as a young man to Holland and to France, where he made significant contributions to anatomy and physiology. Later, while living in Florence, his research was germinal for the development of both geology and crystallography. After Stensen's conversion to Catholicism in 1667, he was ordained a priest, and soon thereafter consecrated a

bishop in Rome. After ten years of selfless pastoral and missionary work in northern Germany, he died in Schwerin. His remains were interred in the Basilica of San Lorenzo in Florence at the behest of Grand Duke Cosimo III. The beatification of Niels Stensen took place in St. Peter's Basilica on 23 October 1988. On 10 December 1988 a memorial plaque to Niels Stensen was presented to the Academy by the University of Copenhagen and Nordisk Insulinlaboratorium. After the ceremony of unveiling, the plaque was blessed by Monsignor Edward Cassidy, who represented the Holy Father. The Academy has published a booklet briefly describing the life of Niels Stensen and the presentation of the plaque: "BLESSED NIELS STENSEN AND HIS MEMORIAL PLAQUE IN THE PONTIFICAL ACADEMY OF SCIENCES" (Vatican City, 1989).

THE RESPONSIBILITY OF SCIENCE

DAY TWO
28 OCTOBER 1988

EXISTE-T-IL UNE MORALE NATURELLE?

JÉRÔME LEJEUNE
Institut de Progenèse, Université René Descartes, Paris

Monsieur le Président, mes chers collègues, j'ai pris quelque liberté avec le titre qui m'était proposé. Parlant plus volontiers Latin que Grec je voudrais vous entretenir de la responsabilité morale des biologistes, plutôt que de l'*éthique* [1] de diverses disciplines.

I - L'ANIMATION DE LA MATIÈRE

Dans sa quête de la vérité, le biologiste bute sur une double évidence qui se présente aux deux extrémités du développement de l'être. Cette double évidence est très simple: *l'esprit anime la matière.* Voyons d'abord la macro et la micro structure du cerveau, depuis le câblage le plus complexe que nous connaissions actuellement sur terre (qui mesure deux cent mille kilomètres de long, si on le calcule en neuro-tubules), jusqu'à cet extraordinaire jeu des synapses qui fait qu'un flux de particules est engouffré par la membrane receptrice lorsqu'une petite vésicule se rompt et émet un médiateur chimique.

Curieusement, notre machine à éliminer le fortuit pour ne retenir que le déductible, c'est le propre de la raison, est un compteur de particules d'une incroyable vélocité. Dans la synapse même, les particules passent une à une dans chacun des canaux: le petit démon de Maxwell est à la racine de l'activité de ce système qui déchiffre et met de l'ordre dans l'univers.

Mais ce qui est le plus étonnant, c'est que la moindre pensée, le moindre mouvement, déclenche ces flux d'ions et cet extraordinaire comptage de particules: l'esprit anime véritablement la matière.

Tout au début, lorsque l'être commence sa carrière, c'est l'information génétique qui, mis à part les accidents, dicte toutes ses qualités. Selon l'heureuse formule des mathématiciens l'être appelé à la vie se trouve comme réduit

à sa plus simple expression.[2] Bien sûr le langage est d'une miniaturisation extrême. Je vous rappellerai une impression: dans la tête d'un spermatozoïde, il y a un mètre linéaire d'ADN, et si l'on rassemblait à Rome toutes les molécules d'ADN qui vont définir toutes et chacune des qualités de tout et chacun des cinq miliards d'hommes qui nous remplaceront sur cette planète, cette quantité de matière représenterait à peu près deux comprimés d'aspirine.

Ce que nous savons, au-delà de tout doute possible, c'est que toute l'information nécessaire et suffisante se trouve présente dès la fécondation, c'est à dire au moment où l'information véhiculée par le spermatozoïde et celle véhiculée par l'ovule, se trouvent réunies dans l'œuf fécondé.

Cette notion que l'esprit anime la matière, est inscrite en quelque sorte dans notre langage même. Nous employons le même mot pour définir une idée qui nous vient à l'esprit ou pour définir un nouvel être qui vient à l'existence: dans les deux cas, on parle de «conception». Ce concept-là n'est pas une pauvreté du vocabulaire, mais reconnaissance, implicite si je puis dire, qu'au tout début l'âme et le corps, l'esprit et la matière, sont tellement intriqués qu'il est impossible de les exprimer l'un sans l'autre; le langage ne l'a jamais fait.

Ceci nous amène à considérer la première responsabilité du biologiste: expliquer à nos contemporains que la biologie moléculaire exclut totalement le dualisme cartésien formel selon lequel il y aurait d'un côté un esprit, et de l'autre un corps. Il n'y a qu'un corps animé, mais animé par une nature d'homme.

Une question immédiate se pose alors: existe-t-il une sorte de mode d'emploi, une sorte de notice d'entretien de cette nature humaine? Existe-t-il une «morale naturelle»? Si je puis me permettre de résumer très respectueusement, mais peut-être un peu abruptement ma pensée, je dirais que le Décalogue représenterait le mode d'emploi et les Commandements de l'Eglise la notice d'entretien de la nature humaine.

Mais il faudrait tout d'abord s'assurer qu'il existe effectivement une nature humaine. Or ceci a été fort débattu; la nature humaine n'est guère à la mode ces temps-ci, et pendant une époque très récente, on a cru démontrer qu'en réalité, la condition humaine n'était qu'une sorte de convention admise par une certaine société, et différente pour une autre, et que rien ne permettait de savoir quelle convention était la bonne.

S'il existe une morale naturelle, il serait sage de s'y conformer, non pas pour diriger la science (car cette morale naturelle est elle-même un objet de la science), mais bien plutôt pour diriger les utilisations de la science et pour décider vers quel but doit tendre la mise en application des techniques à partir de nos connaissances, comment il serait bon de les utiliser. La science est véritablement l'arbre du bien et du mal; elle donne indifféremment des fruits bons

et des fruits mauvais; toute notre responsabilité de scientifiques est d'essayer de cueillir les fruits bons et de ne pas offrir les fruits mauvais à nos contemporains ou à nos descendants.

II - De la nature humaine a la morale naturelle

Certes, il est difficile de définir la nature humaine et, cependant, nous devons essayer de comprendre ce qu'elle est. Pour le généticien que je suis, le premier moyen serait simplement de dire: Eh bien, nous savons avec certitude que cet énorme message génétique, 10^{11} bases dans l'ADN, correspond à une quantité d'information phénoménale: or, nous savons que c'est parce que l'être conçu possède cette information qu'il est humain: autrement dit, la génétique moléculaire la plus objective et la plus moderne pourrait se résumer en une paraphrase malhabile du début de l'Evangile de Saint Jean: *au commencement, il y a un message, ce message est dans la vie, et ce message est la vie; et si ce message est un message humain, cette vie est une vie humaine.* Bien sûr, on pourrait s'atteler à déchiffrer ce message et c'est déjà en cours; mais je ne veux pas empiéter sur ce que nous dira demain notre confrère Rich sur la façon de lire ces extraordinaires Tables de la Loi de la vie, qui se trouvent inscrites dans notre ADN.

Il serait toutefois très insuffisant de ne considérer que l'ADN. Certes, l'ADN est bien comparable à la bande magnétique sur laquelle se trouve inscrite la symphonie de la vie, mais il ne faut pas oublier que le reste de la cellule fécondée est comme le magnétophone qui va déchiffrer le code et exécuter la symphonie. Quand nous parlons de quantité d'information exprimée en bits, il n'y a pas seulement celle qui est inscrite sur le ruban, il y a celle qui est comprise dans toute la machinerie à lire le ruban et à mettre en œuvre ce qu'il veut dire!

Et là, ce n'est plus de quelques 10^{10} a 10^{13} bits qu'il s'agit, mais d'un chiffre absolument énorme et que personne pour l'instant ne peut évaluer avec précision.[3]

La première notion est donc une définition génétique de l'être, mais pour la seconde notion, il nous faut revenir au début de notre propos, à notre cerveau. Il suffit de soulever la calotte crânienne pour découvrir chez l'homme les aires frontales et les zones de Broca, et de Wernicke qui n'existent pas chez les primates. Ces zones sont nécessaires au langage articulé et à la pensée cohérente.

Sans recourir à la neuro-anatomie comparée on peut faire une constatation plus grossière peut-être mais tout aussi convaincante. Voyageant beaucoup,

je visite chaque fois que je le puis deux lieux extrêmement instructifs: l'Université d'une part, le jardin zoologique de l'autre. Dans les Universités, j'ai fréquemment rencontré d'éminents confrères qui hochent doctement la tête en se demandant si, tout compte fait, leurs enfants quand ils sont très jeunes ne seraient pas des sortes d'animaux. Mais dans les jardins zoologiques, je n'ai jamais observé de congrès de chimpanzés se demandant si, tout compte fait, leurs enfants ne deviendraient pas un jour des universitaires!

J'en conclus, à titre personnel, que la nature humaine est évidente à chacun. Sur cette planète l'homme est le seul être à se demander d'où il vient, qui il est et ce qu'il a fait de son frère. Il est aussi le seul à avoir découvert, et ceci depuis toujours, qu'il existe une relation entre la passion de l'amour et la reproduction du semblable. Le chimpanzé le plus malin, le mieux dressé, ne saura jamais et ne pourra jamais savoir qu'il existe une relation entre la copulation et la survenue neuf mois plus tard d'un petit singe qui lui ressemble. L'homme, lui, l'a toujours su et les païens représentaient, avec la plus grande justesse, le dieu de l'amour sous les traits d'un enfant. C'est cette particularité, c'est cette connaissance quasiment génétiquement inscrite dans le cœur de l'homme qui confère a son comportement — et spécialement à son comportement amoureux — une dignité qui n'existe pas dans le restant du règne vivant.

Si l'on accepte alors qu'il puisse exister une morale naturelle, il en découle immédiatement que dissocier l'amour de l'enfant et l'enfant de l'amour est une erreur de méthode. D'où, la prescription tout à fait naturelle de l'abstinence continue dans le célibat chaste et la continence périodique dans le mariage heureux. Si la monogamie correspond bien à la nature humaine et si la morale tend à conserver au mari cette prérogative d'être seul habilité à déposer des cellules reproductrices dans ce temple intérieur qu'est le corps de la femme, alors on en déduit très simplement les notions morales traditionelles: la contraception, qui est faire l'amour sans faire l'enfant, la fécondation extracorporelle, qui est faire l'enfant sans faire l'amour, l'avortement, qui est défaire l'enfant, et la pornographie, qui est défaire l'amour, ne sont pas conformes à la dignité naturelle de l'homme.

Lorsque la technique nous donne emprise sur l'être humain très jeune, sur l'embryon qui peut même se former dans une fiole quasiment alchimique, et même revenir du froid le plus absolu, cette même morale nous apprend qu'aussi jeune qu'il soit, aussi fragile qu'il puisse être, l'embryon humain est un membre de notre espèce et de ce fait, doit être protégé de toute exploitation. Il n'est pas un stock de pièces détachées où l'on puise selon besoins, il n'est pas une denrée périssable qu'on congèle ou décongèle à volonté, il n'est pas un bien de consommation qu'on pourrait vendre ou échanger, il est très exactement notre prochain, notre semblable, notre frère.

III - Pierre d'achoppement ou garde-fou

Il faut maintenent se demander si cette morale inchangée depuis toujours, représente une gène à la recherche; autrement dit, est-ce un tabou regrettable ou au contraire, un guide précieux. Je ne prétends pas fournir une résponse à priori, mais je vous proposerai d'examiner deux exemples.

Le premier, c'est le respect de l'embryon tout jeune, j'entends de l'embryon humain: est-ce un tabou qui gène la recerche? Je ne le crois pas; l'histoire de ces trois dernières années est extrêmement éclairante à ce sujet. Il y a trois ans, nos collègues en Angleterre envisageaient de régler par une loi l'usage expérimental d'embryons humains qui auraient moins de quatorze jours. J'eus l'honneur de témoigner devant le Parlement britannique, pour donner l'opinion d'un généticien. Il était proposé: «Si vous nous donnez le droit d'utiliser des embryons de quatorze jours, nous étudierons différentes maladies et nous obtiendrons des connaissances menant peut-être à la guérison pour la débilité mentale, pour la fibrose kystique du pancréas (mucoviscidose), pour la dystrophie musculaire, pour la trisomie 21, pour l'hémophilie».

Témoignant devant le Parlement britannique, je fus obligé de faire remarquer, de façon tout-à-fait «matter of fact» que sur un embryon de moins de quatorze jours, on ne peut pas étudier un trouble du cerveau qui n'est pas encore formé, ni un trouble de la coagulation du sang, l'hémophilie, parce que les organes qui forment les cellules sanguines ne sont pas encore différenciés, ni une anomalie des muscles qui n'apparaîtront qu'une semaine plus tard. Finalement, ce projet ne permettait nullement d'élaborer un protocole logique permettant d'affirmer: ces expériences sont scientifiquement nécessaires et absolument indispensables à l'étude de ces cinq maladies. Je puis vous confier, et ceci est amusant, que cette intervention extrêmement simple fut très mal accueillie; l'hebdomadaire scientifique Nature titra: «a French influence in Britain»! Quelque chose de tout à fait «shocking». Le journal Nature alla jusqu'à proposer un abonnement gratuit a quiconque fournirait un protocole d'expérience démontrant la fausseté de ce que j'avais dit. Cela fait trois ans. Le journal Nature n'a publié aucun protocole et, à ma connaissance, personne ne reçoit gratuitement cette excellente publication scientifique.

Il n'était vraiment pas nécessaire de manipuler des êtres humains, car, au cours de ces trois ans, le gène de la mucoviscidose a été découvert, le gène de la distrophie musculaire a été cloné, la protéine qu'il fabrique, la dystrophine, est maintenent connue: on a fait de grands progrès dans la compréhension de la trisomie 21 et pour l'hémophilie, on fabrique par génie génétique le facteur anti-hémophilique dans des bactéries artificieusement manipulées, ce qui élimine una voie de transmission possible du SIDA. Et tout ceci sans que la vie d'un seul être humain précoce, ait été mise en jeu.

A ce point permettez-moi de citer simplement une phrase de nos collègues du Max Planck Institute qui écrivent (je cite en anglais, car ils l'ont publié dans Nature): «The abuse of these techniques through experiments with human embryos (and pre-embryos if one considers a pre-implantation embryo not to be an embryo), must be condemned by the scientific community». Cette déclaration date de quelques mois et je crois très reconfortant que les savants d'un pays qui a connu comme loi la doctrine dénaturée des Nazis, restaurent la dignité de la biologie; honnête servante de la médecine, elle est au service du patient et ne le ravale jamais au rang d'animal d'expérience.

Si ce respect de la nature humaine n'est pas un empêchement à la recherche, est-il un garde-fou? Je serais assez fondé à la croire. J'en prendrai un exemple extrêmement récent, puisqu'il se discute ces jours-ci: la pilule abortive RU 486. Il s'agit d'une anti-progestérone, une fausse-clef qui bloque le site sur lequel agit normalement la progestérone, hormone indispensable à la poursuite de la grossesse. En termes techniques, ce produit se nomme Mifepristone; en termes pratiques, c'est le premier pesticide spécialisé anti-humain. On peut considérer, sans erreur de calcul je crois, que si ce produit est effectivement fabriqué industriellement, il tuera chaque année plus d'êtres humains que ne l'ont jamais fait Hitler, Staline, et Mao Tse Toung réunis!

Curieusement, sans que je puisse vous dire pourquoi, ce projet d'holocauste chimique, qui avait été reçu avec une fanfare de propagande dans notre pays, vient d'être retiré du marché par son fabricant sans très bien préciser pourquoi. Je serais très heureux si le fabricant avait soudain compris qu'éliminer des êtres humains extrêmement jeunes par un produit chimique, c'est très exactement le début d'une guerre chimique et que lui, fabricant de médicaments, ne voulait pas s'engager sur cette voie. S'il en était ainsi, cette fonction de garde-fou que je crois pouvoir reconnaître à la morale naturelle, aurait fait ici son effet.

IV - La voie, la vérite et la vie

Mais reste une dernière question et c'est la vérite, la seule question. Notre puissance s'accroît tous les jours, notre ami Rich vous en parlera demain. Nous allons confectionner des êtres nouveaux (bactéries, végétaux, animaux) qui n'ont pas été fabriqués par la sélection naturelle ni par l'évolution. De ce fait nous allons modifier certainement la destinée de l'homme avant de le modifier lui-même peut-être. Je ne sais pas si nous saurons, de notre vivant à nous tous aujourd'hui, modifier le cerveau humain, mais personne ne peut démontrer que ce soit pour toujours impossible. Autrement dit, nous allons devenir de plus en plus puissants: la bombe biologique est probablement plus redoutable

pour l'humanité que la bombe thermo-nucléaire. Alors il nous faudra bien quelque chose qui nous guide, il faudra bien établir ou retrouver un terme de référence, car qui nous dira ceci est bon et ceci est mauvais? Qui nous l'enseignera?

Dans mon métier de médecin et de généticien, ces questions se posent chaque jour.

Bien sûr certains proposeront de modifier les mœurs chaque fois qu'une innovation semblera le requérir. Cette méthode est sans avenir car elle ne peut pas surmonter la difficulté décisive: la technologie est cumulative, la sagesse ne l'est pas.

Alors que nous reste-t-il? Il nous reste la Sagesse même: «Ce que vous avez fait au plus petit d'entre les miens c'est à moi que vous l'avez fait». Si les spécialistes n'oublient pas cette parole, alors la science restera l'honnête servante de la famille humaine, mais s'ils l'oublient, alors on pourrait tout redouter d'une biologie dénaturée.

(1) De nos jours, les «comités d'éthique», paraissent avoir été inventés pour changer la morale!
(2) A remarquer ici que «l'essence» précède «l'existence». En effet, le message codé de l'ADN sera transcrit en ARN, qui sera ensuite remanié. Secondairement les protéines qui sont les machins-outils de la cellule, seront construites conformément au code de l'ARN messager. Au total, étant donné la machine à traduire (le cytoplasme) d'une part et la formule de l'ADN (le noyau et ses chromosomes) de l'autre, on pourrait connaître exactement «l'essence» de l'être nouveau avant même qu'il se soit exprimé, c'est-à-dire avant même que son «existence» soit reconnaissable.
(3) Même si on arrivait un jour à estimer ce chiffre énorme (et il n'y a pas d'impossibilité théorique à cela), il resterait une difficulté majeure que la théorie de l'information n'a nullement résolue. Quand on a mesuré la longueur d'un message, c'est à dire évalué la quantité d'information qu'il contient, on n'a nullement mesuré la «signification». Répéter sans aucune erreur des variantes telles que bla bla bla, ran tan plan, et autres ron et ron petit patapon, peut nécessiter quantité d'information identique à celle d'un sonnet de Pétrarque. La «quantité» d'information de l'ADN du chimpanzé est très comparable à celle de l'ADN de l'homme, et pourtant il est bien sûr que l'ADN de l'homme veut dire quelque chose de plus..., puisque justement l'homme parle.

DISCUSSION

MALU

Monsieur le Président, je dois sincèrement féliciter le professeur Lejeune pour son exposé tout à fait remarquable. Je suis entièrement d'accord avec ce qu'il a dit et c'est vraiment très, très important.

LICHNEROWICZ

Parmi les choses qui ont été dites fort bien et beaucoup mieux, je pose simplement une question: il serait bon pour nous tous, je crois, de regarder

l'histoire du concept de nature. Car, quand Saint Thomas parle de nature, dans les philosophies occidentales dominantes de l'époque, et quand nous utilisons la morale naturelle ou le droit naturel, je ne suis pas sûr que ce soit compris dans le même sens de Saint Thomas. En effet, nous vivons aujourd'hui dans une nature qui en son temps etait cultivée comme un jardin, mais qui maintenant est presque un artefact de l'homme. Je pense donc qu'il serait très bon qu'une équipe étudie le concept de nature.

LEJEUNE

C'est urgent, car s'il n'existe pas de nature humaine, nous n'avons plus aucun guide; il n'y a pas de mode d'emploi, pas de notice d'entretien, on peut faire n'importe quoi. Et nous savons très bien que faire n'importe quoi, est une catastrophe. Mon impression concorde avec la vôtre: il est très grave que nos philosophes, nos psychologues ne tiennent pas compte du fait que les êtres humains sont faits selon un certain modèle qui ne dépend pas de notre bon gré.

ABRAGAM

Je voudrais tout d'abord rendre hommage à la qualité exceptionnelle de l'exposé que nous avons entendu, je ne parle pas de l'art de l'orateur, de la clarté de la présentation des idées, de la conviction qui l'anime. Je ne suis pas convaincu d'un certain nombre de choses que notre confrère Lejeune a dit, mais je ne suis pas biologiste, et je n'irai certainement pas discuter les choses sans doute indiscutables ou en tout cas que d'autres que moi pourront discuter sur l'aspect biologique des problèmes qu'il a évoqués.

Là où je suis un peu plus réticent, et où je rejoins peut-être notre confrère Lichnerowicz, c'est dans la notion de morale naturelle. Cela me paraît une expression trompeuse, pour ne pas dire dangereuse. Je crois qu'il existe des morales des grandes religions révélées, il y a la morale chrétienne, il y a la morale de la religion juive, il y a la morale islamique, qui se rejoignent sur beaucoup de points, et ce que nous a dit Monsieur Léjeune est dans le droit fil de ce qui a guidé l'humanité, ou en tout cas une grande partie de l'humanité, depuis des siècles. Je prendrai deux exemples.

Notre confrère Lejeune dit que les humains ont toujours su que lorsqu'ils commettaient l'acte de chair, c'était pour créer dans l'amour un nouvel être. Eh bien, je crois me rappeler que des peuplades primitives jusqu'il n'y a pas très longtemps, n'avaient pas la notion de père d'un enfant, cela n'existait pas pour eux. C'était quelque chose qui était découplé de la copulation. Ensuite,

si nous remontons un petit peu dans le temps, si nous prenons la société romaine, eh bien dans la société romaine, l'amour, si vous voulez, était quelque chose qui était tout à fait séparé de la nécessité d'avoir des enfants et des héritiers.

On peut toujours dire que c'était une société pervertie, et c'est possible, mais enfin, je crois que l'idée de morale naturelle qui coule de source me paraît une notion tout à fait contestable. Et personnellement, je dirais presque que la morale n'en a pas besoin.

LEJEUNE

La Morale n'en a pas besoin, mais nous, nous avons bien besoin de savoir qu'il existe une morale! Les premiers Tahitiens auxquels vous faites allusion savaient parfaitement qu'un enfant naissait neuf mois plus tard, après la copulation; mais ils n'attachaient pas une grande importance à ce que nous appelons, nous, la paternité biologique. Plusieurs hommes étaient très heureux de prétendre être le père du même enfant! Une sorte d'adoption collective. Les Romains avaient, eux, totalement dissocié le respect de l'être humain, puisqu'ils admettaient l'esclavage, mais ils savaient très bien quand même qu'un esclave était un être humain. De même, ils savaient fort bien que neuf mois après la copulation, apparaît un enfant. Ça, les hommes l'ont toujours su. Le fait que la morale naturelle ne soit pas toujours observée, prouve simplement qu'elle n'est pas contraignante et que l'homme conserve toute sa liberté. La morale naturelle n'est pas un automatisme instinctif; cela ne veut pas dire qu'elle n'existe pas.

THIRRING

There are two things I want to add, and I have to emphasize that it's certainly not as a physicist I speak. I can just give my personal opinion. There are two things I would disagree with, one which was said, and one which was not said — which sounds absurd, but I will tell you what I mean.

What I don't quite agree with is that the only purpose of love is reproduction. Let me give some examples, one is perhaps trivial. We certainly eat to gain enough energy, but that's not the only point. There has developed an art of cooking, which is an art in itself. It has not only the purpose of giving us enough energy, it also provides enjoyment.

Regarding love, I see the situation in the same way. I don't think the only point of love is reproduction. I mean I cannot deduce it logically. I see in nature many things which develop and become an art without serving the original pur-

pose. If we look at the butterflies and see the beautiful colours, then certainly the original purpose was to attract other butterflies, but nevertheless, nature could have done with less, but it didn't. They developed for their own sake, let's put it this way.

Now for the second thing — what you did not say. I certainly agree with you that abortion is not the right way of birth control. On the other hand, I think the question of over-population is such a pressing problem that if you do not do anything, it's not that we will kill the unborn but that we will kill the born, which I think is worse.

What happens is that in an over-populated world, people all concentrate in the big cities, where we drive them to crime and we drive them to drugs, which is perhaps even worse than to be dead. So, although what you say is quite correct: abortion is not the right thing, yet we have to add what is the right thing in order to cope with this pressing problem.

LEJEUNE

J'ai dit qu'il existait un lien de nature entre l'amour et la reproduction et qu'il était imprudent de l'ignorer. Je n'ai pas dit que l'amour n'avait qu'un seul objet, la reproduction. La dilection mutuelle est l'objet majeur de l'amour; il n'y a aucun doute là-dessus.

Maintenant, permettez-moi de répondre que je ne suis nullement coupable de ce que je n'ai pas dit! Je n'ai pas parlé de la surpopulation, car la surpopulation est un mythe, au moins en Europe. L'Europe est en train de diminuer en nombre absolu; la race blanche est en train de se suicider. Prenez l'Italie cette année: le chiffre moyen d'enfants par femme est à 1,27 cette année. Il faut 2,12 ou 2,13 pour maintenir la population! L'Italie cette année en est à 1,27. Ce n'est pas d'explosion démographique qu'il faut parler, mais d'implosion. Quant à la prétendue explosion du Tiers-Monde, je ne vois pas au nom de quel principe certains veulent imposer à d'autres un contrôle qu'ils ne demandent pas. Quel droit ont certains blancs pour dire qu'il y a trop de Chinois ou trop de Ganhéens, trop de Sud-Américains? Dire cela me paraît une grave erreur morale. Pour le géneticien que je suis, chaque homme se compte un par un. Et on ne peut pas dire qu'il y en a un demi-milliard de trop; médicalement cela n'a pas de sens.

GERMAIN

Je suis personnellement assez en accord avec le conférencier sur le respect de l'embryon. Mais comme d'autres, je m'interroge beaucoup sur la validité

du concept de «morale naturelle» qui, effectivement, a prévalu très longtemps et a rendu des services indiscutables; et encore plus sur la nature biologique de la morale. D'abord, parce que la morale ne se réduit pas, heureusement, aux problèmes de l'amour et de la reproduction. Ils sont certes très importants; mais la morale c'est bien autre chose.

Deuxièmement, parce que les trois derniers siècles de l'aventure humaine sont sans précédent. Nature et culture ont développé depuis trois siècles des interférences incomparables, inédites. Alors, où chercher le fondement d'une morale exigeante?

On a pu chercher ce fondement, en particulier au temps des Lumières, dans la raison humaine; après tout, c'est une conception assez proche de celle de morale naturelle. Après les mutations vécues sous l'influence de l'explosion des sciences, une telle conception ne me paraît plus relever de l'évidence immédiate.

Ma réponse personnelle c'est que, au stade de l'évolution où nous nous trouvons, cette morale repose sur une foi, une foi anthropologique, pas nécessairement religieuse; sur une conviction. Maintenant, nous avons acquis des pouvoirs tels que, en quelque sorte, le destin de l'humanité est dans nos mains. Il s'agit de savoir ce que nous voulons faire de l'homme. Que nous soyons attachés à des courants relevant de l'Islam, du Bouddhisme, du Christianisme ou de conceptions laïques, il s'agit de reconnaître la morale comme conviction, de la faire prévaloir et de la transmettre comme conviction. Conviction qui est le fruit de la liberté conquise en grande partie grâce au développement des sciences; conviction qui engage notre responsabilité personnelle et collective.

LEJEUNE

J'avoue que je ne vois pas de contradiction entre ce que j'ai essayé d'exposer et ce que vous venez de dire. Une précision sur un point seulement: je ne pense pas du tout que la morale naturelle découle exclusivement de la raison; elle est inscrite dans le cœur humain aussi. Un exemple tout à fait évident et qui n'était pas enseigné par la morale naturelle habituelle, est fourni par l'écologie. Pourquoi les hommes s'intéressent-ils à l'écologie? Parce qu'en détruisant le milieu, on porte atteinte aux hommes, et c'est finalement une morale naturelle de respect du prochain et même du prochain très éloigné: du descendant à venir. Par exemple, il ne faut pas détruire la forêt amazonienne; ce n'est pas nous qui allons en souffrir, mais nos enfants ou nos arrière-petits-enfants. On voit que la raison nous indique comment faire, nous donne emprise sur le réel; mais pour mesurer la portée réelle de nos actes, c'est au cœur qu'il faut s'adresser.

SZENTÁGOTHAI

Mr. Chairman, I was highly impressed, and I particularly agree with Professor Lejeune's conclusion. However, since he mentioned a few examples, I wish to add some comments. Now, of course I believe that you approve of transplantation, of material taken out from people who are in the final stage because of some accident, taking out the heart or liver or kidney, if this is possible, and where people have to be kept alive on a vegetative level. However, we now have this possibility for the treatment of Parkinsonism. Now I am quite certain that it will not be successful to transplant a mature adrenal medulla, because the cells simply do not have the capacity to grow. They produce dopamine, but they are not able to establish synapsis. However, there are very good biological experiments on rat models, which show that if you take out from young embryos, or the newborn, pieces of the substantia nigra, then that is highly successful. Of course the model has not been done with the real illness, but it's very similar and you can see that a beautiful establishment of synapsis occurs. So in fact, if you would be able to do transplants from newborn human babies who die (fortunately their number is decreasing), or from abortions which have been done on medical indications, you would save lives, at least for the time being. I hope that soon they will develop other methods which are more acceptable, but still we are presented here with a slight predicament.

The other point concerns married couples. If there is atresia, an impasse in the female genital tract, and if you make this so-called test-tube baby, you have to keep the fertilized egg for some time and then replace it in the mother. I don't think that this is separated from love. The love in a couple does, of course, come to a certain peak in the sexual act, but it is a continuous thing.

I certainly strongly disapprove of hiring mothers both on a moral basis and because it would lead to too many problems. But with married couples I think it would be quite acceptable, and I can't see any contradiction to the so-called natural model.

LEJEUNE

You raised three questions. For the transfer of an organ from a person who is already dead — after the cerebral death — no problem.

Quand on propose de prélever des cellules nerveuses chez un fœtus, si le fœtus a subi la mort cérébrale, sa substantia nigra est morte elle aussi. Il s'agit donc très précisément de prélever des cellules vivantes du cerveau vivant d'un fœtus vivant. S'il était mort, la transplantation chez un sujet atteint de Parkinson ne servirait à rien. Premièrement l'on n'a pas le droit d'aller prendre

un morceau du cerveau d'un embryon vivant, d'un fœtus vivant. Deuxièmement, et je donne mon opinion technique, non plus morale, l'idée de transférer de la substantia nigra dans le cerveau, simplement pour faire fabriquer *in situ* de la dopamine, est un mauvais système pharmacologique. Et il suffira de faire un progrès dans la compréhension du mécanisme réel de la maladie de Parkinson pour se dispenser absolument d'une thérapeutique dont l'efficacité est très douteuse. J'ai lu les résultats et je n'ai pas été convaincu.

Maintenant, sur les bébés en bouteille, il est absolument certain qu'un enfant fabriqué dans une bouteille est aussi légitime que les autres, a droit à tout le respect qu'on porte à tous les autres, et il est certain que ce n'est pas apparemment en contradiction avec la morale naturelle. La raison pour laquelle je serai personnellement très réservé, c'est que cela semble en contradiction non pas avec la morale naturelle par rapport à l'embryon, mais avec la morale naturelle par rapport au mariage. Lorsque le technicien amène les spermatozoïdes dans la bouteille où il a déjà mis l'ovule, il remplit la fonction qui était justement la fonction propre du mari. Et en quelque sorte une troisième personne s'introduit dans la relation normale entre deux personnes qui en fabriquent une troisième. Là il y en a une quatrième, l'opérateur. Ceci n'est pas une distinction purement académique. Une femme qui venait de subir le transfert de son embryon fertilisé avec le spermatozoïde de son mari fut interrogée par son mari à la sortie de la salle d'opération, trois medecins y ayant participé. A son mari lui demandant: «Comment ça s'est passé?» elle répondit simplement: «J'ai fait l'amour avec les trois». Bien sûr, ces médecins s'étaient fort bien tenus et il faut l'esprit d'une femme pour décrire une manipulation technique parfaitement décente de cette façon surréaliste ou plutôt réaliste. Monsieur Testard a publié dans son livre cette histoire véridique, une illustration très claire de la notion de substitution de personnes. Donc, même lorsque l'embryon est parfaitement respecté, le mariage ne l'est pas.

PULLMAN

Au risque de me répéter, je ne peux pas commencer mon intervention sans rendre hommage à la qualité exceptionnelle de l'exposé de notre confrère Lejeune, exposé qui était non seulement logique dans son esprit, mais également émouvant. Je suis rarement ému en écoutant des exposés, cette fois-ci je l'étais.

Je voudrais poser une question qui a peut-être une allure que, pompeusement, j'appellerai cosmique: Vous avez distingué, dans la continuité de l'évolution biologique, une coupure, disons une coupure positive, qui sépare l'homme

de l'ensemble des espèces animales qui l'ont précédé, et cette coupure est liée, dans votre conception, à l'apparition de l'esprit et, peut-être en parallèle, un peu plus tard, à l'apparition également de ce que vous appelez la morale naturelle. D'autre part, en généticien et en scientifique rigoureux, vous avez également parlé de l'ADN et de l'extrême complexité, surtout de la dimension de l'ADN humain, qui comprend quatre milliards, cinq milliards de paires de bases. Alors la question que je voudrais poser à vous et à Alex Rich également est celle-ci: cette apparition de l'esprit, de la morale, peut-elle aussi, est-elle liée de façon organique, d'une façon scientifique, à la complexité croissante de l'ADN; est-ce que l'esprit apparaît à partir d'une certaine grandeur ou complexité de l'ADN? Je ne vous demande pas de me le dire à une paire de bases près mais s'il s'avère que cette particularité très importante dans l'évolution est une fonction essentiellement de cette complexité de l'ADN, et comme l'évolution n'est pas terminée, nous pouvons alors prévoir que, à moins de quelque chose d'extraordinaire, d'un cataclysme, l'ADN va encore croître, va encore se compliquer. Nous allons donc avoir des super ADN qui produiront peut-être des super esprits, des super morales. Quelle est la connexion, du point de vue alors purement, rigoureusement scientifique, biologique, entre la grandeur et la complexité de l'ADN et ces caractéristiques extraordinaires que nous observons chez l'homme, cette coupure dans l'évolution, l'esprit? Que peut-on dire, si jamais on peut dire quoi que ce soit, sur l'avenir dans ce domaine?

LEJEUNE

Sur l'avenir, je ne puis rien dire. Mais sur le présent, on peut répéter une chose qui a été dite depuis très longtemps. Thomas d'Aquin a eu, je croix, cette expression extraordinaire: «Lorsque la matière a subi sa dernière dispostion, l'esprit ne peut pas manquer d'y être». C'est une opinion théologique à laquelle, en tant que géneticien, je souscris pleinement. Je ne suis pas capable de vous définir exactement quelle est la dernière disposition et je ne crois pas non plus que mon ami Rich soit capable de vous dire exactement grâce à quelle dimension d'ADN vous arriverez à cette disposition. Mais reprendere l'idée de Thomas est un bienfait de la providence que j'accepterais volontiers.

WEISSKOPF

May I ask you one question? I was also very much impressed with the way you presented your views. In particular, I was impressed by your emphasis on the fact that these are not purely scientific questions. These are human ques-

tions where the soul comes in essentially. But let me make one remark where I either misunderstood you or I really disagree. I agree with you first, let me say, about the deplorable fact that in the developed countries, the population seems to decrease. I hope that this is only a temporary phenomenon, but it is important to be aware of it and even to do something about it. However, the problem of the increase of population — I would almost say a catastrophic increase of population in the Third World, South America or Africa — I think you have treated in a way that I could not understand because one cannot say this is their business. I mean we are one humanity and here is the problem where real damage can be done to them, and also to us, but mainly to them. I think there is here a moral command, a moral necessity, to do something about the situation because it does produce poverty and death, terrible situations, wars, etc. So to my mind, and maybe also to yours, in case I misunderstood you, it is our moral duty to study the situation and to find ways to prevent this overpopulation in the Third World.

LEJEUNE

Je ne crois pas que nous soyons en désaccord. J'ai dit qu'il est très difficile à des blancs de dire aux noirs: «Vous êtes trop nombreux». Et je le dis non pas parce que j'ai peur que l'on m'accuse de racisme (étant généticien, je ne peux pas être raciste), mais je ne dirai pas qu'il y a trop de noirs, ou trop de blancs ou de jaunes, parce que je ne le sais pas. Peut-être vous choquerai-je, mais c'est peut-être l'avenir de l'humanité que les races blanches diminuent et que les autres races augmentent. Et, en toute sincérité, je n'ai pas d'argument scientifique qui me permette de dire oui ou non. Non scientifique, mais moral. Il y a certes une question morale dans les régions déjà très peuplées et qui ne peuvent pas donner à leur population une vie suffisante. Ces populations doivent elles-mêmes décider de la dimension de leur reproduction. Personne au monde n'a de connaissance suffisante pour dire: il y a sur la planète trop d'êtres humains de ce type et pas assez de cet autre. Chacun peut certes donner son sentiment, mais en sachant parfaitement que nous ne sommes pas juges d'une telle situation. L'homme connaissant le lien entre l'amour et la reproduction, il est normal qu'il contrôle, par sa raison, sa reproduction.

RICH

I'd like to append a few comments. We see continuity in biology. That continuity is certainly expressed at the level of DNA, relevant to the point you

just raised. Our DNA is over 99% identical with the higher apes. Clearly there is a difference, but we don't know the nature of it. Referring to some of the earlier points, Parkinsonism is a very widespread disease; there are over 2 million people who suffer from it in the United States. It's a very dreadful disease. There is clearly evidence from animal experimentation, which Dr. Szentágothai has just referred to, that these substantia nigra transplants seem to be effective. Now I think we have to consider the question of rights and responsibilities to these two million people who have the disease as well as the question of how do we address treating it. Now if one has an embryo that is dead, but the substantia nigra is still functional, I personally think there is no reason not to use that as an experimental approach.

Now, I believe in fact that that will be a transient means because I think we have in the offing gene therapy treatments that will come in five years or so which will address that problem more directly. Nonetheless, there have been physicians in Scandinavia who have carried out such experiments. They've done so with very good motivation, and I do not think we can criticize them. They are trying to address a very important need for a very large number of people. The experiments with this particular therapy may or may not work, but I think we should not make a blanket prohibition because the origin of the tissue is fœtal.

On the other hand, I agree entirely with what might be called the broad overview of having to respect humans and to have a very high level of ethical appreciation. But as always, the choices are difficult. Concerning couples that are infertile because the fallopian tubes are blocked, again I agree with Dr Szentágothai. It's irrelevant to me that a physician is involved in carrying out *in vitro* fertilization. The main fact is that this couple is able to have a child, and that is so meaningful to them. In response to such a human need I think I certainly would not criticize that method as a form of therapy for that disease. These issues are complex. There are many sides and one has to look at the ethical considerations on all sides. I do not think there is such a thing as a moral order. I do think we have evolved a system of ethics which I would strongly support, and which I think is generally shared, but I believe that we have to think in a serious and sustained way about the many different sides of the problem. They are not simple, and to set up rules about what we can and cannot do sometimes doesn't recognize the full complexity of the issues.

LEJEUNE

Unfortunately we cannot continue the discussion; it is too late! There is one point on which we are in full agreement: it is very complex, but the yardstick is very simple: we shall not exploit any member of our kin, however remote or tiny.

ETHICAL DILEMMAS FACED BY THE UNIVERSITIES IN DEVELOPING COUNTRIES

MARCOS MOSHINSKY
Instituto De Física, Universidad Nacional Autónoma De México, México

The Papal Encyclical Letter «Sollicitudo Rei Socialis» brings up many of the grave problems that face the world at the end of the XX century. The very division into first, second, third and, on occasions, even fourth world, that the encyclical letter mentions time and again, indicates the tremendous differences in development and the seriousness of the problems we face.

Coming, as I do, from a Third World country, Mexico, and having been connected for over 40 years with its main academic institution, the Universidad Nacional Autónoma de México, I have had the opportunity of facing in my daily life the ethical dilemmas of this institution which, in many ways, resemble those of other Developing Countries.

Thus I wanted to share with you these impressions in the hope that, through discussions in this meeting of the Pontifical Academy on «The Responsibility of Science», we could arrive at some conclusions that would help us in understanding and solving some of these dilemmas.

The analysis of the problem would require an historical introduction both of the Developing Countries themselves and of the role that the institutions of higher learning play in them. As I am a physicist and not a historian, I will start this discussion at the period just after the Second World War, when I came of age and reached the university level.

At the time communications were not what they have become, and comparisons with life in other countries, and even with life in other social levels in one's own country, were not easy to make. Thus there was a feeling of relative contentment with one's fate, particularly in view of the disasters and hardships that the war had brought to other people.

At the end of this conflict there was a feeling of hope, even in that part of the world that had come into third place but did not realize then that this would become a permanent characteristic for most of its members.

with the Encyclical Letter «Sollicitudo Rei Socialis» that these problems are not merely economic and social, but also moral and that they imply a responsibility for all the world, and not only for that part of it that is associated with the number three.

At this stage you are probably starting to get impatient with my introduction, as most of what I said, at least in a qualitative way, is known to you; and furthermore I state only problems, and one only sketchedly, but do not offer any solutions. Yet I needed this background to go into the subject of my talk «the ethical dilemmas facing the universities in Developing Countries».

Again I will take as my example my own institution, the Universidad Nacional Autónoma de México (UNAM). In one sense it is atypical as most universities in the Third World are young, while my institution is, together with San Marcos in Peru, the oldest on the American continent, dating from 1554. It was then called, very appropriately for this meeting, the Royal and Pontifical University of Mexico, and its curriculum was very similar to those of Catholic universities in Europe, particularly in Spain, of that period. This remained its situation during the colonial era and, at the time of independence (1821), it continued to exist almost unchanged except for the royal denomination. Yet the upheavals of the middle of the XIX century in Mexico put it in opposition with liberal governments that came to power, and finally it was closed and substituted by a system of independent professional schools and a kind of liberal arts entrance college called *preparatoria*. This situation prevailed until 1910, when all the professional schools and the *preparatoria* were again joined together in Universidad Nacional de México, which led a precarious existence during the years of the Mexican Revolution, became autonomous in 1929, started the foundation of modern research institutes in the 1940's and finally got a campus in the early 1950's. As this date coincided with my full-fledged entry into the academic community. I would like to indicate the characteristics of the evolution of a Third World university in the last 40 years.

The UNAM had not been free of political movements and interference in the 1930's and 1940's. The activists of local ideology, as well as those with Fascist or Communist leanings, were quite active in that period, but their activity subsided with the transfer of the institution to the University City, as it was then the outskirts of the capital, and they remained essentially quiescent until 1966. At the time I thought this was a consequence of the facilities and opportunities offered by the new campus. Seen from the present viewpoint it seems more a consequence of the years of hope shared by much of the world in the 1950's and first part of the 1960's.

For those of us who were at the faculty of UNAM at that time our objectives seemed clear. Many of us had obtained our doctoral degrees in the U.S.

The twenty years following the war were a period of great development everywhere. In fact many of the Developing Countries could have incorporated most of their population into a middle class had it not been in part because of another problem: the population explosion. To give an example, Mexico had 20 million people in 1940 and by 1990 it will have 90 million. An almost five-fold increase in 50 years, which is quite common in what is known today as the Third World, is one of the more serious problems faced by the countries that belong to it. In fact in the case of Mexico, the capital, Mexico City, has now almost as many inhabitants as the whole country had in 1940, making it the biggest, most congested and polluted city in the world, that has created an ecological problem in the surrounding area by taking away its water and exporting to it the city's waste.

Despite these very serious problems, by the end of the sixties there was still hope that the problems faced by the Third World could be solved in the not too distant future. Mexico, for example, had in that decade an inflation lower than the U.S. and the annual growth of its economy was at least twice as high as the increase of its population. But slowly in the seventies, and much more rapidly in the eighties, this situation has changed for the worse, as is mentioned many times in the Papal Encyclical Letter.

The reasons for this change are complex, and differ for each country. In Mexico, for example, the desire to accelerate growth, taking advantage of the oil discoveries, led to imprudent policies that contributed to the present disaster, an inflation rate of 10,000% and almost no growth in the last six years, and a foreign debt over a hundred thousand million dollars (I do not use the billion unit as it has different connotations depending on the country). But the very fact that the crisis has affected almost all the countries of the Third World, in some cases even more gravely than in Mexico, shows the existence of an international problem, in which responsibility is also shared by the first and second world, whose insane competition and spending on armaments has contributed to the distortion of priorities and objectives all over the planet. In this again I refer to the Papal Encyclical Letter.

In my view, the main difference between the situation of the Third World in 1967, when the Encyclical Letter «Populorum Progressio» of Pope Paul VI was written, and what we face today, is the loss of hope. For populations where hope was the main ingredient that made life bearable, this loss brings about a very explosive situation. At a previous meeting of this Pontifical Academy two years ago, I remarked that the deterioration of the living conditions in the Third World countries seemed to me as dangerous as the possibility of nuclear war. Today, when the last possibility has receded a bit, I think that facing the problems of the Third World is even more urgent than in 1986. I fully agree

or Europe and had seen the importance of the role of the universities in these advanced countries, particularly with the explosion of knowledge following the Second World War. Furthermore, we had seen how leadership, at least in the sciences, was a matter of will and not only of tradition, as after the war it had passed from western Europe to the U.S. and the Soviet Union.

Why could not the countries of the Third World participate in this exciting search for knowledge, and through it change for the better the economic and social environment of their countries, and incorporate them eventually, depending on their ideologies, in the first or second world?

In the fifties this seemed feasible and required first of all the raising of the academic standards of our institutions, and the awareness of our governments, and of our societies in general, of the fundamental roles of the universities in the struggle for development.

I remember our excitement, not only in Mexico, but throughout Latin America, which I visited frequently in that period, about the task that was facing us, and our discussions about how to accomplish it in the most efficient way.

But by the middle sixties the social climate started to change, at first slowly but then accelerating rapidly. Maybe the critical year was 1968, when many student movements exploded all over the world. In Europe and the U.S. these movements were concerned mainly with the poor quality of life that awaited the students upon graduation. In the Third World in general, and in Mexico in particular, the concern was not so much the quality of the jobs, but the fact that they were simply not available in the numbers that were required.

Unfortunately, neither the governments nor the private sector were capable of solving this fundamental problem. Instead the governments responded to student unrest sometimes with repression, but more often by pressuring the universities to lower their admission standards, and increase their staff with hastily prepared lecturers, to keep many young people at these institutions instead of in the streets, and prevent them for a few years from pressuring the already reduced job market.

Those that had been struggling for years tryng to raise the academic standards, were branded as elitist at the service of the more privileged and selfish groups in the society, and ruthlessly attacked if they tried to give a public expression to what a university should be.

On the other hand, though, the university was not viewed by many students, and some of the professors, as the institution in which knowledge was created, communicated and acquired, but as a kind of upward escalator to social mobility. As it had ceased, at least partially, to perform this role, the disillusion and resentment had set in, particularly for those in the lower income brackets, for which the university seemed the only esclator marked up.

The situation we described, initiated in 1968, has become progressively worse with the passing of the years, as the economic situation deteriorated, as I indicated at the beginning of this talk. In Mexico it has been complicated further by the desire to change some aspects of the political structure through the use of university students, among others, as a pressure group. To get the support of the latter, some political parties have proposed a «welfare» university, in which academic requirements would be reduced to a minimum and for which the state should not only foot the bill for tuition, as it does now, but also cover the living expenses of those that require it. Furthermore, these parties argue that the administrative staff of the university, rector, deans, directors of schools and research institutes, should not be appointed by a board of trustees (which in Mexico consists of professors with a distinguished academic record, who are selected by the university Senate), but should be the result of a «democratic» process giving parity to students and professors.

The situation that I have described as applying to UNAM at the present time, is fairly typical for institutions of higher learning in the Third World. It reflects grievances to which one should give an ethical solution, but also widely distorted views of what a university should be.

The ethical dilemmas mentioned in the title of my talk have to do with the way to attend to the grievances mentioned, without abandoning the academic tradition that has enhanced the prestige of the universities since their foundation 900 years ago in Bologna.

Among these dilemmas I would like to mention the following:

1. In the Third World, much more than in the advanced countries, the university is viewed as an up escalator for social mobility. Is this view justified and, if so, how can it be improved?

The answer is that the university can only propitiate social mobility through the communication, acquisition and creation of knowledge. This implies that these activities must be carried on at the highest academic standard feasible, requiring a searching self-criticism from all the teaching staff, and the maximum effort of which the students are capable. Any other course of action will transform the process into a farce, that will destroy any possibility of social mobility for both students and professors.

2. In view of the fact that public universities in the Third World are likely to have a much larger proportion of needy students than elsewhere, what would be the best course of action for these institutions and for the government and private sector when tackling this problem?

The answer implies several stages. The students coming from public high schools come frequently with a poor academic record, which incidentally also happens in advanced countries for students in poor neighbourhoods. An en-

trance examination should be required for all at the university level. Those who fail and continue to wish to enroll, should be provided with appropriate propaedeutic courses and, if required, should receive living expense payments during these courses, which could be made available from funds provided by government and private initiative, but managed by an independent organization, whose decisions should only have the academic diligence of the candidate as a criterion.

Once at the university the way to help the disadvantaged students is to provide the best possible academic facilities and teaching staff for *all* students. One of the most worrisome characteristics of public universities in the Third World is that they are becoming «ghetto institutions». The constant interruption of the academic calendars due to political and social problems drives away the middle class students to private universities, and, in some cases, to foreign ones. The needy students are then left alone and are more easily manipulated by agitators of all political colors, and find out, when they finish their university studies, if they manage to do so, that it is more difficult for them to find a job than for those coming from private institutions.

Again for needy students a fellowship program is essential but it should have the same characteristics as in socialistic countries: if the student tries hard he should be supported; if the student just coasts along, he should be suspended.

3. What about political activity in the universities? Of course personal political activity of students and professors should not be interfered with, but political activity in the university as an institution should only be considered in a dictatorial regime either of the right or the left. If political parties can operate legally, they are the natural outlet for the corresponding activity, and the universities should study critically the different political viewpoints, but not become a battleground for them. The harm done to the academic level of the universities of the Third World, by incessant political battles, often decided by force rather than reasonable dialogue, has been considerable.

4. What about the attitude of the public universities in the Third World toward students coming from higher economic levels? I have stated before that middle-class students should be retained at public universities, assuming of course that they comply with the academic requirements. I see no reason, though, that they pay no tuition, if they or their families can afford it. Furthermore, they should be made aware, in their passage through a public university, that the type of selfish consumerism mentioned in the Encyclical Letter is neither easily available nor socially acceptable in the context of the Third World.

5. What about the requirements for the teaching and research staff in public universities of the Third World? Ideally they should be the same as for the staff in good universities in the first world, combined with a heightened sense

of social responsibility, and all of these at salaries that have been so eroded by inflation as to cause a burst of laughter if they were mentioned here.

Thus, if the staff of public universities in the Third World had all the qualities mentioned in the previous paragraph, they would make, at least the Catholic ones among them, ideal candidates for canonization.

The reality is of course much different. Only a small percentage of the staff of a Third World university reaches first world levels. Yet these institutions are so huge (over 200,000 students at the bachelor and graduate levels at UNAM), that this percentage constitutes a sizable university by itself. For the rest, about half are recuperable and the other half should never have been hired.

What to do with this type of staff? A thorough self-examination is in order. Those that will have fully made a farce of their teaching and research duties should be fired, but those whose faults lie in their own deficient preparation should be kept and intensive programs for their upgrading should be implemented by those that have the necessary academic qualifications.

I realize that this program sounds utopic, but, in my opinion, if something equivalent to it is not implemented, then not only the universities, but the Third World itself will sink into oblivion, or worse still, into the fourth, fifth, sixth, etc., position.

DISCUSSION

DÖBEREINER

I agree. I think the project which you propose is ideal for our conditions. Just as you say, we must keep fighting for this kind of programme for the university. But how can it be implemented? There are very many complications, from political to financial ones. Still, I agree with you, one should always fight for what we think is right. Maybe some concrete proposals will come out from here and other sources, and then one day maybe we will be able to convince the authorities to at least listen to some of your suggestions — this is the ideal which we always are dreaming of. I think our problems are very similar to yours, and we face the same things.

MOSHINSKY

Well, one of the things which I think we should do is, of course, state these things as many times as we can, because some people have other opin-

ions of what the University should be, and they are quite vocal in stating them. For them, universities have other objectives than the acquisition, the creation, the communication of knowldge. Well, they have their points of view, but I think that we should state our points of view forcefully and defend them continuously, and try to influence as many people as we can.

BERGSTRÖM

Only a simple question. How do you see and how is the situation now as to centres of excellence or graduate groups? Is it a possibility to keep these groups alive during difficult times by outside support or cooperation or training?

MOSHINKSY

Well, these centres of excellence do exist. I have stated many times that there are centres of excellence in many of the countries of the Third World, but they are very few compared with the needs we have in this matter. As I mentioned in my remarks to Professor Weisskopf, the situation at the moment is very serious for our centres of excellence because of the general economic crisis. However there has been an effort, even by the government, which has realized that it's important to protect them, and there have been some laws passed, in Mexico at least, that have contributed to this. I think that international cooperation in this field would be very welcome, and there are some organizations, of course, that are doing this, specifically in physics, I would say. The Russian Centre of Theoretical Physics and the Third World Academy of Sciences have also had this interest. So I would say systematic international cooperation through foundations, sometimes through government organizations, would be welcome. Also it should be taken into account that these centres are of an international level, and they should be considered and supported if they are to stay at this level and if they are to be competitive with similar organizations elsewhere.

BERGSTRÖM

I mentioned this because, as I told you, the point is to get the big aid agencies to get at least a minimal interest in science. But how to administer it? In the health field we have these voluntary funds that are administered by reputable scientists from developing as well as developed countries. There is now an in-

itiative in the new leadership of UNESCO to try to get this type of aid money under scientific control. I see that as one distinct possibility of really getting funds that are worthwhile.

MOSHINSKY

In this connection I would also like to indicate that for example the Italian government — I will speak of physics only — has been giving quite considerable aid to the development of physics and other aspects of science through the International Centre of Theoretical Physics and it is a plan that could be considered by other countries.

L'ETHIQUE ET LA REALITE

BERNARD PULLMAN
Institut de Biologie Physico-Chimie, Fondation E. de Rothschild, Paris

La Responsabilité de la Science, thème central de nos délibérations ici, est essentiellement de toute évidence un problème de l'Ethique des Savants. En tant que tel, il peut paraître donc comme relativement simple tant pour beaucoup d'entre nous, surtout dans nos civilisations développées, l'éthique paraît être une vérité absolue et évidente. En fait, la situation est beaucoup plus complexe et cela pour plusieurs raisons.

En premier lieu parce que tout le monde n'a pas le même concept de l'Ethique, de ce qui est ou n'est pas éthique. Prenons un exemple. Le contrôle de naissances, j'entends par là le contrôle mécanique ou chimique des naissances (pas l'avortement, que je mets à part) est considéré comme contraire à l'éthique par un certain nombre d'individus, savants ou non, et par des représentants qualifiés de certaines religions. Il est considéré comme parfaitement conforme à l'éthique par beaucoup d'autres individus et courants de pensées, dont certains considèrent même comme contraire aux exigences de l'éthique de laisser naître des enfants dont la majorité sera condamnée de toute évidence à la misère et à la souffrance. Un autre exemple est le concept de la «guerre sainte» qui prévaut encore aujourd'hui dans certaines communautés et certaines religions alors qu'il est rejeté avec horreur par d'autres.

En second lieu, et bien qu'une telle considération puisse paraître hérétique il y a le problème de la relation entre l'éthique et la réalité, qui est un peu celui de l'action rêvee et de l'action efficace, des choix et des nécessités, face aux difficultés réelles de la vie.

Je m'explique et je prends comme exemple un thème considéré souvent comme typique et des plus graves dans les discussions sur la responsabilité de la science, des savants, à savoir celui des armes nucléaires.

Que les savants aient joué un grand rôle dans l'invention de ces armes est l'évidence même. Que l'on dise que *par conséquent* ils portent une part de res-

ponsabilité de l'usage qui en est fait, est ou peut paraître juste. Que, en fait, les décisions sur le rôle et l'utilisation éventuelle de ces armes leur échappent quasi totalement est néanmoins également l'évidence même. Face à cette situation, pour bon nombre de nos collègues scientifiques et un certain nombre de nos confrères l'éthique dans ce domaine se résume en une seule exigence: il faut détruire ces armes. C'est le cri du cœur de l'éthique absolue dont la réalisation comblerait de satisfaction la notion que ces collègues et confrères ont de leur responsabilité scientifique.

Le problème est que le monde dans lequel nous vivons n'est malheureusement pas aussi commodémment agencé pour que les scientifiques puissent se débarrasser de leur responsabilité ou leurs remords par de gestes aussi simplistes que de vouloir gommer la réalité présente et retourner à une sorte d'état prénatal.

Je vais faire à ce sujet quelques remarques, très non-orthodoxes, provocantes et que quelques-uns d'entre vous peuvent même trouver choquantes. Je m'en excuse. Disons que je veux, pour le besoin de la cause, énoncer quelques paradoxes mais je défie quiconque de trouver des erreurs de logique dans ces paradoxes. La raison en est que le paradoxe n'est pas dans mes affirmations, car elles ne traduisent que des réalités, le paradoxe est plutôt dans la nature humaine. Voilà ces remarques:

1) La bombe atomique a *arrêté* une guerre, elle n'en a jamais provoqué une. Les 2000 ou 3000 guerres répertoriées dans l'histoire humaine ont toutes commencé sans bombe atomique.

2) La bombe atomique a sauvé plus de vie humaines qu'elle n'en a détruit. Pour rendre la démonstration de cette affirmation persuasive, procédons par le raisonnement suivant. La 2ème guerre mondiale a duré six ans et causé la mort d'environ 30 millions de victimes. Statistiquement cela veut dire d'environ 5 millions de morts par an. Si la bombe atomique avait été inventée et utilisée un an plus tôt elle aurait évidemment arrêté la guerre un an plus tôt et sauvé ainsi 5 millions d'êtres humains (moins la quantité, négligeable, disons de 100.000 humains (2%) tués par l'explosion). Si la première bombe ne l'avait pas fait la 2ème l'aurait fait, avec donc encore une économie de 96% sur les morts de la dernière année. Aurait-il été moral ou non d'utiliser la bombe dans cette perspective? Où est l'éthique absolue en face d'une telle réalité? Réalité dure mais incontournable, comme on le dit aujourd'hui.

3) L'existence de la menace nucléaire est le facteur essentiel qui a préservé le monde d'une conflagration générale (3ème guerre mondiale) pendant les 40

dernières années et le protège encore peut-être de ce super-malheur aujourd'hui. Certes nous ne manquons pas de conflits locaux, dont certains n'ont rien à envier, en matière de cruauté et du nombre de morts, à une hécatombe nucléaire, mais ces conflits se produisent essentiellement entre des peuples ou des ètats dépourvus d'armes nucléaires ou lorsqu'ils impliquent un état qui en possède dans des circonstances qui rendent l'utilisation de ces armes improbable.

4) Bien sûr, malgré ces «avantages» des armes nucléaires, nul ne peut prétendre que ce ne soient là des moyens dangereux et qui ne forment certes pas une base logique et acceptable à la longue pour le maintien de la paix. La question se pose donc comment s'en débarasser *sans pour autant mettre en danger la paix*, fragile, du monde? Voilà une question typique à la frontière de l'éthique et de la réalité. Or, en fait, nous assistons aujourd'hui à un commencement du désarmement nucléaire en Europe sous forme du démantèlement et de la destruction des fusées de portée moyenne. Mais quelle a été la première étape dans ce développement positif nouveau, l'évènement qui l'a déclenché? C'est l'installation des fusées Pershing en Europe de l'Ouest, donc une augmentation de la concentration et de la confrontation du dispositif nucléaire. Ceux qui s'y opposaient pechaient par la méconnaissance de la logique du réalisme politique: le danger d'une confrontation nucléaire était plus grand avant l'installation des Pershing, lors de la seule présence des S.S. 20 Soviétiques, qu'après leur implantation. Cet exemple montre comment l'*éthique* du désarmement ne peut être satisfaite que par des mesures *réalistes*, tendant à un contrôle continu de l'équilibre des armements, garantissant la persistance de la sécurité réciproque des parties engagées. Heureusement, très heureusement, le début d'un tel processus paraît maintenant engagé.

Cette constatation d'une vérité expérimentée conduit à une série de conclusions importantes.

1) J'ai parlé dans la phrase précédente de l'équilibre *des armements,* et non seulement de l'armement nucléaire. Quel que soit notre obsession morale sur les armes atomiques il n'est pas réaliste et j'ajouterai pas moral de ne concentrer nos critiques que sur ce type d'armement. J'ai été stupéfait de constater, il y a quelques mois, le peu d'écho, le peu de protestation qu'à provoqué le bombardment chimique par l'Irak du village Kurde de Halabja. Or il y a eu dans ce malheureux village, d'après ce que l'on dit, de 3000 à 5000 hommes, femmes, enfants morts en quelques minutes, empoisonnés par des gaz toxiques. Comment se fait-il que nulle part je n'ai vu ni entendu des protestations contre ce massacre épouvantable, aucune protestation des scientifiques

en particulier? Pourtant ces gaz n'existeraient pas sans eux. Très récemment des protestations ont paru dans la presse et ont été énoncées par différentes autorités politiques mais je n'ai pas eu d'écho d'une condamnation de la part des scientifiques.

2) Certes, nous sommes l'Académie Pontificale *des Sciences* et il est donc normal que nous soyons préoccupés en premier lieu par le problème de la responsabilité morale de la Science. En revanche ce qui me paraît hautement discutable c'est qu'en mettant l'accent constamment sur la responsabilité éthique des savants on les enrobe en quelque sorte dans un complexe de culpabilité, comme s'ils étaient eux plus fautifs que toutes les autres catégories des citoyens. Or, permettez-moi de le dire, je ne crois nullement qu'il en soit ainsi.

Une responsabilité pour le moins comparable pèse aussi sur les épaules des autres catégories de citoyens et parfois d'une manière semblable. Ainsi nous sommes une Académie des *Sciences* et nous parlons donc de la responsabilité de la Science. Mais puisque nous sommes en même temps une Académie *Pontificale* pourquoi ne pas se pencher aussi sur le problème de la responsabilité de la religion ou plutôt, hélàs, des religions? En fait il y a une grande analogie, dans le domaine qui nous préoccupe ici aujourd'hui, entre la science et la religion: *les deux ont en commun la vocation et le potentiel de contribuer puissamment au bonheur des hommes et le désagrément ou le malheur d'être souvent détournés de ce but.* En ce qui concerne la science nous venons d'en discuter. En ce qui concerne la religion et sans même rappeler les évènements du passé tels que les guerres de religion, l'inquisition, les conquêtes sanglantes sous couvert de la propagation de la foi, les croisades, à combien de détournements assistons-nous encore aujourd'hui de leur message fondamental, combien de souffrances se font encore en leur nom, combien de dangers potentiels résident dans la résurgence, en certains endroits de la terre, de certaines formes d'«intégrisme» religieux? Je ne crois donc pas que les scientifiques doivent avoir le monopole de remords, ce qui naturellement ne résout en rien leurs problèmes de conscience.

3) Face à cette réalité complexe et quel que soit la responsabilité des savants, en particulier dans l'invention et la production des armes, il me paraît évident que pour résoudre le problème de leur destin, une position purement éthique, une condamnation verbale, une discussion limitée au monde scientifique est insuffisante et vouée à l'inutilité plus ou moins grande. Pour contribuer *utilement* à la solution de ce problème, et *d'autres problèmes analogues dans d'autres domaines de l'existence humaine,* pour pouvoir donc contribuer *efficacement* a l'élévation («upgrading»), à l'amélioration de la vie humaine, il me paraît indispensable *d'élargir* notre activité, nos contacts, nos réunions aux représentants qualifiés d'autres activités dont le rôle dans ce processus est, quoi que

nous puissions prétendre, pour le moins aussi important que le nôtre: je pense aux hommes politiques, aux économistes, aux sociologues, aux militaires, etc... Ainsi, puisqu'il nous a été démandé spécifiquement de réfléchir sur le rôle de l'Académie Pontificale des Sciences dans l'avenir, à l'aurore du 21ème siècle, je pense que c'est peut-être dans une initiative tendant vers un tel *élargissement des formes de son activité* que l'Académie pourrait trouver un champ fertile et un prestige accru. Après tout, il nous a été demandé à nous (lettre du Père Dardozzi du 17 Mars 1988) de réfléchir sur les responsabilités, dans les aspects éthiques des applications de sciences et technologies, des Universités, Académies, Industries, Organisations Militaires etc.... Y a-t-il un grand sens de le faire en l'absence des représentants qualifiés de ces domaines d'activité humaine? Que dirions-nous si des militaires discutaient dans une de leurs Académies sur la responsabilité des Scientifiques dans la production et l'utilisation des armes, en l'absence de représentants de ceux-ci? La réunion nous paraîtrait certainement, pour le moins, étriquée. Je pense donc que l'Académie Pontificale devrait prendre l'initiative de telles consultations étendues à toutes les instances susceptibles de contribuer à la solution réaliste des problèmes, quel qu'ils soient, impliquant la conscience éthique des hommes. C'est dans un tel forum élargi que nous arriverons, peut-être, à cerner d'une façon plus objective que nous ne pouvons le faire en nous réunissant en vase clos entre nous le rôle réel et donc la responsabilité réelle de la science face à l'ensemble d'autres activités et facteurs qui contribuent à la marche et au développement et éventuellement à l'élévation de la Vie Humaine.

DISCUSSION

CHAGAS

Merci, Monsieur Pullman. Est-ce que je pourrais faire un petit commentaire? Quand nous avons choisi au Conseil le thème de la responsabilité, c'est parce que nous avons pensé qu'il y a des responsabilités positives et que ce sont ces responsabilités positives que nous voulions vraiment marquer. Ce n'est pas une accusation, disons, aux scientifiques, mais une invitation aux scientifiques d'examiner comment ils peuvent contribuer à améliorer la condition humaine.

PULLMAN

Je comprends très bien; je voulais être un peu provocateur dans mon exposé.

CHAGAS

Et d'autre part, moi-même j'ai proposé au Saint Père qu'on introduise des économistes dans nos cadres, et je dois dire que quelques uns — pas beaucoup — mais quelques uns de mes collègues n'ont pas été très satisfaits de cet élargissement.

PULLMAN

Je ne propose pas l'élargissement de l'Académie à l'introduction des économistes, mais l'élargissement de nos discussions, ce qui n'est pas du tout la même chose.

CHAGAS

Mais à ce propos, nous avons toujours invité des personnes qui sont en dehors de la science, et nous avons beaucoup fait pour que l'Académie réellement s'en serve dans le contexte du développement social.

THIRRING

This brilliant exposition of Mr. Pullman was so clear that I am afraid that I will add only trivialities. Nevertheless, it touched on so many things I was thinking about that I cannot help adding something. You asked why is the scientist more responsible than any other citizen? Certainly it's not clear *a priori*, because the questions we are touching upon concern all of humanity. But I think to some extent we have a privileged position which obliges us to speak out, at times because we are in a better position to do it than other people. In two ways: one is that scientists enjoy in authoritarian countries a kind of immunity which other people do not enjoy. For instance, in Eastern block countries, a member of the Academy may be religious and go to church. If another person does this, he goes into a concentration camp. So we can sometimes do things which other people cannot do.

Secondly, we have a certain social esteem, at least among some people, right or wrong, and therefore what we say may seem to have more value than what other people say. Therefore I think it's our particular duty to make our views known.

You mentioned the atomic bomb. The fact that with the atomic bomb you can kill, or evaporate, within a few seconds up to a million people is something

which is wrong by any moral standards. Whatever you may think natural morality is, I cannot help thinking that this is a crime. We cannot put up with its existence. We have been putting up with it for too long a time. In the year 1960 or so, we already had this situation, but we took it for granted.

Then, with the installation of the Pershing missile, the evil grew worse and worse, but people were still putting up with it. Only now have we been making some cuts, but they are negligible, and I think this obliges us never to be quiet to the fact that such a crime might be committed which is certainly morally wrong whatever standards you have.

PULLMAN

Thank you. There is no question that you are right as to the essence of the problem. My only indication was that if you really want to destroy the bomb and stop the holocaust, you have to do it realistically. Just condemning it and sitting and condemning it again doesn't lead very far. You have to do it. And how do you do it? That's the whole problem.

LEJEUNE

Je voudrais dire combien j'ai apprécié ce voyage terrestre sous une conduite aussi aimable et aussi éclairée. Je me permettrai de faire une petite réserve sur un calcul, qui est celui de la soustraction que vous avez faite des morts de Hiroshima et Nagasaki, que vous enlevez pour le gain des cinq millions qui seraient économisés. Il me semble qu'en bonne morale, il n'était peut-être pas nécessaire de se livrer à cette soustraction. Je m'explique: la puissance atomique aurait peut-être pû être démontrée sans écraser deux villes mais en utilisant Eniwetok pour commencer, et dans ce cas, c'est bien cinq millions de vies qui auraient été protégées et on n'aurait pas à déplorer les deux cent mille qui ont été surajoutées. Le gain aurait été beaucoup plus moral.

PULLMAN

Moralement vous avez évidemment raison. Est-ce que pratiquement c'était réalisable à ce moment, dans les circonstances du moment — est un autre problème.

WEISSKOPF

I am afraid that I am the only one in this Assembly whose hands are soiled, I would say, since I worked for three years on the development of the atomic bomb. It is very hard to say whether what one has done is good or bad because these concepts are so difficult to define. There was a tremendous danger at that time that Hitler would develop the bomb, but I do not want to justify this. I just want to add how much I sympathize with your argumentations and how deeply I was impressed just because I was personally so involved in it.

Now I fully agree with Lejeune, that every dead person is a dead person and 200,000 are in a way just as bad as 2 million or more. I do believe that this was in some way a crime, and I say it as a citizen of the United States. As you probably know, there was a group of us who supported the demonstration of the bomb, which would probably have had a similar effect. But who knows? We don't know history, and I must say that I had my own experience which perhaps shows the opposite. When General Groves, the American general, saw this experiment which we made in New Mexico and saw the sand all molten and centred in a kind of mirror, he looked at us and said, "Is that all?" He thought that there would be a hole all the way through to the centre of the earth. Well, he was a general. How would the Japanese generals have reacted? But I do not want to discuss this. The main point is that not only was the application in some ways catastrophic from the moral point of view, but I deeply feel there was something not right about the necessity of bombing a second city.

Now, as to the final solution, of course this is very difficult. Simply saying, "Abolish all nuclear bombs tomorrow", even if this were possible, is not the right solution. I would like to express my feeling with a statement which I made in a speech a year ago. Namely, we must arrive not at a complete elimination of nuclear bombs, but at a state of affairs where all the important people and the public see the nuclear bomb as an impossible weapon. It is not a weapon of war. It doesn't help in one way or another, because it annihilates both sides. We must come to a point where people say, "Nuclear weapons, who cares? They won't be applied anyway". We are not there yet, but that is where we must arrive.

BLANC-LAPIERRE

Ceci sera très court; c'est simplement un point de méthodologie. Je pense que nous pourrions procéder de façon pragmatique à la suite de ce qu'a indiqué le Professeur Pullman dans son souci d'ouverture, sans faire une ouverture de l'Académie elle-même. Peut-être, au cours d'une semaine comme celle

que nous vivons, pourrait-on prévoir une demi-journée où deux ou trois orateurs de mondes complémentaires, et bien choisis, seraient amenés à venir nous exposer un point de vue qui complèterait peut-être le nôtre.

RICH

I would like to express my support for one aspect of Professor Pullman's presentation, that is the relative, almost complete absence of commentary by national groups, scientific groups, any groups, about the use of chemical weapons, a use which I think is rather well documented. Just in yesterday's *Herald Tribune*, I read a report that in Libya the largest chemical plant known, devoted apparently to the manufacture of chemical weapons, is now being built. This is a very significant danger. I think it would not be inappropriate for the Pontifical Academy in some format to make a statement on chemical weapons, somewhat analogous to the manner in which we made a statement about nuclear weapons. The point about chemical weapons is that one does not have this enormous psychological barrier to their use. Indeed, as illustrated by the use of these weapons in Iraq, there was no commentary, you know, as if it hadn't occurred. Such weapons are, as it were, the offspring of technological developments in science, and I think it would be quite appropriate for us to try to use our position to galvanize opinion against these weapons.

PULLMAN

Puis-je ajouter à l'appui de ce que vient de dire notre confrère Rich que c'est à l'honneur du Président Mitterand — je ne dis pas ça parce que je suis Français — d'avoir suscité le premier, à l'échelle mondiale, une offensive contre les armes chimiques. Il doit se tenir très bientôt, en janvier, une réunion mondiale organisée par le Président Mitterand qui a justement pour but d'essayer de faire quelque chose à propos des armes chimiques, de les condamner. Il serait peut-être tout à fait souhaitable, dans le sens de ce que vient de dire Alex Rich, que l'Académie Pontificale puisse, avant cette réunion — disons maintenant, dans cette session — jeter son poids dans la balance par une déclaration à l'occasion de cette conférence de ce que cette conférence devrait faire, pour montrer que nous sommes associés à cet événement important, parce que nous nous sentons très concernés par ce problème.

CHAGAS

Je voudrais vous remercier; je suis tout à fait d'accord avec vous. C'est vraiment indispensable que l'Académie se prononce sur ce problème.

LICHNEROWICZ

Juste un mot. La réunion est essentiellement pour un traité d'engagement à la non-production, car, actuellement, il y a de vagues traités sur le non-usage (et on voit ce qu'on en fait) mais la conférence de janvier est prévue pour la non-production. Or tous les pays produisent et produisent abondamment — surtout les grands pays développés — et les autres commencent à le faire sérieusement.

MÖSSBAUER

I would like to support what Professor Rich has just said. A statement of the Pontifical Academy concerning chemical weapons would be very useful, but it would be very useful also for an additional reason. I am a little worried that here we are the convinced, and we are discussing the problems of the responsibility of science, of ethics in science and so on, amongst people who are already convinced. If this stays just within our circle here it's not very useful, so we must really think about how we can bring the message out to the public — not only the message on the problems of chemical weapons, but the general message of the responsibility of science. Very often, in meetings on these problems, the group which listens to the talks is already convinced before the meeting, but the message doesn't get out to the general public. I think we must be very concerned about how to reach the public, and how to really get results beyond the circle which is assembled here.

BERGSTRÖM

Well, I agree with what has been said here, but one mustn't forget that the so-called conventional weapons are now so efficient that they too can kill millions in a very short time. I see the responsibility of science and research not so much in this negative way, but rather as the only non-controversial way to cooperate among countries, and the only way to decrease the inequalities that will otherwise fuel future difficulties in the world. What the Academies really should do is to find ways in which science can be used in a positive way to rapidly increase activities in all these fields of cooperation. There is an interesting aspect of the Japanese research project called "The Human Frontier": one of the requisites for getting their support is that proposals must contain cooperating scientists from three countries.

LEJEUNE

Je voulais dire très brièvement combien j'ai été heureux que Monsieur Pullman parle de la guerre chimique. Si une déclaration de l'Académie pouvait être utile, ce serait peut-être de faire espérer que la guerre chimique n'aura pas lieu.

ETHICAL ASPECTS OF ECOLOGICAL QUESTIONS

SILVIO RANZI
Dipartimento di Biologia, Università di Milano, Milano

The Beginning and Development of Civilization

I would like to consider the ethical problems related to ecology.

About 8,000 years before Christ the first farms appeared in the Near East, and in 4,000 B.C. they existed in Southeast Asia. Before that time, from the end of the ice age, when man had abandoned the caves, he had led a nomadic life. In small groups he had hunted the red deer and had migrated with them, but he had left very few traces, and he had caused changes in the environment not very different in importance from those that can be caused by every other kind of animals of prey. With fire he had undoubtedly caused some forest fires, but we do not know for sure the results of these fires, which on the other hand, were not very different from those caused accidentally by lightning.

The farm, and that is the beginning of agriculture, is undoubtedly the greatest revolution in the history of humankind. It is the beginning of land ownership, perhaps at first limited in time, but is the beginning of the right of whoever sows to reap the fruit of the seed. Scholars of prehistory believe that human society changed considerably when man took up a permanent habitation in a given land. The tribes of hunters had certainly — as is seen in many other mammals and very definitely in the apes — a dominating male who was the head. But the farm brought the need for guards in order that the property would be respected, and the head had to coordinate the activity of these guards. From our point of view the first appearance of these farms was a serious violation of the environment. This violation of the environment regards the area taken over for construction, and that occupied by the heaps of rubbish which in some cases increased over thousands of years forming real hills which still exist today. A third violation, of the environment, which has always been the most extensive, and remains extremely extensive today, consists of

the cultivated areas: the field of barley of man's early communities in the Near East, which soon became areas of cultivation of the greatest variety of vegetables and grains, plus the cultivation of rice in Southeast Asia, and corn, first grown in what is now Mexico.

If we bear all this in mind, we can say that for 10,000 years in Asia Minor man has interfered with the environment, while in central Europe, with the creation of the first farms man's effect is apparent from a much later period, which we can establish at the fourth millennium before Christ. In North America the beginning of cultivation is even more recent, and perhaps goes back to a couple of millennia before Christ.

Agricultural development in Europe has led to the destruction of the forests. The forest area is now reduced to a small part of the original extent. Deforestation was begun in order to obtain land for agriculture and land for human habitation, but it may be said that each new activity of man led to further deforestation. For the raising of cattle it was necessary to cut down forests. Wood for burning, and thus deforestation, was necessary for cooking and for heating. Wood serves also for the working of metals and for the construction of ships. In fact one can say that the history of the naval powers up to our century had as a concomitant the destruction of an equal area of forests. We might ask how many woods were destroyed in the Lepanto or Trafalgar battles. For anyone who has visited even as a simple tourist the areas concerned, it may be impressive to hear it stated that Latin writers speak of the woods on the mountains that now rise above them as mere fields of stone. Historians tell us that when in the seventh century the Arabs pursued the conquest of Mediterranean Africa they crossed through the woods that were on the Libyan shore, those shores which we today see as deserts. The historians of Charles V say that in the 16th century it was possible to walk from the south of Spain to the north of Europe without going out of the forests, and this information is amazing to anyone who knows the Europe of today.

The destruction of the forest is a prediction of desertification. Today approximately half of the land that is out of water consists of arid or semi-arid desert, and the phase of temperature increase that the earth is now experiencing, leads to a continual increase of desert land.

The problem of the damage done by deforestation was felt by the Romans, the Greeks, and has become particularly present in recent times; we might recall that William Penn in 1681 decreed that in Pennsylvania they had to reserve one acre of forest for every five acres put into cultivation, although at that time he did not have the means to make this decree respected. Today the principal states have available officers who control the forests, such as those of the American Federal Reserve.

By forest is not meant a large number of trees, but it should be regarded in an ecological sense. That is, the forest consists of all the organisms, plants and animals, large and small, which are related to it because the forest gives them protection, or they obtain, directly or indirectly from the forest nourishment. The large trees of the forest give protection by their leaves to minor shrubs, grasses, fungi and bacteria, which, in an area that is so shady and damp, can grow by getting their nourishment from the humus of the forest, which is particularly rich in nutritive substances from the decomposition of the organisms that live and die in this type of environment. Also, the animals are linked to the forest not only by the climate, but also by their alimentary chains. The herbivores, the principal consumers, feed on grasses and leaves. The carnivores, which feed on the herbivores and which constitute the secondary consumers, eat these herbivores and in their turn are eaten by other carnivores (tertiary consumers). Without the forest the herbivores characteristic of this ecologic environment cannot be fed, without the herbivores there won't be any carnivores. Moreover, the forest makes possible the life of many insects which in turn are eaten by insectivorous animals. The disappearance of the insectivores will condition the carnivores, which feed on them, thus constituting the fourth level of consumers.

The examples can be multiplied. An animal characteristic of the forests of central Europe and which attracted the attention of Caesar's legionaries, was the urus (*Bos primigenius*); the object of intensive hunting, it disappeared with the death of the last animal of this species which occurred in Poland in 1627 as is usually stated. After the last two wars it seemed that European bison (*Bison bonasus*) of the forests of east-central Europe, was about to undergo the same fate. It was only the great care and the great love of nature of the Polish people that saved the species from destruction, sheltering the survivors in the forest of Bialowieza, which was made a national park. Today the few examples thus protected have reproduced themselves and the danger of the disappearance of this animal seems averted.

We have given the story of these two ungulates (hoofed animals) which disappeared or diminished in numbers with the disappearance or the reduction of the forest, but the same could be said for all the animals characteristic of the forests in temperate climates whose numbers have been reduced.

As regards Europe, it can be said that the process of anthropization and the consequent disappearance of the forest lead to the disappearance of the original European fauna, because also the arboreal fauna is decreased: squirrels and dormice among the herbivores, and martens among the carnivores tend to become rarer.

If instead of Europe we consider Africa, it is calculated that two-thirds of the tropical forest have been destroyed in the last centuries, and the phenomenon is now assuming even vaster proportions.

In the European mountains the characteristic animals are always decreasing in number and thus chamois, mouflons, ibex are tending to disappear. Italy can be proud of the conservation of this latter species, in the National Park of the Gran Paradiso thanks to the work of Renzo Videsott.

Another large mammal, which is represented by the neolithic artists in the grottos of the Pyrenees, the mammoth (*Elephas primigenius*) disappeared in the distant past, but its disappearance in Europe and in Asia seems related to a change of climate and the disappearance or reduction of the tundra. Man, through his hunting, contributed to reducing the number of these animals. At Predmost, in Moravia, skeletons of paleolithic hunters are buried among bones of mammoth arranged in such a way that it is clear that it was intended to protect the human remains. In this cemetery the remains of mammoth concern about a thousand individuals.

Changes in the landscape

If one wants to study the changes produced by man in nature, one must refer to the changes that man causes by completely modifying the landscape. When Europe was covered by forests, man moved about along the rivers. At the beginning of the century Amazonia was in the same condition that must have been pre-Roman Europe. The rivers represented practically the only way to cross the forests. In Europe the Roman consular and imperial roads led to the same changes that the superhighways and the Alpine tunnels today demonstrate in all their destructive grandeur. Whoever today crosses the Alps using the great tunnels realizes what great violence the landscape has suffered. The mountain, no longer covered by woods, is no longer able to withhold the waters and to let them slowly filter down. Full of torrents, landslides are therefore enormously more frequent, while the waters carry away the humus, gradually transforming the mountain slopes into heaps of stones. The woods are very important from the hydrogeological viewpoint. In the woods, the rain, whose violence is reduced by the leaves, slowly seeps downwards where it is lessened by the leaves and the grass which are on the earth where it filtrates through interstitial spaces, while the large and small roots of the trees permit it to penetrate deeply. With the cutting of the forest the plants capable of holding back the water are lacking; but, what is worse, the earth, not held back by the roots of the trees, is washed away. Thus the mountains are transformed

into heaps of stones, and even in the pastures the more superficial layer of the humus disappears.

An example of the phenomena described is presented by Pavan for the island of Madagascar. The first settlement of the island, which was rich in water and covered with beautiful forests, took place one or two thousand years ago, the people who landed there coming from Asia or from Africa. The cutting of the forests, to produce an irrational agriculture and the raising of cattle, has transformed the island in such a way that today 70% of the territory has become unproductive, arid and inhospitable, and the scarce forest, remaining in the mountainous regions, is still today the object of continuous destruction.

The example of Madagascar must be a warning for what is happening in the Brazilian forest, where a programmed destruction is going on in order to obtain wood and to build roads. Half of the oxygen produced by the tropical forests comes exactly from there, and we don't really know to what point animal life on planet Earth can survive without this oxygen.

Ever since ancient times, man has carried out reforestation. This practice is today developed to the highest degree in every advanced country by specialized organizations such as the Corpo Forestale dello Stato (State Forest Organization) in Italy.

Another type of violence against nature consists of the quarries of sand and pebbles along the rivers. This causes very serious damage which usually escapes superficial notice. There are thousands of cubic meters of material which man removes and which, as enormous empty spaces, completely disturb the hydric regime, setting up a new regulation of the waters and thus forming artificial lakes and wells.

Even the coast-line is the object of great changes through man. The coastal roads completely disturb the equilibrium of the beaches and of the reefs, especially if placed in the immediate vicinity of the sea. To this must be added the removal of the reefs for use as construction materials. Thus are disfigured the lovely beaches or the wild reefs, and more or less ugly constructions line the seashore, while the same sandy shores become sources of precious sands destined for construction and are thus impoverished.

The work of man does not stop here because dikes and pumps dry up areas of the sea and coastal lagoons in order to make available a larger surface of land for cultivation. As far as we are concerned here we must point out that it is always a question of violence on the part of man against nature. If the Italians look at the fields of Latina or the Dutch look at the Polders of Frisia, one can, on an economic basis, speak of a good bargain, even if the naturalist must lament the areas which thus disappear. There is in these cases an economic necessity, which has its importance. A similar judgment applies to the great

reclamations of land of the present and also some of the past, such as, with regard to the Italian ones, the reclamations which Gioacchino Murat had executed on the shores north of Naples, and those which the Venice of the Doges created by blocking some rivers with dikes. However we cannot justify the approach taken at present in Italy when, in order to reclaim a few hectares of land to distribute to the farmers, they reclaim fishing areas and coastal lagoons. A similar policy does not seem justified on economic grounds because the fishing area produces more than the field. In this way picturesque areas disappear, resting places for migratory aquatic birds are destroyed, and migratory pathways are altered with a result that can even lead to the extinction of certain species and with obvious harm to the activity of hunting.

In some cases the results of all this are very serious, as in the sad case of Venice, where the high waters result from the «reclamations» made in the area around the lagoon and probably because of the deep canals dug therein, while it is doubtless that the taking of the water from underground has created a real lowering of the city level. So today because of man's activity we see the beginning of the disappearance of the city of Venice, an inevitable disappearance if some remedy is not applied to the damages produced by the pumping out of the water from the deep layers and by the depletion of the sandbanks which represented an area around the lagoon where the excess water could flow in times of high waters.

The need for water

Man needs water. He needs water to drink and in general for domestic uses, but he also needs water for industrial use. In particular the production of electric power requires impressive masses of water even if this water does not undergo great changes after it has been used.

Christianity bids us, among the works of mercy, to «give drink to the thirsty» and this shows us the great importance that water has for humankind.

In the Old Testament we read that when Aaron touched the waters of the Nile, all the waters in the river were changed into blood and the fish that were in the river stank, so that the Egyptians could no longer drink from the waters of the river.

Today the problem of water has two sides, contained in these two phases: the increase of its consumption and the increase of its contamination.

It is estimated that the minimum world need for water by the year 2000 will exceed 4000 billion cubic meters of fresh water alone per year, a figure which represents 4% of the total precipitation on surface land, which is 100,000

billion cubic meters per year, and 12% of the average yield of all the rivers of the world.

The Aral Sea was once the fourth largest lake in the world, but today it is shrinking. This sea is located in the south-central deserts of the Soviet Union, where the people (about 40 million Muslims) depend heavily on irrigation for agriculture; use of the lake and inflowing river waters by mankind has been going on for about 3000 years. Both the size and the depth of the Aral have fluctuated before in geologic time as climates and inflow patterns changed; although a dry period has contributed to the current recession, in large measure the desiccation is the result of anthropogenic factors — the diversion of river water for use in irrigation. The total area of the sea has already dropped by 40% compared with what it was just a quarter century ago, its salinity has almost tripled, and dust and salt storms are frequent.

Increase of Contamination

At this point we must mention something about the contamination of the waters, and that is, about the changes in the water caused by man.

The contamination can be seen in relation to the influence on the availability of water described above.

In fact, pollution can make the deep waters unusable. This is the case of Milan, where in 1968 there were 376 wells (out of 650 in use for the aquifer) polluted by chromium, and of these 70 containing more than 50 «gamma» per liter, which is the acceptable limit based on data from the World Health Organization. The situation was such that some of the wells were closed.

Aside from these aspects connected with the problem of future availability, we must consider also those relative to the protection of Nature.

One source of pollution consists of water used for cooling. Great masses of water taken from rivers, springs and lakes are used as refrigerants, and returned to circulation with an increase in temperature which can even be as much as 10°C. It is calculated that about 75% of these waters comes from the cooling of the power plants. The embryonic development of the Italian frog and of the axolotl of *Ambystoma* raised in aquariums, does not take place above 32°C. The alimentary chain of plants (producers), small invertebrates (primary consumers), small fish (secondary consumers), large fish (tertiary consumers) cannot take place above a certain temperature limit, because the heat kills or reduces considerably both the producers and the primary consumers, so that the secondary consumers cannot survive because of lack of nourishment.

Today the waterways that cross the large cities or the industrial areas or that have some relation with them, in many cases present very notable increases of temperature, due to the inflow of warm water used for cooling. In others they are reduced to collectors of toxic substances, suspended substances, floating material, sediment and organic substances which devour more oxygen than the system can recover from the air or from chlorophylic photosynthesis. In recent years there has been added the appearance of absolutely new substances in the water systems, of which if some are limited to resisting oxidizing degradation (synthetic detergents), others (pesticides), synthesized and utilized for killing, act as poisons.

Thus, from the biological viewpoint, the waterways of the very populated regions are rapidly dying. In them life is killed gradually or suddenly, according to each case, and with a series of stages which depend on the ecological requirements and the sensitivity of the various organisms constituting the biological population. Generally it can be observed that some animals (among the fish: the Salmonides) are the first to suffer from the adverse conditions. Then come the aquatic larvae of some insects (Plecotteri, Tricotteri, Efemerotteri) and little by little other zoological groups, the microscopic algae, generally the last ones, and also the macrophytes disappear. When the pollution does not reach levels of extreme toxicity, some species of protozoa, of nematodes and anellides and the larvae of many chironomidi seem to be particularly resistant. In conditions of extreme pollution, it is the bacteria that represent the most important portion of the entire biomass, in the form of *sewage fungus complex.*

It is not possible to give here a more detailed picture of how nature and its resources are modified after pollution: this evidently depends on conditions most often extremely contingent and depending on the type of pollutant; nor does it seem possible to give an idea of the phenomenon on a national scale.

In the lakes the change of water is very slow. In Lago Maggiore Tonolli and Piontelli have calculated that after 30 years 12.5% of the original water has not changed. In other lakes the period during which the water remains is still longer; in the Lago di Bolsena after 30 years there is still 79% of the original water.

Even in the less deep lakes such as the Four lakes which make up the Ruoversi Lakes in Finland (respectively 20, 22, 45 and 47 meters deep) the period that the water remains is several hundred days. It therefore seems clear from these data that a polluting agent introduced into a lake has a retention period much longer than in a river and thus exerts to a greater extent its harmful action.

Contamination of the sea

In a planet where salt water constitutes 97% of the total water available to man, the sea is logically of great importance. Its progressive deterioration, even if it is not so accentuated as that of inland waters, constitutes one of the great problems which man must now face. The proliferation of industries in the coastal regions and the discharges from the rivers convey into the seas a large number of chemical compounds, some of which are toxic, and which unfortunately defy even the most modern methods of treatment. Phosphorous detergents, for example, are a typical problem of our era. Their toxicity seems due essentially to their tensoactive strength, by which they can concentrate their polluting agents to a great degree. On the other hand, even in low concentrations they upset in a dangerous way the percentage of oxygen dissolved, and inhibit the proliferation of the autotrophic planktonic organisms, consequently limiting the capacity of self-purification of the marine environment.

In many countries today there are prohibitions against producing phosphorus detergents, and this limitation is a positive step.

One particularly alarming aspect of marine pollution is related to oil rig platforms, and to wastes from refineries and petrochemical plants. Very serious accidents can occur there.

The pollution of waters of the sea by petroleum is now of world interest and increases with the increase of consumption of petroleum and its derivatives.

Serious accidents, even if they are exceptional occurrences, are always possible and destined to increase continually, either because of the increase in the number of transportation vessels, or because of the tendency to build oil-transport ships of larger tonnage in order to reduce costs.

Moreover, with the continually increasing discoveries of submarine petroleum deposits and the consequent exploratory drilling, the danger is increasing; a recent case is the accidental breaking of a drilling well in the Bay of Santa Barbara in California, which caused enormous ecological and economic damage.

The dry freighters, the passenger ships and definitely every motorboat can add to the pollution in various ways: jettisoning ballast water contaminated by petroleum, or wash water from the tanks used for the transport of petroleum, or by leakages through defects in the plants.

The effects of this pollution, which from year to year grows more extensive, on the flora and fauna and the possible repercussions on health, on coastal installations, and on tourism, constitute a problem of extreme gravity. Pollution of the beaches, with the resulting harm to the bathers, is the source of continuous complaint; moreover fishing equipment, boats, wharfs, buoys and

other marine structures are soiled in a serious way. The pollution by petroleum also affects the natural migration of fish and therefore the activity of fishermen. Fish are able to tolerate considerable amounts of pollution, but they acquire an unpleasant taste which makes them unsuitable for sale. The research carried out to ascertain the consequences of this pollution has shown that water containing 0.05 ppm of oily refuse ruins the flesh of salmon and that 0.2 ppm is enough to give an unpleasant taste to crustaceans. Also marine birds suffer in a preoccupying way from the pollution by hydrocarbons; their feathers stick together and the protective layer of air between the feathers and the body becomes destroyed or becomes so thin that it no longer provides a valid thermic isolation. Moreover, animals lose their ability to stay afloat; some drown, others are pushed ashore and are thus subjected to preying animals. It is calculated that each year thousands of birds die and the phenomenon is so vast and preoccupying that in England there have been built suitable centers of shelter, cleaning and rehabilitation for the birds struck by the tide of petroleum.

Contamination of the atmosphere

Air pollution is more advanced in the Northern Hemisphere thanks to the factories of America and Europe. These factories, as well as all combustion motors, emit fumes which contain carbon dioxide. This carbon dioxide is produced by burning oxygen; therefore it corresponds to the disappearance of a certain quantity of oxygen from the atmosphere. The decrease of oxygen is not so preoccupying as the increase of carbon dioxide. The conclusions of the research of the International Geophysical Year indicate an increase of about 0.2% per year, with a gobal increase which from the beginning of the industrial age can be estimated at about 10%. If the increase of carbon dioxide in the atmosphere continues at this rate, and nothing concrete is done to combat it, the damage cannot be evaluated. The increase of CO_2 causes an increase in the temperature of the atmosphere and this will cause the polar ice to melt, with consequent increase in sea level and the flooding of the cities on the coast. Against this there has been proposed an increase of planting when the woods are cut.

It would be necessary that motors and furnaces be perfect so as to burn all the CO_2 in very pure fuels. In effect, the equipment for purification which the strictest regulations impose on the factories and that they are trying to apply to combustion motors have exactly this aim. But there are even today factories which emit sulphurous products, nitrous gases and even fluorides.

Sulphur dioxide, in itself very toxic, is oxidized and combines with water, thus becoming sulphuric acid. The result is acid rain. The physical action of this rain is seen in the plants which die and in the monuments of cities which are rapidly eroded. In a few decades statues and bas-reliefs of marble in Venice have very seriously felt the effect of this action.

The nitrogen oxide which is formed in combustion becomes nitrogen dioxide through the action of the atmospheric oxygen. Nitrogen dioxide has a reddish brown color and absorbs the solar light in the area between blue and ultraviolet. There is thus a photochemical process which leads to the reformation of nitrogen dioxide and atomic oxygen. This oxygen combines to form ozone and oxidizes a great variety of substances, among which are many residues of hydrocarbons not completely oxidized by combustion motors, as demonstrated by a symposium held at this Academy. There follows the formation of substances such as peroxyacylnitrates and formaldehyde which are irritating to the eye. This is the case of Los Angeles in recent years. They are at present trying to avoid this although the classic smog has irreparably damaged plants and endangered the very life of the citizens.

REFERENCES

AMMERMAN A.J. and CAVALLI SFORZA L.: The Neolithic Transition and the Genetics of Populations in Europe: *Princeton Univ. Press 1984.*

BATES M.: Man in nature: *Prentice Hall N.J. 1964.*

CLARK G. World prehistory in new perspective: *Cambridge Univ. Press 1977.*

COMMONER B.: Il cerchio da chiudere: *Garzanti, Milano 1972.*

CHIGI A.: La natura e l'uomo: *Editrice Studium, Roma 1965*

MARINI BETTÒLO G.B. ed.: Study week on chemical events in the atmosphere and their impact on the environment: *Pontif. Acad. Sc. Scripta varia 56, 1985.*

MERCHANT C.: La morte della natura. *Garzanti, Milano 1988*

MICKLIN P.P.: Desiccation of the Aral Sea: A water management disaster in the Soviet Union: *Science 241, 1170, 1988*

PAVAN M.: SOS pianeta terra: *Lipo-Tipo M. Ponzio, Pavia 1969*

PAVAN M.: Dissesto ecologico fame e insicurezza nel mondo: *2° edizione Meroni Tip. lit. edit. Albese, Como 1987.*

RANZI S.: La protezione della natura e alcuni problemi di ricerche scientifiche: *Natura e Montagna 6, 112, 1966.*

RANZI S.: Il problema della conservazione della natura e delle sue risorse: *Atti XLIX riunione SIPS 2, 641, 1968.*

RANZI S.: La Biologia marina e il Mediterraneo. *Acc. Naz. XL Rend. Sc. fis.* (5) *5, 67, 1981.*

RANZI S.: Pace scienza e scienziati: *Cultura e Scuola 89, 197, 1984.*

RANZI S.: Inquinamento atmosferico e piogge acide: *Cultura e Scuola 98, 217, 1986.*
RANZI S. E CIGADA LEONARDI M.: Istituzioni di Zoologia *7ª ed. Casa Editrice Ambrosiana, Milano 1988.*
TIEZZI E.: Tempi storici, tempi biologici *Garzanti, Milano 1984.*

DISCUSSION

DÖBEREINER

I think the question of reforestation and burning forests, or not burning forests, very easily becomes an emotional question. I was very interested to see Professor Ranzi's attempts to explain some scientific problems because I do think that we know so very, very little, and it is so important that we do much more in science on explanations related to matters such as desertification. Twenty years ago one thought that in ten years one would be able to say scientifically why desertification occurs, yet today we are still unable to stop desertification because we do not really know what the real reason is. The same, of course, is the case with forests. For example, for centuries there has been a traditional knowledge of how to exploit temperate forests. There is no knowledge of how to exploit tropical forests. There should be, but there is no research on this. A farmer could make a living on a piece of forest land if he only knew, or if science could tell him, how to cut certain trees to guarantee the regeneration of the forest and keep the tropical forest as it is. This should certainly be possible, but there is no scientific knowledge about it.

There is one point I would make here which only became clear for me in the meeting we had last week on *Agriculture and Quality of Life.* There we talked a lot about ecological problems and forests. One of the major problems of ecology in terms of burning forests (or what is thought to be one of the major problems of burning forests) is the increase in CO_2, which everybody says results from the Brazilian forests being burnt. I don't think that, scientifically, you can say this. Any biomass which is burnt is in fact only the product of photosynthesis which has been incorporated into the vegetation. If, for example, we burn a forest which was built up by photosynthesis in a lifetime, in our lifetime at least, it can only increase the CO_2 content of the atmosphere by the amount which has been in fact fixed. If we go further, and if you replace the forest by, let's say, a sugar cane plantation, the sugar cane will grow much faster than the forest, and the sugar cane will in fact take up from the atmosphere much more CO_2 than we have released by burning the forest. So I

think these things need more scientific study. If, for example, we devise a project which envisages burning some forests, whatever they may be, but reforesting them again, wouldn't this be better than enhancing the exploitation and burning of coal and oil which comes from the subsoil? Since biomass is a closed cycle, when we burn coal or oil we bring up carbon which has been accumulated for millions of years, and we add this to the CO_2 of the atmosphere. Of course I am not in favour of burning forests, certainly not, but I think that these sorts of considerations have to be taken into account. Certainly, I think much more research and better scientific bases are needed to confirm all these emotional hypotheses which are so often mentioned and which frequently influence certain strategies which are not always justified.

GARNHAM

Professor Ranzi's presentation was very interesting from the historical point of view. I think this subject of deforestation is also very important from the point of view of public health and the provision that these forests make for certain tropical diseases which are carried by mosquitoes and other forest insects. Of course, if the forests are entirely abolished, certain species will disappear. Incidentally, the monkeys will disappear, and they are the reservoirs of these viruses such as yellow fever. But on the other hand, the absence of forest contributes to the breeding of very dangerous species of Anopheline mosquitoes which caused severe epidemics in Brazil, for instance, in the 1950s. So I think the importance of forests in relation to public health and diseases is a question that should be carefully considered when the forests are altered.

RANZI

Par exemple, on peut toujours se souvenir de ce qui est arrivé à Madagascar. A Madagascar, il y a deux mille ans quelqu'un est venu de l'Arabie et a apporté une agriculture qui n'était peut-être pas très bonne pour le terrain. Le résultat à present c'est que les neuf-dixièmes de Madagascar sont un désert.

MARINI-BETTÒLO

I should also like to say something about what was discussed in the Study Week on *Agriculture and Quality of Life*. Certainly deforestation is one of the first concerns about the future environment, but I think that it is not only a

question of substituting sugar cane plantations for the trees. It's a question of the soil. The soil in some regions, because of its chemical composition, its low level of humus and even other factors, like the climate, is subject to becoming infertile and unproductive. This is the great fear, not deforestation itself, because we can always reforest or do something else. This means that more techniques, more biotechnology, should be applied to the present cultivated land, not to the forests, to ensure increased harvests and so to have better crops and food for everyone. This is, I think, the way to protect the forests: we must give to cultivators the means to get better crops from their land so they do not leave the land which has become unproductive.

RANZI

Il ne faut pas oublier que la nature, comme nous la voyons à présent s'est formée pendant des millions d'années. Si on détruit une forêt, si on change le cours d'un fleuve, on change en peu de temps ce qui fonctionnait très bien pendant des millions d'années.

DÖBEREINER

I think I was misunderstood. I am the last person in the world to defend the burning of forests. I personally have a farm where I never cut a tree, ever. I just wanted to make the point that it is necessary to make more scientific investigations in order to understand how the ecology works. If this is not done, the emotional subject will take over and this is bad. This is the only point I wanted to make and I do not defend burning forests.

RESPONSIBILITY OF SCIENCE: HOW NEUROSCIENCE RELATES TO MENTAL EXPERIENCE

JOHN C. ECCLES
Ca' à la Gra, Contra, Switzerland

This is a rather specialized talk, but I think most significant for mankind. There is a unique responsibility that is largely overlooked by neuroscientists, who have made excellent programs for the scientific understanding of the brain.

However, the great majority of neuroscientists do not wish to consider the philosophical problems that inevitably arise when studying the cerebral cortices of man and animals. There is now general agreement that conscious experiences are in some mysterious way related to the activity of the cerebral cortex. The usual materialist explanation is the so-called *identity theory,* which evades the problem by the dogmatic assertion that *neural «events» in the higher levels of the brain are identical with mental events — thoughts, intentions, imagination.* All of our conscious experiences are thus explicable as being essentially materialistic and have no autonomy or effectiveness. *Free will* is an illusion, as also is *moral responsibility.*

Two recent experiences have triggered me to make this intervention, in which I stress a special responsibility of neuroscientists:

(1) I attended a conference *Geist und Natur* organized by Chancellor Albrecht and Karl Frederich von Weizacker at Hannover in May. I was horrified at the resurgence of irrationality in the most bizarre forms in movements calling themselves *The New Age* and *Postmodernism.*

A large part of the audience of about 1500 were devotees of such cults as Astrology, Taoism, Homeopathy, Alternative Medicine, Mysticism and Eastern cults, Tai ji, Tarot cards, Witchcraft — you name it. The bookshop catered for them. They were opposed to the scientific study of the human body and to the education of the young about their bodies. They want ignorance so that they can practice their magical techniques in curing the sick, to the great

profit of the practitioners of *alternative medicine.* The public are lamentably ignorant of their bodies and brains and lack any appreciation of the necessity for critical rationality in assessing the falsity of the pervasive irrationality. For example I give the dominance of astrology and the wide variety of magical healing techniques. Also Professor Runcorn mentioned the dangers of another irrationality, Creationism, in America.

(2) My second experience has been in the conference that has just been held on the brain here in the Academy. It was a good conference with wonderful accounts of a wide diversity of studies on the human brain. There were several contributions that did deal with the mind-brain problem in a constructive and creative way. But for the most part the relation of the brain activity to conscious experience was neglected.

At the end of the conference the distinguished senior American, Mountcastle, expressed dogmatically the statement that our knowledge of the brain was inadequate for dealing with the brain-mind problem. So for 20 years neuroscientists should *concentrate exclusively* on the brain, using such techniques as in neuroanatomy, neurocommunication, control systems, neurophysiology, etc. There seemed to be general agreement, at least there was no overt protest, though it was expressed several times later.

In contrast, early this week I had proposed a general theory of unitary mind-brain interaction that I believe opened up great vistas of investigation.

In the light of my Hannover experience at the conference *Geist und Natur* and the burgeoning literature on minds discussed irrationally with no reference to the *scientific understanding of the brain,* I have come to realize that neuroscientists have to accept the mind-brain problem as urgently needing their dedicated attention. If we follow the advice of the materialists with a 20-year moratorium on the scientific study of the mind-brain problem, then the irrationalists of all varieties, including the science fictionalists, will take over the *ideology of mankind.* This disaster can be checked only by neuroscientists who struggle with the scientific and philosophical problems of our spiritual nature as is illuminated by our rational critical study of the brain and conscious experience. We must not be inhibited by the materialists. This is the unique responsibility of the neuroscientists.

NOTE: *Sir John Eccles' presentation having been given at the very end of the day's Session, there was unfortunately no time for discussion or comment.*

THE RESPONSIBILITY OF SCIENCE

DAY THREE
29 OCTOBER 1988

SPECIAL SESSION HELD IN BOLOGNA
AT THE INVITATION OF THE UNIVERSITY
OF BOLOGNA
TO CELEBRATE THE 900th ANNIVERSARY
OF ITS FOUNDING

EXCHANGE OF OFFICIAL GREETINGS IN BOLOGNA

INDIRIZZO DI SALUTO AGLI INTERVENUTI

PROF. FABIO ROVERSI MONACO
Rettore dell'Università di Bologna

Presidente Prof. Chagas, illustri Signori Accademici, Colleghi, Signore e Signori, la visita della Pontificia Accademia delle Scienze ha un carattere di eccezionalità che ben si collega alla eccezionalità dell'evento vissuto dal nostro Ateneo nel corso del 1988. Di questa visita, unica nella storia dell'Accademia che non ha mai tenuto le proprie sedute plenarie al di fuori di Roma, ringrazio il Presidente, gli Accademici, e fra questi in particolare il nostro collega Prof. Puppi, per la grande sensibilità manifestata.

Il tema, quello della responsabilità della scienza, appare in grande interesse e degno di concludere quest'anno di incontri scientifici di grande livello.

Più volte abbiamo inserito fra gli argomenti oggetto dei nostri lavori tematiche di carattere interdisciplinare, volte ad affrontare grandi problemi della ricerca, della scienza, dell'insegnamento: così è avvenuto per il Convegno di apertura del Centenario, così per il Convegno principale dello scorso settembre, così per i Convegni su Università e Ricerca.

L'argomento affrontato dagli Accademici completa le tematiche di ampio respiro da noi affrontate, poiché è indubbio che la responsabilità della scienza sia continuamente crescente. Ogni giorno è più incisivo l'impatto della scienza sulla vita dei singoli, delle comunità, delle società organizzate, ed i problemi etici che ne derivano assumono nelle nostre menti e nei nostri cuori crescente rilievo.

Di questa esigenza volta a richiamare i grandi temi ed i grandi principi, di questa esigenza di chiarezza è espressione la firma solenne, avvenuta in Bologna il 18 settembre di quest'anno, della Magna Charta delle Università.

Firmata inizialmente dai Rettori europei, perché nata nell'ambito delle Università europee, essa ha poi avuto la convinta adesione e la firma di tutti i Rettori degli altri paesi e degli altri continenti convenuti a Bologna.

Vorrei ricordare in questa sede due principi contenuti nella Charta. Anzitutto l'affermazione che l'Università deve assicurare alle generazioni future una

educazione e una formazione che consenta di contribuire al rispetto dei grandi equilibri dell'ambiente naturale della vita. In secondo luogo l'affermazione che, per essere aperta alle necessità del mondo contemporaneo, l'Università deve avere, nel suo sforzo di ricerca e di insegnamento, indipendenza morale e scientifica nei confronti di qualsiasi potere politico ed economico.

Sono principi ovviamente condivisibili ed anzi, sotto un certo profilo — potrebbe sembrare, ma soltanto sembrare — superflui. Ma non è così. Voglio ricordare, in questo mio breve intervento di saluto, che questo ruolo dell'Università, come formatrice non soltanto di uomini con capacità professionali, ma di uomini veri, e nello stesso tempo questa rivendicazione di indipendenza e di autonomia, comportano per le Università medesime, come strutture, e per i Professori universitari, come uomini e scienziati, l'assunzione di precise responsabilità.

Il problema morale della responsabilità della scienza, della responsabilità morale del ricercatore e dello scienziato mai come ora è stato rilevante e mai come ora risulta compenetrato con le attività di ricerca e, per l'inscindibile legame che le collega, con le attività di insegnamento che si svolgono nei nostri Atenei.

Signor Presidente della Pontificia Accademia delle Scienze, voglio dunque rinnovarLe il ringraziamento più sentito dell'Università di Bologna per avere tenuto qui, in quest'Aula dello Stabat Mater dell'Archiginasio, questa sessione pubblica dell'Accademia che altamente ci onora.

WELCOMING ADDRESS ON BEHALF OF THE UNIVERSITY OF BOLOGNA

PROFESSOR FABIO ROVERSI MONACO
Rector of the University of Bologna

President Chagas, illustrious Academicians, colleagues, ladies and gentlemen, this visit of the Pontifical Academy of Sciences, being of an exceptional nature, is very much in keeping with the extraordinary character of the event taking place in our university throughout 1988. This visit is unique in

the history of the Academy, since it has never held a plenary session outside Rome, and I thank the President and the Academicians one of whom is our colleague Professor Puppi, for their gracious presence here.

The theme, "The Responsibility of Science", is clearly of great interest, and is a fitting one to conclude this year of high-level scientific meetings.

Among the topics which have been the object of our interdisciplinary efforts, we have included on several occasions those which address the major problems confronting research, science and education. This was true of the conference which opened our Centenary, it was true of the main conference this past September, and it was true of the conference on the University and Research.

The theme which the Academicians have chosen to examine complements the wide-ranging subjects we have approached, seeing that without a doubt the responsibility of science is a continually increasing one. Each day the impact of science on the lives of individuals, on communities, on organized society, is becoming more incisive, and the related ethical problems assume greater prominence in our minds and in our hearts.

It is just this need to turn our attention to the great questions and the great principles, it is just this need for clarity, which is expressed in the solemn signing of the Magna Charta of the Universities which took place here in Bologna on the eighteenth of September this year.

It was signed first by the European rectors, since it was among the European universities that it came into being, and then it received the firm support and the signatures of all the rectors who had come to Bologna from other countries and other continents.

I should like to bring to mind, in this context, two principles contained in the Magna Charta. In the first place, the affirmation that the university, must ensure that future generations will receive an education and training which will enable them to foster respect for the equilibrium which must be maintained in the natural environment. Secondly, the affirmation that, in order to be open to the needs of the contemporary world the university, in its research and teaching endeavours, must have moral and scientific independence with regard to all political and economic powers.

These are principles which are generally assented to and thus, in a certain light, they might seem — but only seem — to be superfluous. They are not. I should like to stress in this brief address that this function of the university as a shaper not only of persons with professional training but of truly human beings, and also this insistence on independence and autonomy, mean that the university as a structure, and the university professors as men and scientists, must take upon themselves definite responsibilities.

Today more than ever, both the moral aspect of the responsibility of science and the moral responsibility of the researcher and scientist are great; and today more than ever this responsibility is inseparable from research work and from the teaching activities which take place in our universities.

Mr. President of the Pontifical Academy of Sciences, I wish therefore to express once again the most sincere thanks of the University of Bologna for the signal honour of holding here, in the Stabat Mater Aula of the Archiginasio, this public session of the Academy.

SALUTO DELL'ACCADEMIA DELLE SCIENZE DI BOLOGNA

ALBERTO PASQUINELLI
Presidente dell'Accademia delle Scienze di Bologna

Signor Presidente e Magnifico Rettore, è con profondo piacere che mi unisco al saluto porto or ora ai convenuti e ringrazio tutti i presenti per la partecipazione a questo incontro.

Ciò che vorrei sottolineare ricalca esattamente i motivi che sono stati appena posti con tanta chiarezza e tanto vigore da chi mi ha preceduto. Ritengo anch'io che la responsabilità del sapere, la responsabilità dell'insegnamento scientifico mai come oggi appaiano tanto rilevanti in una società che è di fronte a compiti di estremo rilievo per le profonde trasformazioni, i grandi problemi che vanno affrontati e risolti.

Sono lieto di vedere tra i presenti tanti colleghi dell'Accademia delle Scienze di Bologna che hanno gentilmente espresso il desiderio che prendessi la parola a nome di questa istituzione. La nostra istituzione è ormai vecchia di oltre due secoli e in quanto tale ha al suo attivo un patrimonio di esperienze e di acquisizioni storiche che credo possano molto proficuamente essere messe a frutto in questo momento, in questa circostanza di profondo rinnovamento culturale, quale almeno ci si auspica che possa aver luogo nei prossimi decenni. Si tratta di favorire una svolta peraltro fortunatamente già avvertita e segnalata da molteplici centri di cultura a livello internazionale verso un orientamento

dell'insegnamento superiore e delle attività culturali a livello di atenei e di accademie sempre più ponderato, sempre più razionale, sempre più ispirato alla serietà profonda e all'impegno che tradizionalmente sono propri della ricerca scientifica più autentica. Credo che difficilmente tanti stimoli fondamentali e tante suggestioni quanto mai appropriate possano venire da occasioni che non siano come la presente, ove illustri maestri provenienti da settori disciplinari diversi, da mondi culturali diversi ecc., danno prova di un orientamento costruttivo e di una volontà di fare a livello di cultura accademica veramente quanto mai stimolante e promettente.

Non mi resta che concludere questo breve intervento se non auspicando che l'inizio costituito dall'incontro odierno abbia un seguito sistematico e costante con l'istituzione e lo sviluppo di rapporti organici tra la Pontificia Accademia delle Scienze e le istituzioni della nostra città che si muovono a livello culturale universitario o, comunque, superiore. Oltre ad esprimere questo auspicio sono lieto di esprimere anche il fermo intendimento e l'impegno quanto meno di tutta l'Accademia delle Scienze di Bologna, che, nel solco della propria oramai bisecolare tradizione di forte impegno scientifico, critico, metodologico e interdisciplinare, può garantire su questa linea.

Quindi ringrazio ancora vivissimamente i convenuti, il Magnifico Rettore dell'Università di Bologna, che tanto ha operato in questa direzione e che tanto continua a fare e, ci auguriamo, tanto potrà fare negli anni futuri. Ringrazio come è doveroso in modo particolare i presenti che sono venuti anche da lontano per dare forza e sostegno a questa iniziativa, e voglio vivamente sperare che da questo nostro lavoro possano poi discendere delle sollecitazioni per una cultura finalmente libera da sovrapposizioni indebite, finalmente ispirata ad una profonda razionalità di cui l'uomo del nostro tempo credo che abbia sempre più bisogno. Grazie ancora.

GREETINGS FROM THE ACADEMY OF SCIENCES OF BOLOGNA

PROFESSOR ALBERTO PASQUINELLI
President, Academy of Sciences of Bologna

Mr. President, Rector Magnificus, it is with profound pleasure that I join in the greetings that have just been extended to those gathered here, and I express my thanks to all who are participating in this meeting.

That which I would like to stress is in complete agreement with what was so clearly and vigorously stated by the previous speaker. I fully agree that today the responsibility of knowledge and the responsibility of scientific education are more relevant than ever in our society which faces tasks of extreme importance involving sweeping transformations and enormous problems which must be faced and solved.

I am pleased to see among those present so many of my colleagues from the Academy of Sciences of Bologna who have expressed the desire that I speak on behalf of our institution. Our academy is now more than two centuries old, and among its assets it can therefore lay claim to an accumulation of experiences and historical accomplishments which, I believe, might be most profitably drawn upon at this moment and in the far-reaching cultural renewal which we expect to take place in the coming decades.

It is a question of encouraging a development which, fortunately, many cultural institutions throughout the world have already identified, that is, a more thorough, reasoned and inspired orientation of the instruction and cultural activites of universities and academies toward the serious dedication and involvement which traditionally appertain to authentic scientific research. It is my belief that these many fundamental stimuli and suggestions, which are so appropriate just now, may well come from occasions like the present one, where illustrious scholars from diverse disciplines and sundry cultural spheres display a constructive attitude and a will to act at a level of academic culture that is truly stimulating and promising.

In concluding this brief address, one point remains, to augur that from the point of departure which today's meeting constitutes, there will be systematic and constant sequels, that relationships will be developed between the Pontifical Academy of Sciences and the cultural institutions of our city which are involved with higher education. In addition, it is my pleasure to express the firm intention and commitment of the entire Academy of Sciences of Bologna to continue in its two hundred year old tradition of intense scientific, critical, methodological and interdisciplinary activity.

I extend my heartfelt thanks to the Rector Magnificus of the University of Bologna who has made such great efforts in this direction, who does so now, and who will continue to do so, we hope, in the coming years. I also thank in a special way those who have come from far away to strengthen and encourage this initiative. It is strongly to be hoped that from our common efforts measures will emerge leading to a culture that is finally free from undue pressures, one that is at last imbued with a profound rationality which, I believe, is ever more essential to the human race today.

SALUTO DELLA PONTIFICIA ACCADEMIA DELLE SCIENZE

CARLOS CHAGAS
Presidente della Pontificia Accademica delle Scienze

Magnifico Rettore dell'Università di Bologna, signor Presidente dell'Accademia delle Scienze di Bologna, Vi ringrazio per l'occasione straordinaria offertaci invitandoci qui a Bologna, straordinaria anche perché noi rendiamo omaggio all'Università che è la fonte dell'intellettualità del mondo occidentale. Oso dire che noi siamo tutti, intellettuali del nostro mondo occidentale, figli spirituali dell'Università di Bologna. Per me anche di più, perché essendo uno scienziato non posso dimenticare i grandi scienziati che hanno lavorato qui, per esempio Malpighi, ma voglio citare anche Aldrovandi e Righi. Voglio parlare anche di Spallanzani che non è stato professore qui, ma in questa Università ha studiato. Ho la soddisfazione di possedere nella mia libreria un libro originale di Spallanzani in prima edizione. L'ho comprato negli Stati Uniti. Poi ho conosciuto veramente l'Emilia-Romagna, senza conoscerla, ma leggendo una mirabile biografia fatta da un membro di una straordinaria famiglia di Bologna, che è la famiglia Prodi. Il professore Prodi, ex professore di patologia di questa Università, ha scritto un libro fantastico. Un po' difficile per me da leggere, perché è così bello come italiano che qualche volta sono stato obbligato a ricorrere al dizionario per capire bene. Io non ho conosciuto Prodi, ma mi hanno sempre detto che è stato uno dei grandi professori di patologia in Italia. Io posso dire che scientificamente sono un prodotto dell'Università di Bologna. Perché? Perché mi sono sempre dedicato allo studio delle produzione dell'elettricità degli esseri viventi.

Sappiamo tutti che fu Galvani che per primo dimostrò l'esistenza della produzione di elettricità in esseri viventi. E anche di più, in questo momento devo dire che essendo biofisico ho avuto la difficoltà che Galvani ha avuto nella sua polemica con Volta, questi era molto più rispettato perché a quell'epoca i fisici erano molto più considerati dei biologi, soprattutto di un anatomista istologo come Galvani. E inoltre debbo dire che uno dei libri più preziosi della mia biblioteca è quello di Carlo Matteucci, che ha fatto una descrizione dell'elettricità prodotta dai pesci elettrici più di quarant'anni fa. Il libro di Matteucci è un documentario fantastico sull'elettricità prodotta dalle torpedini. Io ho lavorato con pesci brasiliani, non per ragioni nazionalistiche, ma perché in Brasile non ci sono molte torpedini e nel bacino amazzonico si può ancora tro-

vare questa specie, anche se è una delle 25.000 in estinzione, l'*electrophorus electricus*.

Se dunque, come uomo di scienza, ho molteplici motivi personali per rallegrarmi di questo incontro con l'Università di Bologna, mi si permatta, in qualità di Presidente della Pontificia Accademia delle Scienze, di esprimerne uno e ancora più grande. È da Bologna che è partito per l'Occidente l'impulso originario a quel sapere scientifico universitario che ne ha caratterizzato così radicalmente la storia nell'ultima metà di questo secondo millennio. Ebbene, la presenza dell'Accademia Pontificia delle Scienze alle celebrazioni dei novecento anni della fondazione di questa Università vorrebbe essere un simbolo che indichi come proprio dal sapere universitario e dal suo insegnamento, può e deve venire alla scienza e alle future generazioni dei suoi cultori un impulso decisivo alla presa di coscienza delle crescenti responsabilità che essi hanno verso l'intera umanità.

Con queste parole voglio perciò veramente ringraziare il Rettore e l'Università di Bologna a mio nome ed a nome dei miei colleghi Accademici per questa visita all'Università che è per noi realmente un momento di gloria.

GREETINGS ON BEHALF OF THE PONTIFICAL ACADEMY OF SCIENCES

CARLOS CHAGAS
President, Pontifical Academy of Sciences

Rector Magnificus of the University of Bologna, President of the Academy of Sciences of Bologna, thank you for this extraordinary occasion which you have made possible for us by inviting us here to Bologna. It is extraordinary, also, because the object of our hommage is this University which is an intellectual wellspring for the western world. I daresay that all of us, intellectuals of the western world, are spiritual sons of the University of Bologna. This is especially true of me as a scientist, for I cannot forget the great men of science who have laboured here such as Malpighi, not to mention Aldrovandi and Righi. I should also like to mention Spallanzani who, though he was not a professor here, did study at this University. I have the satisfaction of having in my library

a first edition of a book by Spallanzani which I bought in the United States. Moreover, I got to know Emilia-Romagna without ever having been there, through reading an adimrable biography written by a member of the remarkable Prodi family from Bologna. Professor Prodi, former professor of pathology at this University, has written a marvellous book — a bit difficult to read, as it is in such exquisite Italian that I am at times obliged to turn to the dictionary in order to understand it. I never got to know Prodi, but I have always been assured that he was one of the great professors of pathology in Italy.

I might say that scientifically, I am a product of the University of Bologna. Why? Because I have always concentrated on studying the way living creatures produce electricity. As we all know, it was Galvani who first demonstrated the existence of electricity produced by living creatures. Moreover, I must say that, being a bio-physicist, I have had the same difficulty Galvani had in his disagreement with Volta, who was given much more respect because, at that time physicists were held in greater esteem than biologists, and certainly moreso than a histological anatomist such as Galvani. I must also mention that one of the most precious books in my library is that of Carlo Matteucci who, more than forty years ago described the electricity produced by electric fishes. His book is a fantastic documentary on the electricity produced by the torpedo, or electric ray. I have worked with Brazilian fish, not for any nationalistic reasons, but because in Brazil there aren't many electric rays, whereas in the Amazon basin the species *electrophorus electricus* can still be found, even if it is one of the 25,000 species heading for extinction.

If as a man of science I have multiple personal reasons for rejoicing on the occasion of this encounter with the University of Bologna, permit me, as President of the Pontifical Academy of Sciences, to express a far greater reason. It is from Bologna that the western world received the original impulse which led to the universities' search for scientific knowledge, a search that has so radically characterized the history of the last half millenium. Seen in this light, the presence of the Pontifical Academy of Sciences at the celebration of the nine hundredth anniversary of the founding of this university may be considered symbolic. It exemplifies how our universities, in acquiring and imparting knowledge, can and must bring to science and to future generations of science-practitioners a decisive awareness of their constantly increasing responsibilities toward all of humanity.

With these words, then, I wish to thank the Rector and the University of Bologna on behalf of myself and of my fellow Pontifical Academicians for this visit to the University, this moment of glory.

SCIENTIFIC PAPERS PRESENTED IN BOLOGNA

THE RESPONSIBILITIES OF UNIVERSITIES IN DEVELOPING COUNTRIES

CARLOS CHAGAS
President, Pontifical Academy of Sciences

The question proposed by John Cardinal Newman more than 100 years ago: "What is a university?" is still valid nowadays, and has become one of the foremost preoccupations of all women and men who meditate on the future of mankind and on the place of learning and reflection in a rapidly changing society.

The question proposed by Cardinal Newman is still present in the minds of the political, social and economic élites of the developing countries, as much and maybe more acutely in their privileged younger generations who may attain higher education and are many times unhappy with what the universities give to them.

In the developing countries the question has to be extended in two directions: "What is a university for?" and "How should a university be organized?" How difficult the answers are to these questions!

Though the theme is broad and momentous I can only give some very brief answers to these questions, but I would like to see if we could deal briefly with the still more important question: "How can the developing countries utilize the universities, or should they not even do so and create instead specialized institutions to overcome the manifold problems — spiritual, societal, and economic — that they have to face now and in the near future in order to assure their place in an ever-changing world?

The university, I wish to declare at once, is the only approach for a harmonious and homogeneous development. To reflect on a university, some of the ideas of Newman may still be valid, at least partially. By his definition these institutions are created essentially for the increase of knowledge, to which we must add, also for the holistic approach of their multi-faceted aspects.

It is my opinion that a university must be considered essentially as a research institute and not as a teaching institute. It can teach only because it searches.

So it is only because it undertakes research in all fields of its activity that the university can render services to society. This is a concept which is not easily accepted by many of the societies of the developing countries, which prefer, unfortunately, to import knowledge from abroad rather than to establish their own centres for the creation of knowledge.

The expression "research" requires a well established infrastructure where services occupy a major place. It must provide for sources of information, libraries, video systems, organization of seminars, equipment, formal and informal meetings and a permanent exchange with national and international intellectual communities, elements to be used with Freedom, Autonomy and Universality, the three pillars of a university.

Can developing countries afford this structure, which implies large endowments, or can they progress by developing knowledge in isolated institutions? This is a question which cannot be answered in a simple way. Should these endowments come from governments — a case in which severe loss of autonomy is unavoidable, or from private funds difficult to find?

The idea that the university must be a research institution is accepted with great difficulty by the ruling classes, political or economic, of the developing society because, in general, they do not see the university as a dynamic institution and many times are afraid that the liberal ideas which are the natural outcome and climate of the university may be dangerous for the existing political system.

I firmly believe that the university cannot neglect the spiritual, moral and ethical values in all their programs. This is a duty which can be exercised by universities in developing countries only with great difficulty, because of the pressures they are under from a society eager to obtain social development based only on prompt economic development.

The duty to safeguard spiritual, moral and ethical values is not confined only to religious institutions, to which they are intrinsic. It pertains also to secular establishments of higher learning. In order to protect human rights, moral, spiritual and ethical values must be brought to bear so that the university can exercise one of its foremost objectives: the full maturation of its students as human beings.

Furthermore, by creating knowledge in its various fields, and in recognizing the needs of the people, the university can contribute to the formation of the image of a nation, which is not formed by its military power, economic strength, industrial display, advances in technology or intellectual culture, but mostly by the habits, customs and ideals of the common people.

National culture — in the broad sense we give to it today — which is not nationalistic, is needed to keep the image of a nation and to avoid a world

of a single culture leading to neocolonialism, which can be established by the strength of economic power or by military occupation. Any university, and essentially those in developing countries, has to protect and recover the history of its traditions, the background of its societal heritage, to respect the genetic elements of its people. This protection and recovery are essential because the most profound roots of the existence of a civilisation are necessary to constitute the future of a people.

The universities of developing countries should carry on some activities in which they would follow Newman's ideas. They have to promote reflection on man's position in the world, to perfect the intelligence of the younger generation and thus increase its capacity for thought and criticism, and to locate in the mosaic of our learned knowledge the new ideas, concepts, and intellectual achievements of our times.

How can the universities of developing countries achieve this purpose, which needs philosophical, sociological and theological studies, quite often neglected in the universities of the Third World, whose policy is much more devoted to a world of science and technology and where the creative activities have so many times been marginalized?

I wish now to comment on the way in which the university in the developing countries can face the needs of the society. This responsibility cannot be dismissed, because we are well aware of the fast-moving trends of our times, whether in human behaviour or in social changes. The technology based on the scientific revolution, brought by the scientific achievements obtained during the Second World War and afterward, has modified completely our lives and has undoubtedly upgraded in many regions of the world the quality of life, but has brought also the dominance of economic power, and with it the consumer stage.

It is the duty of the universities to shape the best of those who may contribute to the progress of the nation and to improve the human condition. Literature and fine arts are a part of this activity, which extends itself to other fields of intellectual research, such as history and, for instance, linguistics, which may be considered a good bridge between the science of the human being and the sciences of nature.

How can universities in developing countries satisfy the needs for humanpower in the field of research and development? I believe that there must be a first stage of preparation in the country itself, and in my opinion an indication of development is recognizable when a less developed country becomes able to establish institutions of higher learning capable of performing this first stage of preparation.

However, this is a difficult job for universities placed in countries asphyxiated by an insufferable foreign debt, and where misery, and sometimes hunger, are prevalent and an alienated upper class pays no attention to the importance of the universities' goals.

Neglecting the human arts and suffocated by rigid curricula which do not allow for the development of the intellectual plenitude of their students, science and technology are the major priority of governments and universities of developing countries. This policy is justified by governments and universities on account of the existence of a competitive world, forgetting that the spiritual and religious values make life, the great gift of God, pleasant.

Pure science enlightens the spirit of man and must be supported in the developing countries because it is the assurance of the future of its people. It has to be undertaken at the university. The claim against its support is the expenses involved, even if these expenses are in various places a very small part of what some developing countries are spending for military purposes, not always for defense but for the maintenance in power of political parties, and to enhance prestige. Then too, there is the unnecessary importation of goods which could be produced by the country itself.

Let me proclaim that science and technology, directed as they are increasingly every year to military, economic and political power, cannot by themselves upgrade the conditions of human life. On the contrary, they must be geared to the benefit of women, men and children. This however can only be done if they are combined with a knowledge of human beings and their societal needs.

The common man, in his anonymity, must also be a preoccupation of each member of the university, be he a poet, a scholar, a philosopher, a scientist, a technologist or a musician in the developing countries. The common man has a right to know the consequences, good or bad, of what the university is doing. Thus the concept of the university as an ivory tower has no right to exist any more. We members of the university have the obligation to explain to the common man what we are doing. This was the advice once given to me by Pope Roncalli.

Let me say again that the goals of the university in any part of the world, mostly in developing countries, cannot be drowned by curricula directed only toward professional careers. Even a professional curriculum must be blended with the real needs of a human being. How painful it is for me to see, in developing countries, economic planning structures being created in a cybernetic way, without any observation of the human and social implications, or medical technology forming a barrier between the physician and the patient needing spiritual comfort and understanding.

Let me affirm that I am not pleading for universities to produce only gentry, which is an idea of the past. What I wish to express is that universities in every part of the world, but mostly in the developing countries, should not only prepare human beings "for all seasons" but also for the period after commencement. I want to stress that the universities in less developed countries should prepare their graduates so they will be able to deal with the problems of their human and natural environment and not limit themselves to a rigid specialization which would close their eyes to the changes which we observe around us and which will certainly increase in the future. They must participate in some way in the movements which promote international understanding, which fight for peace, which eradicate misery and racial discrimination, and they must involve themselves, whenever possible, in the fight against nuclear war, in the protection of the environment, and in the defense of human life.

There are still many questions I would like to take up. What have the universities of developing countries contributed to the social development of their nations? Are they the responsible representatives of the national cultures they should be? What are the difficulties the universities in developing countries meet?

The answers to all these questions would take a long time, but all of them are the consequence of the ignorance which governments and societies have of the cultural-formative role universities must play. Economic difficulties, as was said, do not allow for the infrastructure that a university must have. Full-time employment does not exist, and faculty members have little time for reflection and research. They have to find supplementary jobs. Political decisions are taken after a long period of time. The little money allocated to research is mostly used for that research which brings rapid returns. Many, if not all the programs, are developed in the universities of developing countries without sustainment of basic sciences. Resources for the other aspects of culture are missing, which shows the lack of interest in the real development of a university.

The establishment of a university is a special undertaking. In general, universities have been copied from the model of the former cultural powers — in Brazil, for example, they were copied from the French model. Although the adjustment of a university to the culture of the country is a step which cannot be undertaken without some difficulty, it must be done. It is clear to me that in some fields, such as science and technology, international methods, even the very advanced ones, must be used, but they should be devoted mostly to national problems. However, in other fields one has to encourage the native spirit and knowledge. Moreover, there is one policy which is fundamental. The pool of knowledge in a country, to which the universities make a major contribution, has to be a national project.

Foreign aid and external collaboration, needed and welcome, must be the result of a cooperative effort and produce not the slightest rupture in the national structure.

The universities must be the heralds of a different social and scientific policy.

DISCUSSION

MOSHINSKY

In connection with the universities and scientific research in developing countries we have to be fully aware of the importance of the national will to carry out this program. I would like to give you an example that is well known to us. In the middle of the last century Japan was completely out of the development of sciences and had no traditions at all in this respect, but the Japanese realized that you could not have a modern society without developing sciences. The countries of the eastern nations are also showing this national will, so a very important point is to be fully aware of the need for this national will, and to create it. And I want to indicate also that, against this, there is in many of the developing countries a kind of feeling in favour of a cultural revolution in the Chinese sense of the word. Instead of thinking in terms of trying to develop the basis for a sound science and a sound university, there is this rejection of the values of science and of the objectives of the university, this type of cultural revolution spirit which we must fight. We must fight this on the one hand, and on the other we must promote the national will in the sense that has already been shown to us by countries like Japan.

CROXATTO

On this special occasion I wish to express my deep appreciation to the Rettore Magnifico of this University. This is an opportunity to convey not only my own gratitude and admiration, but also that of my university, the Pontifical Catholic University of Santiago de Chile.

I fully agree with what Dr. Chagas has expressed about the university and the Third World, and I think we do have the hope of seeing some changes in our country, particularly at this moment. The Rector of our university has clearly stated that one of the greatest tasks for universities in our countries is to

develop science. That is to say that the search for knowledge will be our primary and most fundamental activity.

THIRRING

I cannot speak for the developing countries, but rather for the developed and the over-developed countries. I think the ideals and values which President Chagas has given in his wonderful speech do not apply only to developing countries. I certainly am aware of some of the problems the developing countries have and that we do not have. However, we have our own problems and our own responsibilites, and I think the values and ideals are exactly the same and are just as necessary. In our countries we have developed very much economically, but this does not mean that culturally we are as highly developed as we should be. In fact, I can say that the cultural level of the general public really is very poor. But we are very lucky to have as one of our problems the flooding of our universities with students, because so many people have the possibility of studying. We should not take this as something catastrophic, but as a wonderful opportunity to give a large fraction of the population those scientific values which we cherish. This is an obligation of our universities which we should not neglect.

PUPPI

Most of what we have said about developing countries also applies very well to other countries. But there is one problem that I met in visiting developing countries. You are right in saying that the emphasis should first be on research and then teaching, but don't forget that people who do research in developing countries belong, psychologically, to universities abroad where they were trained. Their idea, at least in the beginning, is to duplicate in their home country what they have seen in the host institution. It takes a little bit of time and good will, and probably the presence of a good guide, a good master, in order that they find in their own culture and their own country the right orientation for doing personal research which corresponds to the typical situation of the problems in their own country. Maybe with this new emphasis on the environment, each country can find objectives which are typical of its own situation, since the environment is different everywhere, and there are also different cultural environments.

CHAGAS

If you allow me to say one thing, Puppi, you are absolutely correct but, in the place where I work, we have divided the work so that every researcher has the duty to teach only four weeks in the year.

Before I give the floor to Dr. Golinelli, I would like to explain that he is a very advanced-minded industrialist who has done much for the development of science.

GOLINELLI

Dott. Marino Golinelli, Presidente, Alfa Wasserman

Grazie Presidente, Professor Chagas. Farò una breve considerazione in italiano. Essa riguarda la responsabilità dell'Università, la scienza, la società, il mondo della politica e di chi in generale ha la responsabilità per lo sviluppo della società. Vorrei in particolare ricordare la responsabilità della scienza nelle Università, nelle imprese e nell'industria. È una responsabilità che deriva da una interazione fra la ricerca universitaria e la ricerca industriale, per uno sviluppo che possa portare ricchezza e possa essere anche a supporto di quelli che sono i bisogni della società e dell'umanità in generale. Quindi la responsabilità della scienza nei confronti della società, la responsabilità dell'Università, è anche legata alla considerazione che la ricerca può avere come ricaduta nel mondo dell'impresa, nel mondo dell'industria. Quindi anche da parte nostra, di chi opera nel mondo dell'impresa, si deve sentire la responsabilità, l'etica appunto che esiste nei rapporti tra l'Università, la scienza e le imprese. Credo perciò che una delle preoccupazioni dell'insegnamento universitario debba essere proprio la trasmissione di questo sentimento di responsabilità ai giovani ricercatori. Grazie.

GOLINELLI, English version

Dr. Marino Golinelli, President of Alfa Wasserman

I should like to briefly consider the responsibility of the university with regard to science, society, the world of politics and those having responsibility for the development of society. I want especially to stress the responsibility of science within the university and within industry. This responsibility is based on the interaction between academic research and industrial research, where the latter can both produce wealth and help those who are in need. Thus,

the responsibility of science to society, and the responsibility of the university, are both linked to considerations of research in the context of business and industry. Consequently, we who are active in the business world must also be sensitive to the responsibility, — indeed the ethics — which are involved in the interrelationships among the university, science and industry. For this reason I believe that one of the concerns of university instruction should be to communicate this sense of responsibility to future researchers.

HUMAN GENOME SEQUENCING AND ETHICAL PROBLEMS OF THE TWENTY-FIRST CENTURY

ALEXANDER RICH
Department of Biology. Massachusetts Institute of Technology
Cambridge, Massachusetts 02139 U.S.A.

Developments are now taking place in our study of the molecular basis of genetics which suggest that within the next decade or two we will have fairly complete information about the molecular structure and, more specifically, the molecular sequence information in the human genome. This is a significant development in science and one which will profoundly broaden and deepen our understanding of biological problems in general, and of *Homo sapiens*, ourselves. This development is the outgrowth of an astonishingly rapid rate in the growth of molecular biology, i.e., molecular analysis applied to biological phenomena. The central area in this effort has been the understanding that the nucleic acids provide the molecular basis of inheritance, and that DNA contains the genes which are inherited from parents and passed on to progeny. DNA was virtually unknown to the general public three or four decades ago, but it has now been incorporated into the vocabulary of the educated public.

The genome

DNA has the form of a double helix and it is made up of two complementary strings of nucleotides which have different bases. There are four different types of nucleotides, each with individual bases. The two strands in DNA are held together by base pairs. The bases are analogous to letters in an alphabet, and their particular sequence may be thought of as generating words and information in much the same way that letters in a language generate information. A certain fraction of the base sequences in DNA are used to specify proteins which are the molecular machinery of the cell. Proteins are made out of

20 different amino acids and the bases in one strand of DNA are decoded in groups of 3, each of which specifies one amino acid. These are called "coding sequences" in DNA, that is, nucleotide sequences that act by specifying a string of amino acids which eventually fold up to produce a biologically active protein.

The proportion of an organism's DNA that is used for specifying protein sequences varies. Let us consider two different examples, the common colon bacteria, E. coli, and the human. E. coli contains about 4,000 genes. Each gene may be thought of as containing approximately 1,000 base pairs, that is, enough to specify a protein with approximately 330 amino acids. This would account for a total of 4,000,000 base pairs, which is the approximate size of the E. coli genome. Thus, in the E. coli genome, almost all of the DNA is coding, i.e., it is used for specifying proteins or other molecules which are part of the molecular machinery of the organism.

However, the situation is quite different with higher organisms in general and with the human in particular. It is estimated that the human has 50-100,000 genes. For example, 100,000 genes each containing 1,000 base pairs (coding for an average protein with approximately 330 amino acids) would require a total of 100,000,000 base pairs, (10^8). However, the human genome contains 3,000,000,000 base pairs (3×10^9). Therefore, we estimate that only 3% of the genome may be coding for proteins in contrast to the very high proportion that is found in E. coli. What is the origin of these great differences?

One aspect of this difference was discovered only about a decade ago. In E. coli virtually all of the DNA that code for proteins are found in one piece, i.e., completely continuous. This is not true for the genes of higher organisms. In these organisms, the genes are found broken into pieces with intervening segments of DNA connecting the pieces. Furthermore, the intervening segments connecting the coding pieces are about ten times longer than the coding segments themselves. Thus, if 3% of the human genome represents coding sequences, the actual genes may occupy perhaps 30% of the genome, since only 10% of these genes are coding while the remaining 90% represents the intervening segments.

However, with this modification, we are still left with the fact that DNA, including the intervening segments that code for a known product, such as proteins, may represent only one-third of the human genome, whereas the remaining two-thirds represent sequences for which there is not a known function. Many of these sequences occur in the form of repetitive DNA that is found throughout the genome. This remainder has been called "junk DNA". However, that phrase simply represents a statement of the fact that we do not understand why there is so much DNA in the genome that has no apparent function. It might represent the simple accumulation of non-functional DNA

sequences in a seemingly random manner. But this DNA may also be involved in functions of which we have no understanding at present. What is clear is that it represents the vast majority of the DNA in the genome.

DNA sequencing

It is now possible to determine the sequence of the nucleotide bases in DNA, using chemical and enzymatic methods. A typical sequencing experiment is carried out in the following way. DNA can be cut into specific segments using specialized enzymes called restriction endonucleases. These enzymes cut DNA at different specific nucleotide sequences, producing fragments of different lengths. These can be end labeled with radioactive phosphorus atoms. The fragments thus generated can be separated on a polyacrylamide gel according to length. A single fragment of a specific length can then be isolated for sequencing. The labeled fragment is cleaved at random using reagents that specifically cleave the strands at any one of its individual nucleotides by attacking its specific base. This is a method developed by Maxim and Gilbert. An alternative method involves the polymerization of a complementary DNA strand using a single strand of the fragment as a template. The growing single strand can be terminated at random through the use of specific modified nucleotides that prevent further elongation. This method was developed by Sanger and his colleagues. After using either of these methods, the radioactively labeled DNA can be separated into smaller fragments of different length through the use of polyacrylamide gels. These gels can then be read in the sense that the position of radioactive bands on them can be measured. Each band represents a particular DNA chain terminated at one of the four nucleotides. Using four different lanes on a gel, one for each nucleotide, it is possible, then, to measure where these fragments end on the four lanes and in this way develop the sequence from the gel containing radioactive fragments.

Even more powerful methods have been developed more recently for sequencing. Initially, DNA could be sequenced at about the cost of $1.00 U.S. per base. Now the cost has been reduced to approximately $0.17 per base. Ultimately, with the development of even more sophisticated automated methods, the cost may be reduced to $ 0.01 per base.

Newer methods of DNA sequencing are being developed in many different countries. These newer developments involve automated machines which not only prepare the gels with their DNA fragments but also scan the results and simply print out the DNA sequence. Other methods are being developed which

make it possible to separate DNA of increasingly larger size up to and including DNA that may be as large as the entire chromosome. These newer methods make it possible to produce a physical map of an entire genome.

Physical maps vs. genetic maps

The human genome is found in 23 pairs of chromosomes. Using a variety of techniques, it is possible to isolate these chromosomes individually. In turn, it is possible to break up these chromosomes into different smaller segments, which can then be isolated and maintained as separate entities. At present it is possible to grow such large segments of DNA in bacteriophage lambda cosmids that can contain inserted DNA segments with up to 50,000 base pairs. Even larger segments of human DNA can be cloned with sequences containing up to 1,000,000 base pairs. These are grown in yeast by creating artificial yeast chromosomes that can be maintained in that organism. The yeast artificial chromosome with its larger segment of human DNA would simplify the process of making a physical map.

A physical map consists of segments of DNA which are grown in other organisms separately and organized in a manner that relates their connectedness with each other. Thus, a particular human chromosome might have segments of DNA labeled C, D, E, F, etc., where each letter represents a particular cosmid grown in bacteriophage lambda or an artificial chromosome grown in yeast. The important point is that the fragment C would have a small segment which overlaps with fragment B at one end and a segment that overlaps with fragment D at the other end. Once we have developed this technique, we can make an ordered array of DNA fragments covering the entire chromosome. These DNA fragments can be grown separately, isolated, and even deposited on the same nitrocellulose filter paper. In the ideal case, if one had yeast artificial chromosomes containing 1,000,000 base pairs of human DNA, the entire human genome could be found in a minimum of 3,000 of these. However, with longer overlapping segments it is likely that there would be somewhat more than this minimal number.

There is considerable medical value associated with a physical map of the human genome. This would make it possible to isolate and quickly identify particular genes that are associated with the major genetic illnesses in man. Genetic illnesses are identified through genes that usually manufacture a faulty protein or another faulty gene product. At the present time, we can identify almost 4,000 single gene hereditary illnesses. In some cases, the actual gene

involved in the illness has been identified. In many other cases, the gene has not been identified. However, having a physical map would strongly facilitate such identification.

Sequence map vs. physical map

Using the technique of DNA nucleotide sequencing, a large number of DNA segments have been isolated and their nucleotide sequence determined. These sequences are published and are generally stored in "gene banks", which consist of large computers containing the nucleotide sequence data of DNA coding for a variety of proteins as well as other DNA segments. At present the gene banks contain a total of some 15 million base pairs. This number is growing very rapidly and it represents the total amount sequenced in all organisms. Of the 15 million base pairs now sequenced, 2 million represent sequences from *Homo sapiens*. Of course, this represents only a small fragment of the 3 billion (3,000,000,000) nucleotides found in the entire genome. Nonetheless, it represents a start for the project. It is significant that this sequencing activity was carried out mostly with methods which would now be regarded as somewhat obsolete, as they have been replaced by newer, more powerful, and less expensive methods.

The human genome sequencing project has two major goals. The first goal is to assemble a physical map, that is, a series of DNA segments, either in cosmids or yeast artificial chromosomes containing DNA that is physically linked together in a linear manner in the human chromosome. The second goal is to take each of these individual segments either in cosmids or in yeast artificial chromosomes, and carry out the nucleotide sequencing of each of them. In this way, the entire 3,000,000,000 base pairs in the human genome can then be studied. It is estimated that the first goal, obtaining a physical map, should not take more than approximately 5 years, depending upon the resolution of the physical map and the dedication which the pursuit of this goal entails. There has been some delay in carrying out an all-out pursuit of the physical map because the methods that are used for generating the map have been evolving at a very rapid rate. No one wants to start this project using a methodology that is likely to become obsolete within six months or a year.

Although there has been some thought about the second goal, that of sequencing the individual components of the physical map, likewise there has been no coordinated decision to pursue this as yet. This, too, is related to the fact that newer methodologies are being developed which will make this goal a simple one to achieve.

Ethical problems

Let us for the moment transport ourselves one or two decades into the future and try to imagine how this new knowledge will be incorporated into both the practice of medicine and other activities in society. The medical aspects of this issue are exciting and encouraging. Genetic diseases are caused by changes in genes and the nature of the disease is understood directly in terms of a specific metabolic defect. Therapeutic research in treating this disease is usually greatly facilitated by knowledge of the specific nature of the defect in the disease state.

For example, it is well known that a major disease in developed societies is coronary artery disease associated with the deposition of cholesterol into plaques that line the coronary arteries. Our recent understanding of this disease reveals that it is often associated with a disruption or abnormality in the manner in which cholesterol is handled. Cholesterol is normally found in the blood in what are called low density lipoproteins (LDL). These proteins are normally taken up by an LDL receptor, especially in the liver. The receptor internalizes the lipoprotein, an important step in the metabolic handling of cholesterol. Certain individuals are known to have familial hypercholesterolemia, i.e., a genetic disease in which the cholesterol level is abnormally high. This disease has been found to be associated with a defect in the amino acid sequence of the LDL receptor. Individuals with one defective gene in the LDL receptor are likely to have a higher incidence of heart attacks. Individuals with two modified receptors (one from each pair of chromosomes) have an even higher incidence of coronary artery disease and often die at an early age. Knowledge that this disease is caused by a specific defect in the LDL receptor that is responsible for handling cholesterol has provided an important clue in the development of therapy for this disease. This particular defect is not a minor component of heart disease, since 5% of all heart attacks that occur before the age of 50 are found in individuals who have one defective gene for the LDL receptor. Knowledge of the molecular nature of the defect and its subsequent effect allows us to develop therapy for this illness.

A number of other genetic diseases are quite widespread. Cystic fibrosis is a disease associated with chromosome 7. In the United States, 1/20th of all people who originated in Northern Europe contain a defective gene for cystic fibrosis. Thus, 8,000,000 Americans have the defective gene and one child in 2,000 has two defective genes and is clinically ill. The heterozygote, with one normal gene and one defective gene, does not have the disease, but the homozygote does. At the present time considerable effort is being devoted to isolating the defective gene in order to identify the product of the disease and

thereby uncover the molecular mechanism involved in producing the events associated with the secretory disorders in this illness.

One of the more striking hereditary illnesses is Huntington's disease, which is associated with a defect on chromosome 4. In this disease, individuals with two defective genes (homozygous) are normal until they reach their fourth decade of life. In their 30s, they begin to develop neurological symptoms and there is a gradual but eventually complete deterioration of the nervous system. Individuals who come from Huntington families do not know whether or not they will come down with the disease, but most of them have watched relatives who have succumbed to the illness. At the present time we are able to define the general region of the DNA in chromosome 4 that is associated with Huntington's disease. In the near future it is likely that the specific gene associated with the defect will be pinpointed. However, the information available at present is sufficient to carry out a presymptomatic diagnosis, that is, persons coming from a Huntington family can be told whether or not they will come down with the disease. The ability to carry out this analysis immediately gives rise to an important ethical problem. Should otherwise normal, healthy individuals who are in families that carry the Huntington's disease gene be offered the possibility of having their DNA analyzed so they can know whether or not they will succumb to the disease in a decade or so?

Recently a test of this type was carried out in Boston in which 45 people from a Huntington's family were offered this diagnosis. This was carried out in the context of a study with a great deal of genetic counseling. Thus, individuals were told what the nature of the measurement was and what the probability was of a diagnosis saying that they will succumb to the disease. In this study, 45 individuals were offered this diagnosis and ultimately, after much consideration, one-third of them declined to have the diagnosis carried out and two-thirds actually had the test, together with adequate genetic counseling. In this instance, nothing dire occurred. Physicians were afraid there might be suicides and great distress. What did happen is that there was one divorce, but in many cases, people learned that they were not carriers of the disease and this opened up their lives. It took an enormous burden off them.

This is a single example of the results of a genetic study. However, one can ask in a more general way the following: Will this power of genetic analysis stigmatize people because they realize that they are now prone to certain illnesses? If the analysis is carried out while the people are still *in utero*, in a sense, they could be stigmatized even before they are born. Isn't this an unfair burden to put on a person? Would people lose their sense of human dignity in the sense that they feel they are sort of programmed in a predetermined way? Will they in fact have less humanity because we now have a whole set of genetic

criteria about what corresponds to a normal (or "perfect") person? Earlier in this century we saw the malignant effects of a society that sought genetic perfection, as occurred during the Nazi period in Germany. Does this new knowledge have with it the possibility of substantial abuse which we must guard against?

These are serious issues. With this new methodology, one can make predictions about life expectancy. The number of genetic diseases now known is very great. It includes certain types of Alzheimer's diseases that are associated with chromosome 21, and the common illness diabetes, especially juvenile onset diabetes. More recent studies have been carried out that have defined a genetic basis for manic depressive illness. It is quite likely that the extension of genetic studies will find an even larger segment of mental illness that has a genetic predisposition. Another important inherited disease is familial polyposis, which is associated with a defect on chromosome 5 and often leads to a predisposition for colon carcinoma.

Will genetic tests be carried out in the workplace to determine whether or not individuals are genetically acceptable for particular professions? In 1983, only 1.6% of corporations in the United States had genetic screening for employees. However, since the number of diseases that can now be screened has increased considerably, it is likely that the number of these will increase dramatically. Although it is unfair to stigmatize people, it is clear that genetic considerations have an important bearing on the suitability of people for certain professions. For example, suppose someone is a carrier for Huntington's disease, is that person a suitable candidate for an airline pilot? If his physician knows that this pilot has the Huntington's gene defect and is likely to develop subtle neurological defects in his 30s, is it the physician's duty to inform the airline? The onset of this disease is very gradual but it does involve the loss of control. In a similar fashion, if a person is a carrier of a defect for the LDL receptor and he has a high probability of a heart attack, should that individual be an airline pilot?

What one can see from these few examples cited is that it is not a simple issue. Some arguments can be made for using genetic analysis in the workplace and other arguments can be made which say that these analyses should not be used.

Another area in which genetic analyses have become an issue is associated with insurance companies. At the present time in the United States, insurance companies screen for the AIDS virus, since having that disease strongly biases the survival statistics for the infected individuals. However, other insurance companies might require an analysis of LDL receptors, since heart attacks will also modify the survival statistics of the group. Here one can see that there

is a possibility for discrimination based on genetic analyses and some of this discrimination might be considered unjust and improper.

Genetic analysis has the potential to do a great injustice to people because they can be stigmatized at birth in terms of the likelihood of their having certain diseases. However, they might not actually develop the disease because the biological system is not that fully programmed in all cases. Most diseases are influenced by a great number of external factors. An example may be seen in the genetic defect in the LDL receptor associated with familial hypercholesterolemia. Heterozygotes in general grow up to be adults even though they have a higher incidence of heart attacks. However, if a genetic analysis is carried out at an early stage and the person is known to have that defect in the early years of life, then a variety of dietary measures can be adopted which lower cholesterol. In addition, specific cholesterol-lowering therapies are now available which appear to have the likelihood of strongly reducing the incidence of heart attacks. Thus, the genetic analysis may be looked upon as a double-edged sword. It has the positive possibility of providing information which allows the individual to adopt certain therapies which prolong life. However, it also has with it a negative aspect associated with potential abuses.

Genetic counseling is now a well developed part of medicine. In some states in the United States, genetic screening of newborns is required for certain diseases. For example, in phenyl ketonuria, there is a defect in the gene that is involved in metabolizing phenylalanine. These children must be kept on a diet free of phenylalanine in order to prevent mental damage. The damage can be prevented due to genetic screening of newborns. Another method of genetic screening is *in utero* amniocentesis. Here it is possible to analyze the cells from the fetus and discover in advance what genetic defects are present. This brings with it the very serious question about the decision to abort the fetus in the face of substantial genetic defects. This is always a wrenching and difficult problem. This newer information will not change the issues associated with abortion. All it does is provide a broader knowledge base that can be used in making a decision. However, the decision itself is a profound one that requires considerable genetic counseling.

Another element of this new genetic knowledge is the prospect of what is now called gene therapy. In many illnesses, the cause of the disease is pinpointed to the absence of a particular gene. Therapy for the illness can be obtained by introduction of a correct gene into the individual. Experiments are now under way in which a variety of delivery systems are used to implant a gene into tissues that makes it possible to produce the normal gene product. This type of gene therapy has not yet been carried out on humans, but it is likely that it will be carried out within the next few years. This procedure should

not have profound ethical problems associated with it, but it must be regarded simply as an extension of the practice of medicine. If it is possible to implant into somatic tissues a correct gene for producing a substance which is otherwise abnormal or absent in an afflicted individual and if the presence of this substance can alleviate or cure the disease, then it is clear that one should proceed with this type of therapy. There are a number of important technical issues that have to be resolved, namely the ability to implant the gene safely without any negative long-term side effects. However, these are technical problems that will be developed over the next several years. The development of gene therapy will be an important step forward in our handling of genetic diseases.

There is an important component of this which does have a significant ethical aspect. This has to do with the question of whether one should try to alter the germ plasm, that is, the cells that produce the ova or spermatozoa responsible for the next generation. Here, I think, most people feel that modification of the germ plasm in humans is something that should not be attempted, at least for the foreseeable future. The problem of implanting a single gene into a somatic cell to produce a specific gene product is relatively simple compared with the problem of trying to modify germ plasm. We have only limited knowledge of the complexities of embryological development. Most investigators who embrace gene therapy do not think that working on germ plasm is a desirable goal.

There are some general considerations that should be emphasized. First of all, it is necessary to have an informed public that understands the nature of genetic diseases and the fact that these diseases differ considerably one from another. It is also highly desirable to have an educated public that anticipates and discusses ethical problems associated with genetic information before the problems actually become a practical reality. If genetic screening becomes widespread, methods must be developed to insure confidentiality of the results. They should not be readily available. At present we have one or two decades before many of these problems will become acute. However, as mentioned above, some of the ethical considerations are already at hand and their number will only increase over the next few years. Further, we should know that while at the present time we can think of a number of problems that will develop, it is highly likely that many more problems associated with ethical issues will arise as our genetic knowledge increases. It is necessary to have in place a system for dealing with these problems before they become serious. In the United States there are a number of governmental groups that are now setting up committees to discuss and supervise ethical problems related to genetics. These committees are broadly constituted. They do not consist solely of technical or medical people but have several other lay people who have experience in deal-

ing with ethical problems. The latter group is an important component of any body discussing the impact of the new genetic knowledge.

In the 21st century, we will have a more detailed view of the genetic basis of *Homo sapiens.* This more detailed view has with it both problems and promise. The problems are those dealing with how we use this knowledge. The promise is that we may be able to alleviate human suffering with it. The major ethical challenge is that we do not create more problems for people by abusing this new knowledge.

DISCUSSION

LEJEUNE

Juste un commentaire, Monsieur le Président. J'ai bien sûr énormément apprécié l'exposé de mon ami Rich.

Je voudrais préciser que lorsque nous déchifrerons l'énorme message génétique de l'homme, nous redécouvrirons quelque chose que nous savons déjà, c'est que chacun actuellement vivant est porteur d'au moins un gène très défavorable. De ça nous en sommes sûrs statistiquement. Alors, ceux qui voudraient plus tard jouer à la divinité et choisir parmi les hommes ceux qu'ils jugent dignes de représenter notre espèce, il faut qu'ils sachent déjà que chaque homme actuellement vivant porte un gène tellement défavorable qu'aucun sélectionneur ne l'aurait laissé vivre s'il avait connu ce gène. Je ferai un exemple tout à fait classique: le frère de Beethoven était sourd; un bon généticien aurait déterminé que Beethoven serait sourd et il aurait dit: «nous ne voulons pas un enfant sourd». Le plus extraordinaire c'est qu'il ne se serait pas trompé, Ludwig Van Beethoven est devenu sourd à vingt ans et il a composé ensuite, en mordant un morceau de bois qu'il coinçait sur la caisse de résonance de son piano. Simplement, les généticiens doivent être modestes. Ils ne sont que des hommes comme les autres, et la biologie, aussi raffinée qu'elle soit, doit rester l'honnête servante de la médecine et non pas devenir une maîtresse exigeante.

RICH

Yes, I agree entirely. This knowledge cannot and should not be used to try to obtain some kind of mythical genetic perfection. That is not the goal. It can be used in a productive and positive therapeutic sense to make life better

for some people. I think we have to recognize the fact that we are all imperfect, and the glory of our life is that, given this background of imperfection, we indeed can do as much as we do.

CROXATTO

Thanks, Dr. Rich. I agree with your comments. It is not only necessary to eradicate public misconceptions about science, but the universities should, in their curricula, give to future science practitioners broader opportunities to face and discuss the ethical responsibilities of doing science and the moral consequences which can derive from technical applications.

TODESCO

Prof. Paolo Edgardo Todesco, Preside Facoltà di Chimica Industriale

Credo che sia importante chiarire la necessaria separazione che ci deve essere tra il progresso della conoscenza e il comportamento etico. Questo è estremamente importante perché per molto tempo il progresso della conoscenza non era ritenuto così valido, così necessario, perché se ne sottolineasse anche l'aspetto etico. Io credo invece che quante più informazioni si hanno su come la natura effettivamente funziona, tanto più diventa facile operare scelte utili, ma anche, contemporaneamente, tanto più è facile che, se le scelte sono sbagliate, le conseguenze siano molto pericolose. Guardate che la tentazione di operare una selezione naturale è cosa vecchia: a Sparta portavano i bambini mal fatti sul Monte Taigeto. Succedeva molti secoli fa, era un modo di selezione che obbediva a dei criteri etici che erano sbagliati, in quanto si riteneva che un bambino che avesse un piede un po' messo diversamente dagli altri, o un sordo, non potessero affrontare la vita e quindi era meglio che morissero subito. È stata solo l'informazione successiva, che persone deformi facevano delle cose magnifiche, che sordi potevano creare le più belle sinfonie, che ha fatto pensare che era necessario avere più informazioni per giudicare eticamente se uno schema era valido o no. E avendo più informazioni si è capito che portare i bambini deformi sul Monte Taigeto era sbagliato. E quando avremo il genoma completo dell'uomo, certamente avremo molte informazioni e con queste molte informazioni sarà molto più difficile fare scelte eticamente sbagliate e credo quindi che sia ben importante continuare a lavorare perché il numero di informazioni che abbiamo sia il massimo possibile. E questo fra l'altro è in relazione al problema di Dio; se Dio esiste, io non lo so, ognuno può avere il suo parere, probabilmente sa fare queste cose così bene perché ha un nume-

ro di informazioni estremamente elevato che gli permette di fare delle scelte estremamente efficienti, e questa è una cosa molto interessante. Io credo che l'uomo nella sua spinta di conoscere, di cercare di capire, cerca in fondo proprio questo: il massimo numero di informazioni per cercare di fare delle scelte che siano le migliori possibili.

TODESCO, English version

Prof. Paolo Edgardo Todesco, Dean of the Faculty of Industrial Chemistry

I believe it is important to make clear the necessary separation between the advancement of knowledge and ethical behaviour. This is extremely important because, for a long time, the advancement of knowledge was not deemed to be of essential value by those who put ethical values in first place. It seems to me, on the contrary, that the more information we have on how nature functions, the easier it is to make valid decisions and, conversely, the more likely it is that wrong choices will have dangerous consequences. It should be noted that the temptation to impose natural selection is an old one; in Sparta they exposed handicapped babies to the elements on Mount Taygetos. This happened many centuries ago, and was a type of selection which corresponded to mistaken ethical criteria which held that a baby with a twisted foot, or a deaf child, was not fit for life, and therefore should die immediately. It was only the later awareness that deformed persons could produce magnificent works and that the deaf could create beautiful symphonies, which has brought us to realize that it is necessary to have more information in order to make ethical judgments on the validity of a project. Having come into possession of more information, it became clear that it was erroneous to expose deformed children on Mount Taygeto.

On the day when we will have full knowledge of the human genome, we will have a great deal of information, and it will be much more difficult to make ethically mistaken decisions. I believe, therefore, that it is of prime importance to continue working toward attaining the maximum amount of information possible. This has a bearing among other things, on the problem of God. If God exists, (I don't know if He does, each must make up his own mind) He probably does things so well because, having access to an enormous amount of information, He can make exceedingly efficient choices. I believe that man, with his urge to know, to try to understand, is actually seeking just this: the largest amount of information to enable him to make the best possible choices.

RESPONSABILITE DE LA SCIENCE ET DE LA TECHNOLOGIE: LES GRANDS TRAVAUX EN AFRIQUE ET DANS LE MONDE

Prof. MALU WA KALENGA
Commissariat Général à l'Energie Atomique
Centre Régional d'Etudes Nucléaires de Kinshasa, Zaïre

Introduction

La responsabilité de la science et de la technologie s'insère dans le contexte général des inter-rétro-actions entre science, technologie et société. La problématique que soulève ces inter-rétro-actions en Afrique est complexe et à facettes multiples.

En effet, alors même que ce continent n'a pas encore achevé la première phase de son industrialisation, il est contraint, pour sa survie, de s'adapter aux exigences de la société post-industrielle qui voit le jour dans les pays avancés. Ce décalage industriel, qui traduit en fait le retard scientifique et technologique du continent, est lourd de conséquences.[1] Il introduit, en effet, une disparité, de jour en jour plus marquée, entre les intérêts économiques de l'Afrique et ceux des pays industrialisés. La paupérisation croissante de l'Afrique qui en résulte est un facteur particulièrement déstabilisant, qui menace la paix sociale dans de nombreux pays africains. L'entente internationale en pâtit également, sous le poids, en particulier, des controverses en rapport avec la dette.

Quelles que soient les stratégies que l'on peut préconiser pour réduire les disparités économiques entre l'Afrique et le monde avancé, il est évident qu'elles devront toutes requérir une maîtrise plus grande par l'Afrique de la science et de la technologie.

Mais la science et la technologie ne sont pas neutres. La quête de l'Afrique pour une maîtrise plus assurée et plus étendue de la science et de la technologie comportera donc toujours des aléas et des pesanteurs qu'il importe de circonscrire et d'éclairer. Ceux-ci induisent, en effet, des contraintes, souvent dirimantes, au développement de l'homme intégral. On se propose d'identifier

certaines de ses contraintes à l'occasion d'un survol rapide des grands chapitres de la problématique induite par l'intrusion massive de la rationalité dans les conduites du corps social au XX^{e} siècle.

La problematique du XX^{e} siècle

A l'horizon 2000, et au delà, il n'est pas utopique d'affirmer que l'Afrique doit se définir des objectifs de croissance socio-économique au regard d'une sextuple problématique.

Quatre de celles-ci sont universelles. Ce sont:

- la problématique liée à l'explosion de la matière;
- la problématique liée à l'explosion des connaissances;
- la problématique liée à l'explosion de la vie;
- la problématique liée à la gestion de l'intelligence.

Les deux autres sont plus spécifiques à l'Afrique. Ce sont:

- la problématique du management participatif;
- la problématique de la faim.

La problematique liée à l'explosion de la matiere

Au premier regard la première problématique, celle liée à l'explosion de la matière, concerne le problème de la guerre et singulièrement de la guerre nucléaire. Au second regard on voit assez rapidement qu'elle s'organise en fait autour de la nécessité d'une reprise effective du contrôle de la technologie, et singulièrement de la technologie nucléaire, pour la mettre réellement au service de l'homme et de la société.

Deux problèmes méritent ici une attention particulière. Le premier concerne les menaces de guerre nucléaire. Le second concerne l'utilisation des centrales nucléaires.

Ceux qui réfléchissent sur les dangers de la guerre nucléaire s'accordent pour reconnaître qu'on ne saurait indéfiniment s'en remettre pour assurer la paix (armée) à la dissuasion nucléaire basée sur la peur de l'holocauste. L'armement nucléaire constitue une protection qui devient de jour en jour illusoire. De raffinements en raffinements, l'homme perd, en effet, graduellement la maîtrise de la technique de destruction nucléaire. Il s'inscrit, à son corps défendant mais de façon non moins réelle, dans une dynamique de guerre atomique, dès lors que la tentation de l'attaque préventive, ou simplement la probabilité de l'accident fortuit, augmente dangereusement.

La question du désarmement nucléaire est d'intérêt vital pour tous. Sans nul doute l'Afrique est encore à ce jour un continent dénucléarisé si l'on excepte les soupçons qu'engendre l'activité nucléaire de l'Afrique du Sud. Mais dénucléarisée ou non l'Afrique sera, à son corps défendant peut-être, partie prenante dans un conflit nucléaire. Les conséquences de celui-ci sur l'éco-système mondial ne sauraient, en effet, se concevoir comme circonscrites aux seuls belligérants situés, pour l'essentiel, dans l'hémisphère Nord. Des travaux sur ce que prosaïquement on qualifie «d'hiver nucléaire» ne laissent, à cet égard et malgré quelques contestations récentes, que peu de doutes.[2, 3]

Un échange nucléaire mégatonnique, pourtant limité à moins de 5.000 mégatonnes et intéressant les seuls territoires des U.S.A. et de l'U.R.S.S. dégagerait dans l'atmosphère une masse de fines poussières, de fumées et de suies à ce point énorme que le ciel serait obscurci sur toute la planète durant des mois.[4] La chute brutale de température, particulièrement néfaste pour les forêts tropicales humides, associée aux effets mortels des radiations nucléaires et du rayonnement ultra-violet détruirait toute forme de vie sur la planète. L'homme disparaîtrait de la planète comme ce fut le cas des dinosauriens à la période du secondaire.

Le second problème lié à l'explosion de la matière concerne l'utilisation des centrales nucléo-énergétiques. Après l'accident du réacteur RBMK-1000 de Tchernobyl le scepticisme va croissant dans le monde quant aux mérites du nucléaire utilisé à des fins énergétiques civils. Ce scepticisme fait que les contraintes majeures qui affectent aujourd'hui le nucléaire civil sont essentiellement de nature socio-politique. Pour surmonter ces contraintes il est urgent de mettre à l'étude et en œuvre une nouvelle génération de réacteurs nucléaires dits intrinsèquement sûrs. Par ce terme on entend des réacteurs nucléaires dont la sûreté serait essentiellement tributaire d'arrangements passifs, dictés par les seules lois de la physique, et non de dispositifs actifs dont le fonctionnement correct ne saurait être garanti de façon parfaite.[5]

La problematique liée à l'explosion des connaissances

Les inquiétudes que suscite le sur-armement nucléaire s'inscrivent dans la réalisation que la société moderne est fortement marquée par le mal-ajustement entre la culture matérielle et la culture non-matérielle. Sans nul doute ce mal-ajustement a existé de tout temps dans toutes les civilisations, lors de l'invention de l'arbalète, lors de l'invention de la poudre à canon, et au siècle dernier lors de l'invention des machines à vapeur qui ont permis le démarrage de la première industrialisation.

Mais la distance entre la technologie, tributaire pour l'essentiel des sciences physiques, et les institutions sociales qui relèvent des sciences de l'homme, n'a jamais été aussi grande qu'aujourd'hui. Les institutions sociales, les attitudes mentales, la réflexion sociologique, paraissent archaïques face aux potentialités destructives des nouvelles formes de maîtrise de la matière exemplifiées par la fission de l'atome et les conquêtes de la bio-technologie. Cette situation résulte en grande partie du décalage entre les sciences naturelles et les sciences de l'homme.

La séparation traditionnelle, due à la disparité des contraintes, des méthodes et des critères de vérités, entre les sciences naturelles et les sciences de l'homme est dangereuse. Alors que les premières, par leur succès même, contribuent à façonner l'esprit et la culture qu'elles ignorent par ailleurs, les secondes, par leur retard, ont de la peine à contribuer efficacement à la solution des maux de la société. En fait, «les sciences naturelles n'ont ni les moyens ni la vocation de se concevoir comme une réalité sociale, tandis que les sciences de l'homme qui en ont la vocation étant par définition anthroposociales, n'ont aucun moyen de se concevoir dans des enracinements bio-physiques».[8]

On voit ainsi s'accroître, au fil des ans, le pouvoir de la science sur la société et son irresponsabilité. Il se fait heureusement que des acquis récents dans les sciences naturelles, et singulièrement en science physico-chimique, laissent entrevoir des points de convergence entre les sciences de l'homme et les sciences naturelles, qui autorisent l'espoir d'un rapprochement des sciences en général par l'énoncé d'un nouveau paradigme qui permettrait une meilleure progression des connaissances dans toutes les disciplines.[6,7] L'étude des contraintes culturelles qui affectent en Afrique le développement des sciences en général laisse entrevoir que ce nouveau paradigme, qualifié de paradigme évolutif, faciliterait grandement l'épanouissement des sciences dans ce continent.[1,7]

Le second terme de la difficile problématique de l'explosion des connaissances est le morcellement croissant des connaissances. La division de travail en science, en autorisant l'hyper-spécialisation, a été à l'origine des avancées spectaculaires de la science contemporaine. Poussée trop loin, cependant, elle conduit à la limite à la situation paradoxale d'experts qui «connaissent tout sur rien».

Comment créer et entretenir dans un tel contexte, un véritable échange d'informations entre le laboratoire et l'utilisateur des acquis scientifiques, alors qu'il est déjà particulièrement ardu de se comprendre entre spécialistes, même de disciplines connexes?

L'accélération inouie du rythme de production des connaissances qu'autorise la division du travail en science entraîne ainsi paradoxalement un progrès corrélatif de l'ignorance. Les dangers liés à ce morcellement des connaissances

sont multiples. On peut retenir ceux de la technocratie et de l'anonymisation d'un savoir qui «cesse d'être discuté et intégré dans la poursuite individuelle de connaissances et de sagesse» pour n'être plus qu'un «intrant» à la disposition du plus fort ou du plus offrant.[8]

Ainsi donc l'explosion des connaissances dans le monde devient corollaire d'obscurantisme, de résignation à l'ignorance, de démission éventuelle du «Tout Organisateur» politique à la volonté des technocrates.

La problematique liée à l'explosion de la vie

Cette démission du «Tout Organisateur» politique est d'autant plus lourde de conséquences que le poids démographique se fait plus fortement sentir.

Pour bien faire on devrait considérer ici aussi bien le problème lié à l'explosion qu'à l'implosion de la vie, dès lors que le vieillissement des populations dans nombre de pays industrialisés fait également problème. Les dangers liés à la surpopulation paraissent cependant plus préoccupants. La majorité des pays à forte croissance démographique affichent, en effet, des indicateurs du développement économique qui laisse entrevoir un sous-développement économique qui laisse entrevoir un sous-développement structurel par inadéquation permanente entre la demande et l'offre des biens et des services.

Il n'est pas nécessaire d'être malthusien pour appréhender l'urgence des mesures visant à encadrer, dans des limites éthiques acceptables, la croissance démographique dans la plupart des pays du Tiers-Monde. La désertification par surcharge humaine dans un éco-système fragile suffit à elle seule à légitimer dans la région du Sahel, par exemple, un tel programme d'encadrement de la croissance de la population, de façon à maintenir productif l'environnement bio-physique.

La problematique liée à la gestion de l'intelligence

Rendre ou maintenir productif l'environnement biophysique et mettre en adéquation la croissance de la population et celle de l'économie, constituent deux objectifs qui requièrent de l'imagination, un effort soutenu de recherche, un souci constant de tirer le meilleur parti des convictions, des styles de vie des populations, ainsi que des connaissances et des technologies, anciennes et modernes.

A l'évidence la poursuite de ces objectifs nécessite, pour être efficace, la participation effective de tous les opérateurs socio-économiques. Cette parti-

cipation est aujourd'hui d'autant plus nécessaire dans les pays du Tiers-Monde qu'il leur faut conduire simultanément la matérialisation et la dé-matérialisation de la technologie.

L'évolution des technologies dans les pays développés montre, en effet, que le développement économique et social est aujourd'hui plus que jamais tributaire d'un investissement immatériel venant rentabiliser un investissement en biens d'équipements tangibles. On assiste dans ces pays à une véritable «révolution de l'intelligence», à un effort soutenu d'investissement dans l'intelligence qui se marque en particulier par une automatisation croissante de la production dans l'usine.[9] La robotique, la conception et la production assistée par ordinateur, les ateliers flexibles permettent d'économiser en matières premières, en énergie, en temps, et aussi, hélas, en main-d'oeuvre.

Sans nul doute les actions de préparation, d'environnement ou d'écoulement de la production compensent quelque peu dans les pays développés les pressions sur l'emploi. Cela n'est malheureusement pas le cas pour les pays fournisseurs de matières premières qui risquent de voir s'effondrer de façon permanente des marchés traditionnels du fait des économies en matières premières. Du fait aussi des substitutions de celles-ci par des matériaux nouveaux, rendues possibles par la révolution de l'intelligence.

Le défi que cette révolution de l'intelligence lance aux pays du Tiers-Monde fournisseurs de matières premières est colossal. Pour relever ce défi ces pays doivent commencer par maîtriser le «Temps» par une prévision claire et un suivi aussi précis que possible des progrès techniques réalisés ou attendus dans les économies avancés et de leur incidence sur leur vie économique et sociale. Il leur faut également redynamiser leurs programmes de recherche-developpement. Il leur faut plus généralement veiller à l'épanouissement du génie inventif de leur peuple. Le changement de système technologique basé essentiellement sur une utilisation plus intensive et plus fine de l'intelligence, impose ainsi une gestion plus rationnelle et plus rigoureuse de la démarche intellectuelle.

Mais dès lors que l'utilisation de la matière grise se fait plus fine, plus rationnelle, il est indispensable d'avoir une compréhension plus élaborée des phénomènes sociaux afin d'obtenir une adhésion plus franche et plus efficace des opérateurs socio-économiques. Ce recours plus intensif à l'homme met à l'avant-plan les problèmes socio-culturels. Comment par exemple concilier en Afrique l'initiative individuelle avec la solidarité de groupe, solidarité familiale en particulier qui sert souvent de «filet de récupération» dans une société industrielle encore en élaboration où la sécurité sociale est souvent encore embryonnaire?

La problematique du management participatif

Concilier les exigences de l'esprit d'entreprise et de la solidarité de groupe est un problème de management participatif qu'il importe d'approfondir. Ce n'est pas le seul en Afrique. S'y ajoute par exemple le problème de l'assujettissement de la femme qui fait obstacle aux stratégies de développement.

Dans les communautés rurales pauvres, et même dans les villes, les femmes sont si accablées de travail et si peu soutenues par des sociétés où l'homme domine qu'elles n'ont finalement que peu de temps et d'énergie à consacrer à une participation active aux programmes de développement. Il n'est, dès lors, pas suffisant d'accroître l'information des femmes pour les amener à mettre en pratique les stratégies de développement par la science et la technologie, comme celle qui concerne les soins de santé des enfants. Il faut plus généralement libérer leur choix en levant les contraintes sociales qui pèsent sur elles. Il faut changer les mentalités pour amener l'homme à apporter le concours que la femme est en droit d'attendre de lui dans l'entreprise commune. En somme il faut faire prévaloir dans la cité un véritable management participatif en élargissant les espaces de liberté, seule condition pour s'assurer l'adhésion enthousiaste de tous dans l'aventure du développement moderne, face au défi colossal de la révolution de l'intelligence.

La problématique de la faim

La participation enthousiaste et efficace de tous, et singulèrement des femmes, dans les stratégies de développement en Afrique est particulièrement cruciale pour résoudre un autre problème, celui de l'auto-suffisance alimentaire.

L'Afrique est aujourd'hui le continent de la faim, ou en tout cas celui de l'insécurité alimentaire.[10] Dans un régime économique, qui est encore pour la grande majorité de la population sud-saharienne celui de l'auto-subsistance, la sécurité alimentaire ne peut être considérée comme garantie. Les insuffisances climatiques peuvent, en effet, se conjuguer à une croissance démographique forte et à un appauvrissement croissant des sols, par ailleurs assez fragiles, pour entraîner la disette, voire la famine en cas de catastrophes écologiques majeures comme celles qui affectent de façon récurrente la région du Sahel.

L'insécurité alimentaire existe même là où la disponibilité en produits alimentaires est suffisante. Les contraintes économiques, qui sont aujourd'hui celles de l'Afrique, font en effet qu'un nombre croissant de familles n'ont simplement pas les moyens financiers pour se nourrir convenablement.[10]

Le problème de la faim en Afrique est complexe. Il ne se réduit pas, tant s'en faut, au seul problème technique d'amélioration de la productivité agricole.[11, 12] La croissance rapide de la population, l'amenuisement des ressources servant d'intrants à la production agricole (terre arable, qualité des sols, eau...), le marasme économique dû à la détérioration des termes de l'échange des matières premières exportées par l'Afrique, les insuffisances dans la logistique, le manque ou le mauvais état des infrastructures (routes, ponts, silos de stockage des produits) sont autant de facteurs qui concourent à l'insuffisance alimentaire. A ces facteurs s'ajoutent les calamités naturelles, les séquelles des options coloniales en matière de recherche agronomique qui ont largement ignoré la production vivrière, les distorsions dans la structure des prix agricoles qui démotivent le monde paysan, les contraintes culturelles faites de diverses inhibitions qui affectent les régimes alimentaires.[1, 11, 12]

Pour redonner espoir à l'Afrique sur ce front important de l'alimentation, il faut lever de concert les contraintes induites par les facteurs inhibiteurs qui viennent d'être rapidement rappelés.

Il importe donc, à la fois, de stimuler la recherche agronomique pour rendre le secteur agricole plus productif, de corriger les distorsions micro-économiques et macro-économiques qui pèsent sur les prix agricoles, de lever les barrières psychologiques et culturelles à la source de divers tabous, d'encadrer la croissance de la population pour éviter la surcharge de l'environnement bio-physique, d'améliorer la gestion du secteur agricole pour le rendre plus efficace, d'investir massivement dans les infrastructures en milieu rural, de s'intéresser à la femme comme agent de production alimentaire, d'arrêter la dégradation des ressources naturelles de base servant d'intrants à la production agricole... L'approfondissement de toutes ces actions nécessite un effort gigantesque de recherche et d'étude qui permet de mesurer la grande responsabilité de la science et de la technologie pour une Afrique plus prospère.

Conclusion

D'une problématique à l'autre, on a vu émerger l'importance de l'homme et de ses valeurs socio-culturelles dans la survie et le développement de la civilisation moderne largement tributaire des avancées en science et en technologie. La liste des civilisations disparues dans le passé est longue. Ces civilisations ont pu, bien souvent, se prévaloir d'une histoire glorieuse caractérisée par une grande maîtrise de l'agriculture et du commerce, et par une organisation sociale cohérente. Elles ont pu assurer durant des centaines d'années par-

fois, les besoins de base de leurs populations en nourriture, habillement, logement. Elles ont parfois élevé les arts et les lettres à des sommets qui étonnent encore aujourd'hui. Et pourtant ces civilisations ont disparu.

Il ne semble pas que ces disparitions soient le simple résultat d'une évolution naturelle, à la manière des organismes vivants qui perdent à la longue leur énergie vitale. Une explication plus en accord avec les données historiques semble indiquer qu'une des raisons premières de ces disparitions est une sorte ou une autre de faillite intellectuelle et morale qui rend incontrôlable, soit les visées hégémoniques, qui ont de tout temps caractérisé toutes les grandes civilisations, soit l'organisation sociale elle-même. Cette faillite a été souvent le résultat de la démission de l'élite intellectuelle, qui de créatrice s'est transformée, par usure intellectuelle ou morale, en une minorité léthargique et parasitaire.[13]

Cet enseignement de l'histoire autorise à poser en ces temps de crise internationale grave la question suivante:

> «Si aujourd'hui, beaucoup mieux qu'hier, l'homme étend sa maîtrise sur la nature, est-il aujourd'hui mieux qu'hier à même de se conquérir lui-même de manière à préserver plus durablement la civilisation qu'il a façonnée et qui le porte?».

Pouvoir répondre positivement à cette question c'est d'une certaine manière relever et surmonter le défi de la culture. En effet, le présent propos qui se termine a fait ressortir que la démarche scientifique moderne, qui s'est généralisée dans le monde, entraîne avec elle une généralisation du pouvoir de contrôle et de façonnement de l'environnement bio-physique et social. Malgré le retard de certains pays, dont singulièrement ceux d'Afrique, l'aventure du développement basée sur la science et la technologie se vit aujourd'hui globalement, au niveau de toute la planète, au niveau bio-physique comme au niveau social.

Mais paradoxalement si la science et la technologie modernes déploient avec magnificence, à quelques ratés près, leur pouvoir de contrôle sur la matière, elles semblent perdre de leur vitalité et de leur pouvoir de connaissance et de transformation dans la maîtrise des processus et des phénomènes sociaux. Il leur manque un «surplus d'âme», un «surplus de sagesse».

On peut espérer que le rapprochement entre les sciences naturelles et les sciences de l'homme signalé dans ce propos contribuera à réduire la hauteur de ce saut qualitatif nécessaire pour atténuer les maux sociaux qui deviennent de jour en jour plus pernicieux, et ces tensions entre les peuples et les nations qui autorisent les prévisions les plus pessimistes pour l'avenir de l'humanité.

On peut douter cependant que ce rapprochement soit suffisant pour instaurer ce climat de paix et de justice que les hommes de bonne volonté appellent de leur vœux.

Il faudra chercher ailleurs. Il faudra chercher dans ce lieu de convivance où science, technologie, art, religion, philosophie, beauté, compassion, se mêlent et s'entremêlent pour façonner une humanité plus responsable pour des hommes de bonne volonté. Il faudra chercher, à défaut d'un autre mot, dans la «CULTURE DE L'UNIVERSEL».

BIBLIOGRAPHIE ET NOTES

(1) MALU WA KALENGA, Science et technologie en Afrique depuis 1935: histoire, leçons et perspectives; Pré-print; Commissariat Générale à l'Energie Atomique; Zaïre; 237 pages; (1987).
(2) CRUTZ P. and GALBALLY I., Atmospheric effect from post-nuclear fires; Climatic Change, 6, 323-364, (1984).
(3) EHLICH P. *et. al.*, Long term biological consequences of nuclear war; Science, vol. 222, n. 4630; 1293-1300; (1983).
(4) Plus de 100.000 tonnes de fines poussières par mégatonne nucléaire, voir référence (2).
(5) MALU WA KALENGA, Inherently safe nuclear reactor in the light of the Chernobyl accident; Revue Zaïroise des sciences nucléaires; vol. VII, n. 2; 135-142; (1986).
(6) PRIGOGINE I. et STENGERS I., La nouvelle alliance; Galimard, Paris; (1979).
(7) MALU WA KALENGA, Epistémologie, physique et développement: l'influence de Niels Bohr (1885-1962); dans «Recherches nucléaires et développement du Zaïre: 25 ans d'activité; Malu wa Kalenga (éditeur); Presses du C.G.E.A.; Zaïre; 202-226; (1986).
(8) MORIN E., Pour la science; Journal le MONDE du 5, 6, 7 janvier 1982; Paris.
(9) Rapport sur l'état de la technique: la révolution de l'intelligence; Numéro spécial du mensuel «Science et Technique»; Paris; 108 pages; (1985).
(10) WORLD BANK, The challenge of hunger in Africa: a call to action; Washington D.C.; (1988).
(11) MONTAGUE YUDELMAN, Sub-Saharan agriculture research; Bulletin of the atomic scientists; 35-38; (September 1985).
(12) MALU WA KALENGA, L'interconnexion «nourriture-énergie»: l'Afrique peut-elle atteindre l'auto-suffisance alimentaire? Contribution à la semaine d'étude de l'Académie Pontificale des Sciences sur «Agriculture et qualité de la vie: nouvelles tendances»; Vatican (17-22 Octobre 1988), 14 pages.
(13) BARNS H.E., An intellectual and cultural history of the Western World; Dover publication; N.Y., (1960).
(14) MALU WA KALENGA, Science et Foi: un débat archaïque?; Revue africaine de théologie; vol. II, n. 22; 221-236; (1987).

DISCUSSION

ABRAGAM

Je ne veux pas discuter l'ensemble de l'exposé si riche et multiforme du professeur Malu, mais il y a deux points sur lesquels je voudrais marquer ma

position. Le premier, c'est cette distinction entre sciences sociales et sciences physiques, biologiques et mathématiques. Je crois que les Américains ont une terminologie déplorable, à ce point de vue, car ils parlent de *soft sciences* et *hard sciences*, ce qui en soi-même est une prise de position. Cela peut conduire en quelque sorte à regarder de haut les sciences sociales. D'un autre côté le professeur Malu a dit: «Les sciences sociales sont beaucoup plus difficiles que les sciences naturelles». Je crois que là aussi c'est une affirmation dont je n'arrive pas, quant à moi, à apercevoir le sens. Je voudrais rappeler Pascal, qui d'une façon admirable éclairait tout le problème en parlant de l'esprit de finesse et de l'esprit de géométrie. Il a expliqué que dans les sciences de la nature et plus spécifiquement les sciences mathématiques et physiques (et je crois aussi la biologie, la biologie moléculaire), les choses sont relativement simples et demandent une certaine rigueur dans le développement. Dans les sciences sociales il y a, au contraire, une infinité de causes, une infinité de faits et il faut pour les maîtriser d'autres qualités — et Pascal le dit en termes beaucoup plus forts que moi. Je crois qu'on risque de se tromper, j'adoucis volontairement son propos, lorsqu'on essaie d'appliquer les méthodes des unes aux autres.

Le deuxième point c'est le problème de la collaboration et de l'intégration d'équipes de sciences sociales et de sciences naturelles. Et bien, je n'accepte pas ce programme sans une certaine hésitation, car nous avons vu dans le passé d'effroyables conséquences d'une approche de ce genre, je ne vous rappellerai pas la science juive de Hitler, mais beaucoup plus près de nous, nous avons vu les ravages que l'incorporation du marxisme et des sciences exactes, des sciences naturelles peut produire. Je vous rappellerai le triomphe de Lysenko et la déportation de Vavilov, créateur de la génétique en l'Union Soviétique, et d'autre part l'idéologie inacceptable, idéaliste d'Einstein. Il y a certainement des bénéfices considérables à faire travailler ensemble des équipes de savants, de spécialistes de sciences sociales et de sciences naturelles, mais nous devons toujours prendre garde aux dangers qui peuvent être très grands surtout dans les pays où la démocratie et la liberté ne sont pas très fermement et irréversiblement établies. Nous devons prendre garde aux retombées possibles de ce genre de collaboration.

MALU

J'interviendrai d'abord sur la deuxième partie de l'exposé du professeur Abragam.

Je suis d'accord pour reconnaître qu'il y a des dangers à vouloir trop rapprocher les sciences sociales et les sciences naturelles. Mais il y a aussi des gains

intéressants à diversifier les approches lorsqu'on s'attaque à des problèmes complexes. On doit s'efforcer d'obtenir les gains en évitant les dangers. C'est là tout le risque de l'aventure du développement humain.

Concernant le premier point soulevé par le professeur Abragam, je crois utile de commencer par faire remarquer que traditionnellement on distingue trois types de systèmes dans la nature.

Le premier type est constitué de systèmes dits de simplicité organisée. Ce type de système peut être analysé en adoptant une stratégie de simplification déterministe, dès lors qu'en génèral il est caractérisé par un nombre réduit de variables pertinentes.

Le second type est constitué de systèmes dits de complexité désorganisée. Ici le nombre des variables est très grand mais on peut identifier un ensemble réduit de lois qui sont en fait des tendances moyennes. L'analyse de tels systèmes s'inscrit dans une stratégie de simplification probabiliste.

Le troisième et dernier type de système que l'on rencontre dans la nature est caractérisé par un nombre important de variables et de lois pertinentes. Il n'est pas possible dans ce cas de s'en remettre aux deux stratégies de simplification précédentes pour analyser ce type de système, dit de complexité organisée. Il faut chercher autre chose. Ce type de système se rencontre couramment dans les sciences sociales, et de plus en plus dans les sciences naturelles. Dès lors que les contraintes traditionnelles des sciences sociales apparaissent également en sciences naturelles il est normal qu'on commence à s'interroger sur les possibilités d'amener les sciences sociales et naturelles à coopérer, plus étroitement qu'elles ne l'ont fait par le passé, par l'énoncé à un niveau hiérarchique adéquat d'un paradigme commun.

C'est dans cette optique que s'inscrit mon exposé.

Mais j'ai précisé que si une telle entreprise est souhaitable elle n'est pas nécessairement possible. On doit cependant s'efforcer d'approfondir la question eu égard aux problèmes de plus en plus complexes que pose le développement des nations, particulièrement celui du Tiers-Monde.

Chagas

Le professeur Malu a plaidé pour des interpénétrations; l'intervention de Monsieur Abragam induit la discussion sur l'interpénétration plus ou moins poussée entre les sciences dites naturelles et les sciences sociales. Je voudrais parler d'une autre interpénétration, qui d'ailleurs était sous-jacente dans la réponse du professeur Malu; c'est l'interpénétration sur le plan technique entre les nations dites industrialisées et les pays en développement. Je veux dire que

dans les transferts de technologie on a eu tendance à vouloir transférer la technologie des pays industrialisés comme elle avait été mise au point dans ces pays. Je crois qu'il serait extrêmement important que pour la discussion de certains projets — c'est probablement difficile à mettre en œuvre — il y ait une participation active d'un certain nombre de personnes du pays vers lequel on veut transférer la technologie. De cette façon, on éviterait un transfert pur et simple qui résulte à faire passer des pays en développement par des étapes qui ont quelque fois été lourdes et douloureuses dans notre propre industrialisation. Ce n'est probablement pas commode parce que pour que de tels groupes existent et soient efficaces il faut d'une part que les représentants des pays industrialisés ne soient pas seulement des gens qui veulent vendre des choses, et que d'autre part ceux des pays en développement comprennent des gens qui ont déjà assez de connaissances dans la technologie ou en tout cas dans les effets que l'on recherche. Je crois que ceci est quelque chose d'extrêmement important.

LA COMMUNAUTE MONDIALE DES SAVANTS

ANDRÉ LICHNEROWICZ
Collège de France, Paris

Monsieur le Président, mes chers confrères,

La question posée à notre compagnie me paraît ambiguë: ne sous-tend elle pas une confusion grave entre science et technique, entre la communauté mondiale des savants qui est une des rares communautés spirituelles de ce temps et les communautés nationales ou multinationales de techniciens? De la communauté mondiale des savants, notre Académie, avec sa vocation, peut être considérée comme l'un des représentants.

Le plus grand enjeu politique de notre science est, sans doute, l'unification de l'humanité à travers une aventure commune. Tout au long de sa constitution et de sa lente diffusion au sein de peuples aux cultures étrangères les unes aux autres, la civilisation scientifique qui est la nôtre n'a pas seulement proposé des objets, des résultats et des savoir-faire; elle a imposé, dans de larges champs, une manière commune de penser, une «méthode» dont la mise en œuvre a fait prendre conscience, de la manière la plus concrète, de l'unité de l'esprit humain, tout en contribuant à le faire évoluer, au sens fort du terme.

C'est de *science* qu'il s'agit ici, non des *techniques* et de la magie de leurs résultats. Si science et techniques ont été souvent en interaction, si ces interactions tendent à devenir de plus en plus fortes, il reste que l'histoire de la science et celle des techniques sont deux histoires distinctes. La découverte de la machine à vapeur a précédé de longtemps l'apparition de la thermodynamique qu'elle a provoquée, la sélection des semences ou des races animales, celle de la génétique; c'est ici l'élaboration des techniques qui a permis la constitution de larges pans de la science. Inversement c'est la connaissance des lois fondamentales de l'électromagnétisme qui a permis le développement de l'industrie électrique et c'est cette démarche inverse qui est, de nos jours, la plus fréquente: le génie génétique doit tout à la biologie moléculaire et aux méthodes d'action

qu'elle a suggérées. De plus ce sont les techniques qui fournissent aujourd'hui à la science la plupart des moyens de son élaboration.

Une analyse de l'histoire des rapports entre science et techniques dépasserait largement le cadre de cet exposé. Si tous les peuples sont en train de devenir consommateurs d'objets techniques, si certains d'entre eux, nombreux désormais, participent à leur création, tout cela n'aboutit qu'à une unité superficielle et cacophonique, traversée de tensions, dangereuse pour les cultures et, sans doute, pour l'humanité elle-même.

Qu'est donc la science, la vraie science? La science pour quoi faire? A travers cette question, nous rejoignons donc, semble-t-il, quelques-uns des problèmes fondamentaux concernant les finalités et le système de valeurs de notre civilisation. Mais pourquoi nous poser aujourd'hui cette question qui semble venir du fond des âges? Parce que, depuis un demi-siècle, nous sommes entrés dans une période de crise succédant à une longue période d'enthousiasme, toutes deux largement tributaires d'idéologies variées et dans lesquelles ne cessent de s'affronter des conceptions sociales, philosophiques, politiques profondément différentes.

C'est sur la technique et son rôle dans notre civilisation que se cristallise l'affrontement. La profonde confusion intellectuelle, entretenue par tous, régnant entre science et technique, rend la science largement suspecte sur les deux fronts: on lui reproche ici son inefficacité à court terme, là ses complicités. La science se trouve prise au sein d'une tourmente et la stratégie menée, au cours de ce demisiècle, par la communauté scientifique semble l'un des facteurs du phénomène.

Je voudrais ici éviter le ronronnement équilibré, mais confus, de la vulgate et essayer de présenter certains aspects de notre problème sous un jour, un peu provocateur, afin de susciter à l'intérieur de chacun de nous un débat nécessaire, mais riche en contradictions.

Si nous nous reportons au meilleur dictionnaire français contemporain, le Robert, nous trouvons, pour le mot *recherche,* cette définition: «ensemble de travaux, des activités intellectuelles qui tendent à la découverte de connaissances, de méthodes et de lois nouvelles».

Il importe de noter que notre connaissance, dans le domaine strictement scientifique, est désormais beaucoup plus un *savoir-penser* qu'un savoir au sens traditionnel du terme, que les concepts, les méthodes, les actions mises en jeu nous importent plus que la factualité plate des résultats et qu'il existe, de ce point de vue, une certaine homogénéité entre les champs de notre science et de notre technologie. Mais les motivations sont profondément différentes et cela a suffi, dès les commencements, à l'établissement de communautés dis-

tinctes d'un point de vue charnel et spiritual, communautés s'interpénétrant certes aux frontières, mais dont les éthiques bien souvent s'opposent.

Pour les uns, et c'est ceux qu'il convient d'appeler les scientifiques, la motivation première est *le besoin de comprendre*, l'ambition de la découverte du nonconnu, notamment dans le triple domaine de l'infiniment petit, de l'infiniment grand ou de l'infiniment complexe, tous jaugés à notre échelle humaine. Notre science nous apporte tout un savoir de relations, se traduisant en *pouvoirs* sur le réel; contrairement à ce que beaucoup pensent, les pouvoirs ne sont pas d'abord visés, mais donnés par surcroit, grâce à l'ascèse scientifique même, mais mérités certes par un dur travail. On pourrait presque dire qu'aux yeux du scientifique ces pouvoirs ne sont que les *garants* que notre savoir est un vrai savoir sur notre monde réel et non le rêve vain de quelque monde imaginaire, garants qui nous permettent à chaque instant, sans rien perdre, de tout remettre en question.

Pour les autres, la finalité première est *le faire*, et ce système de pouvoirs dûrement conquis par l'homme est l'essentiel. Les théories que la science secrète et le réseau même des expériences privilégiées par lesquelles nous visons à enserrer le réel ne jouent, pour eux, qu'un rôle d'infrastructure ou de superstructure selon les moments ou les goûts philosophiques.

Je propose d'appeler provisoirement *science* (ou recherche fondamentale) ce qui correspond à la première motivation et de jouer à répondre provisoirement à notre question initiale. *La Science pour quoi faire?* Réponse: *pour rien, sinon pour elle-même.* Le type de civilisation née en Grèce et qui est la nôtre, qui, sous l'aspect envisagé, a envahi peu à peu toute l'humanité, est venue de gens qui aimaient se poser des questions sur le fonctionnement de l'esprit, sur les possibilités du discours, sur l'adéquation de l'esprit au monde et qui ne se satisfaisaient point d'histoires, mais se voulaient contraints par des processus cohérents et nécessaires, capables d'interdire le refus de leurs acquis. Au fil des siècles, le besoin scientifique est devenu un besoin primaire de l'humanité et notre civilisation vit de science, comme elle a besoin pour vivre de musique, d'art plastique ou de poésie. La Science a d'abord été ce qu'on nomme un *art d'agrément*, c'est-à-dire en fait quelque chose d'aussi essentiel à l'homme que le pain ou l'énergie, et elle doit demeurer pour une bonne part un art d'agrément.

Lors d'un entretien de Genève, Gaston Bachelard disait: «On dit parfois que la connaissance transmise par l'éducation doit être faite *pour la Société*. Combien serait plus belle une société qui serait faite *pour la connaissance*». Et notre société, sans toujours le savoir, a fonctionné quelque temps comme si elle était aussi faite pour la connaissance. Elle a consacré peu à peu à l'activité scientifique des moyens humains et matériels qui ne sont plus ceux qu'elle consacre à l'encouragement des arts, mais ceux dont l'ordre de grandeur cor-

respond pour une nation à un avertissement vital; puis elle s'est posé la question: comment peut-on contrôler tout cela?

L'activité scientifique semble avoir pour fonction sociale majeure reconnue la constitution et la mise à jour d'un savoir transmissible, parfaitement exotérique, donc universel. L'un de ses objectifs doit être d'œuvrer, par delà le malheur de l'accumulation des connaissances, à élaborer une véritable économie des connaissances, une *économie de pensée* au plein sens du terme. Par nature et depuis son origine cette activité scientifique s'incarne dans une *communauté mondiale*, qui transcende nécessairement toute frontière et toute politique nationale et dont les membres ont fait, implicitement ou explicitement, certains vœux sur lesquels nous allons revenir.

Beaucoup de nations ont même pensé: «Qu'avons-nous à perdre à laisser à d'autres le poids de cette activité dont nous bénéficierons de toute façon?» En fait l'analyse des situations scientifico-techniques des différents pays montre clairement que les seules cellules capables d'acquérir et de transmettre le savoir faire scientifique sont celles qui ont un contact actif et intime avec l'aventure scientifique elle-même, qui sont vraiment des acteurs. Sans communauté nationale qui soit une part de la communauté mondiale, sans un véritable milieu scientifique, il ne peut même pas y avoir communication correcte à chaque instant du savoir disponible.

Si la communauté est mondiale, les moyens financiers nécessaires sont très généralement nationaux. Scientifiques et financiers sont contraints au dialogue, un dialogue plein d'ambiguïtés. Chacun y apporte sans doute une bonne conscience et quelques mauvaises pensées. En ce qui concerne le scientifique, il y a eu souvent péché, un péché généralement inévitable: par politesse administrative ou par intérêt corporatiste, trop de scientifiques ont plaidé l'utilité sociale directe *de chacune de leurs démarches partielles* et ont dû ainsi se placer sur un mauvais terrain, le terrain propre du financier dont la tactique est toujours semblable à celle du jeune Horace.

Les pouvoirs sentent confusément que, pour l'exercice de leur mission, une mission toujours conçue à court terme à l'échelle de temps de la Science, ils n'ont pas besoin de savants, mais en fait de techniciens. Il leur faut laïciser ces clercs. Les pouvoirs ont, par nature, le choix des décisions et les responsabilités; aux techniciens employés d'assurer la réalisation des objectifs, sans se poser de problèmes graves ou saugrenus. Aux savants proprement dits, à ceux qui persistent sera permise une certaine activité en fait marginale; en particulier, ils contribueront à former des techniciens. Telle est, partout dans le monde, la tentation naturelle de dirigeants scientifiquement analphabètes qui ne peuvent, dans leur mission, que méconnaître le besoin scientifique.

Prise dans le tourbillon de l'offensive des pouvoirs, la communauté scientifique a failli perdre, de la manière la moins honorable, son autonomie et a dû, pour survivre, faire face et réfléchir. Ce n'est certes pas un hasard si, dans le monde depuis trente ans, les réunions de savants portant sur ces problèmes se multiplient, si les grands journaux scientifiques leur font écho. Dans l'héritage de l'idéal classique de la science, il est une part inaltérable sans laquelle il n'y a plus de communauté scientifique vivante, mais un syndicat de manœuvres qualifiés qui irait vite se sclérosant et, à travers vents et marées, notre communauté réaffirme cette part faite d'autonomie sourcilleuse, de loyauté dans la discussion, de liberté de la recherche et de la communication, de désintéressement à l'égard des avantages matériels. Mais cet héritage s'est alourdi: des devoirs nouveaux envers la société des humains sont apparus.

Cette communauté scientifique a pris conscience d'elle-même en tant que communauté sociale qui défend non les intérêts matériels de ses membres, mais une volonté morale commune qui doit préserver l'intégrité de la conscience scientifique. Elle sait qu'elle doit veiller désormais d'une manière active aux conséquences humaines de l'œuvre scientifique et s'efforcer de réfléchir sur ces conséquences et de les prévoir avec toutes les ressources de l'imagination critique de ses membres.

Elle doit non plus seulement enseigner la science, mais *informer la société* des implications sociales de ses résultats, communiquer ses espoirs et ses craintes, montrer à tous ce qui est de la science et ce qui n'en est pas à chaque instant. L'information scientifique vraie est devenue le premier des devoirs nouveaux du savant, mais, j'y insiste, *une information faite avec la même probité intellectuelle et la même humilité que la science elle-même*, une information qui élabore les éléments d'une culture scientifique authentique. Il n'en est pas encore ainsi et nous pouvons voir, à travers les médias, combien le rôle de mage détruit chez un homme le savant.

Notre communauté doit ainsi travailler, dans un monde de plus en plus technifié, à permettre les options claires, à conserver à chaque citoyen une possibilité véritable de contrôle, de choix, un choix qui ne soit pas une capitulation devant la publicité, la propagande ou l'autorité qui s'affirme compétente. Elle sait qu'elle doit augmenter son influence dans le monde, détacher des ambassadeurs auprès des puissants et leur faire sentir sa présence non par appétit du pouvoir mais par souci d'assumer, en fait et non formellement, la juste part de responsabilité qui est la sienne.

DISCUSSION

MOSHINSKY

The presentation of Professor Lichnerowicz was of course very interesting, and this division between the scientists on the one hand and the technologists on the other is quite an important one, but I would like to stress one point: we should be clearly aware of the difference in magnitude of the scientific effort for society as it is now, and as it was in the past. At the end of the last century, say in France, there were such great scientists as Pierre or Marie Curie and Henri Poincaré, but how much of the gross national product of France of that time went into scientific research? And how much goes now? It seems obvious to me that it may have increased by a factor of a hundred, that is, by an enormous factor. That means we are subject to many more constraints from the standpoint of society, if we ask for, or if society spends a much bigger amount on these things than it used to.

LICHNEROWICZ

Je dirai seulement que par rapport à la période de gloire que nous avons connue, période de Poincaré, Hadamard, etc., il doit y avoir en France à peu près soixante à quatre-vingts fois plus de mathématiciens. Je ne pense pas que la contribution mondiale, ni française ait été multipliée ni par soixante ni par quatre-vingts.

BLANC-LAPIERRE

Au sujet de la séparation du début entre science et technique, j'aimerais bien avoir un petit commentaire, un commentaire sur une science qui n'est pas la mienne et une technique qui n'est pas la mienne, je veux dire l'art médical. Il me semble que si je prends les recherches sur le cancer, le moteur premier c'est quand même de faire progresser la guérison des cancéreux, et que là comme contrepartie on a des retombées considérables dans le domaine de la connaissance.

LICHNEROWICZ

Ce n'est pas du tout ma spécialité, mais mon impression c'est que la démarche a été inverse. Le moteur premier a été, à travers la génétique, de compren-

dre des choses essentielles et élémentaires sur les êtres vivants. On a fait alors un travail énorme et magnifique en biologie moléculaire qui a révolutionné nos connaissances sur les cellules et leur développement. Il y a eu et il va y avoir des retombées considérables dans le domaine des cancers.

Intervention of L. LEPRINCE-RINGUET
Ecole Polytechnique, Laboratoire de Physique Nucléaire des Hautes Energies, Paris, France

Notre colloque porte sur la responsabilité de la science. Monsieur Lichnérowicz a parlé de la communauté des hommes de science; je voudrais ajouter quelques remarques sur certains aspects de leur responsabilité. L'homme de science, à certains moments, se demande quelle est sa responsabilité: on l'a vu dans le domaine biologique. Je ne parlerai pas de cette discipline, où je n'ai pas de compétences particulières: je m'en tiendrai au domaine des sciences physiques. On peut se demander quelles sont les conséquences des découvertes auxquelles on contribue: vont-elles aboutir à des conflits supplémentaires ou, au contraire, réduire les barrières entre les hommes? La communauté des scientifiques souhaite vivement que ces barrières soient abaissées. C'est une caractéristique de notre éthique.

Notre première réflexion face à une découverte scientifique: sera-t-elle bonne ou mauvaise? Je crois qu'il n'y a aucune réponse définitive. Pour les sciences fondamentales, on peut difficilement envisager au départ ce qu'apportera une découverte. Prenons les rayons X par exemple. Röntgen étudiait le passage du courant dans un gaz raréfié: à un certain degré de vide, il observa un rayonnement qui rendait phosphorescents les ongles ou certaines substances, y compris le verre. Très vite il s'est aperçu qu'il pouvait traverser les substances: on se rappelle la photographie de la main de Madame Röntgen, photographie sur laquelle apparaissaient les os de la main. C'était un phénomène nouveau, extraordinaire. Cette découverte des rayons X a-t-elle servi l'humanité ou contribué à son malheur? Il est bien difficile de prendre une position tranchée. Pendant la guerre, Madame Joliot — Irène Curie — jeune infirmière aux armées, utilisait les rayons X: on s'en servait pour repérer les projectiles dans le corps des blessés, les fractures, etc... Mais Irène Curie se protégeait insuffisamment contre ces rayons; et, tout au long de sa carrière, sa santé s'en est ressentie; ce fut probablement l'une des causes de son décès prématuré. En effet, si l'on en reçoit trop, on en meurt: l'excès de rayonnement, on le sait, est extrêmement dommageable. Il en est de même d'ailleurs pour tout produit pharmaceutique. Qu'il s'agisse des somnifères, de l'aspirine,... un cachet fait du bien; une boite entière, vous risquez gros.

Allons plus loin, avec le transistor, utilisé actuellement à grande échelle dans toute l'informatique. Il a pour base lointaine la diffraction des électrons, découverte par Davisson et Germer en 1927. Est-il bon ou mauvais? C'est extrêmement complexe, et il est certain que l'avènement du transistor a été un élément de progrès matériel formidable pour l'acquisition des connaissances, pour la transmission des événements mondiaux, pour la culture, la formation, l'information; mais il peut être utilisé aussi dans les Etats totalitaires pour imposer une dictature.

Et le neutron, découvert en 1932? Il provoqua une explosion de joie de la part de l'ensemble des scientifiques. La première application fut la radioactivité artificielle, découverte par Frédéric et Irène Joliot-Curie en 1934. Elle est très largement utilisée, permettant des contrôles dans de nombreuses industries ainsi qu'en biologie animale et végétale. La deuxième grande application fut la possibilité de réactions en chaîne à la suite de la découverte de la fission de l'uranium. D'où l'orientation vers la pile et l'arme atomiques. Les savants américains et les très nombreux européens réfugiés aux Etats Unis, pour combattre la vague déferlante du nazisme, s'engagèrent dans ce combat scientifique. Et ce furent la première explosion nucléaire et les deux bombes d'Hiroshima et Nagasaki. Les scientifiques s'étaient mobilisés pour leur éthique afin d'arrêter ce que l'on considérait à l'époque, avec raison, le plus grand danger pour l'humanité. Un peu avant Hiroshima, les scientifiques — Weisskopf et Pullman en ont parlé — souhaitaient utiliser la bombe comme moyen de dissuasion et non de destruction. L'Etat-major en jugea autrement et lança les bombes contre les deux cités japonaises... Peut-on en conclure que les suites de la découverte du neutron sont néfastes à l'humanité? Le neutron est aussi à l'origine des centrales nucléaires actuelles. En France, près de 70% de la production d'électricité est d'origine nucléaire, et nous avons lieu d'en être fiers: elles nous procurent le confort, le progrès individuel, et même une indépendance vis-à-vis des producteurs de pétrole. Il y a des risques sans doute, mais assez faibles vu le sérieux de cette activité et les précautions prises.

Prenons la fusion thermonucléaire issue d'une réaction mise en évidence, en 1931, par Cockroft et Walton. Jusqu'à présent, cette découverte s'est traduite par les bombes H, bombes qui n'ont jamais été utilisées; leur puissance de destruction est telle qu'elle a constitué un élément de dissuasion et de maintien de la paix; il ne faudrait pas cependant considérer que la dissuasion et l'équilibre de la terreur sont des éléments rassurants de la paix. Non. L'équilibre de la terreur entre deux grandes nations, on peut le concevoir. Mais entre un nombre plus important de nations ou d'ensembles de nations, un équilibre stable serait quasi impossible. Je me rappellerai toujours Oppenheimer, venu à Paris, passant à la télévision avec Desgraupes et moi, et répondant à la ques-

tion: «De quoi avez-vous peur?» — «J'ai peur de la peur». Certains scientifiques, pour ne pas dire la quasi totalité, souhaitent ardemment une réduction de plus en plus importante des armements nucléaires, mais ne nous faisons pas d'illusions: on n'empêchera pas les grandes nations de garder la possibilité de les fabriquer à nouveau le jour où elles le voudront.

Le découvreur en science fondamentale prévoit rarement toutes les applications. Chadwick, le père du neutron, n'a pas vu l'ensemble de celles de sa découverte qui furent nombreuses et étalées dans le temps. Il en est de même pour la physique des solides. Il est impossible de prévoir les conséquences d'une découverte. Au CERN, on étudie l'antimatière, on crée des antiparticules, des bosons, des leptons, des fermions, etc. C'est un travail de recherche fondamentale auquel participent des équipes très nombreuses. Pour le grand appareil de 27 kilomètres de tour, on a constitué quatre grandes équipes d'au moins quatre cents physiciens chacune. Steinberger, qui vient d'avoir le prix Nobel il y a quelques semaines, est au CERN l'un des patrons d'une de ces grandes expériences. Se pose-t-on là-bas le problème de la responsabilité des hommes de science devant ces recherches et devant la découverte de nouvelles particules? Généralement, non. Je connais bien les chercheurs du CERN, ils travaillent, ils cherchent à découvrir, à réaliser de grands appareillages avec des techniques nouvelles, elles-mêmes utilisables dans d'autres domaines; mais l'idée de la grande responsabilité du scientifique ne les tracasse pas, alors que, après la guerre, dans le domaine du nucléaire, des gens comme Oppenheimer se posaient beaucoup de questions; et les scientifiques plus ou moins liés à des centres militaires peuvent, eux aussi, s'interroger.

Il est très important pour nous, essentiel même, d'informer le public. Le scientifique peut l'informer d'abord des résultats de la science, des possibilités d'application, lui donner une certaine sagesse que ne lui offrent certainement pas les médias qui diffusent le superficiel, l'ultrarapide, et pratiquent la falsification des résultats et des possibilités. Le scientifique a pour devoir de prévenir, dans la mesure de ses connaissances, d'une part les gouvernants, d'autre part le public. Il y a de la part du scientifique, me semble-t-il, un devoir de communication. Cela fait partie de l'éthique de notre communauté, et cette communication doit être la plus exacte, la plus fidèle et la plus attrayante possible.

INTERVENTO CONCLUSIVO SULLA SESSIONE DI BOLOGNA

PROF. GIAMPIETRO PUPPI
Professore Emerito all'Università di Bologna

Mi è stato affidato il compito di riassumere il contenuto delle nostre discussioni qui a Bologna.

Ho interpretato il mandato nei termini di richiamare la vostra attenzione su alcuni punti che a me sembrano essere emersi con particolare vigore, e per la loro intrinseca importanza, e per l'attenzione che ad essi è stata riservata.

Iniziamo con l'eterno problema della dicotomia nel sapere tra Scienza dell'Uomo e Scienza della Natura.

Vorrei dire che più che nel sapere esso è sempre stato presente nella «pratica» del sapere, se è vero che «ufficialmente» il sapere non è altro che quanto è posseduto dai sapienti.

E i sapienti, nel primitivo ordinamento della Università di Bologna e di quante poi sono nate sul suo modello, erano aggregati in due distinte strutture: l'Università dei Legisti e l'Università degli Artisti.

La prima dedicata appunto al sapere filosofico-giuridico-storico in se e nelle sue applicazioni agli ordinamenti; la seconda viceversa dedicata al pensiero scientifico e alle sue applicazioni nell'ambito delle Scienze della Natura e della Medicina.

Nel corso dei secoli la dicotomia è rimasta, anche se l'attenzione verso i due poli del sapere è variato e, con vicende alterne, la Scienza della Natura, liberata dalla sudditanza alle Scienze Umane con il tramonto dei sistemi filosofici omnicomprensivi, ha assunto la sua autonomia.

A questo hanno, a mio avviso, contribuito due elementi fondamentali: l'affermarsi di un proprio linguaggio, quello matematico quantitativo, e il riconoscimento che è in quel linguaggio e non di quello qualitativo filosofico che si legge la natura; in secondo luogo la scoperta delle leggi fondamentali che reggono i fenomeni naturali e che formano un insieme rivolto alla unificazione

di numerose e diverse leggi fenomenologiche, e in definitiva alla unità del sapere scientifico.

Questa unità del sapere scientifico ha, come tendenza, un antagonista potente nella frammentazione in discipline e sottodiscipline imposta sul piano pratico dallo straordinario sviluppo delle conoscenze scientifiche; è un processo che attualmente appare come divergente, malgrado le continue parziali sintesi effettuate.

Quando si invoca l'unità del sapere è da riconoscere, per evitare malintesi, che esso diventa sempre più impensabile in senso stretto (uno sterile enciclopedismo) e che esso ha senso solo in termini di *linguaggio comune, metodologia comune, analogie strutturali* nelle differenti discipline. In questo preciso significato l'unità del sapere può essere perseguita anche dalle scienze umane.

Passiamo ora ad un secondo punto e cioè la responsabilità della scienza e la responsabilità degli scienziati. Sono due concetti che possono anche formare un tutt'uno in un mondo chiuso di sapienti; e probabilmente lo erano nelle antiche caste sacerdotali, nelle antiche accademie, nelle comunità monastiche medioevali e più recentemente forse in ambienti fortemente caratterizzati da impostazioni ideologiche di tipo omnicomprensivo.

Non sono più tutt'uno in quanto le nuove conoscenze vengono sì cercate dagli scienziati, ma non restano di loro esclusiva proprietà e neppure in generale della sola comunità scientifica; ma immediatamente, almeno per quanto riguarda l'ambito civile, diventano patrimonio comune di tutti che ne possono fare uso sotto l'aspetto applicativo.

Questo controllo che sfugge in tempo reale agli scienziati può essere ricuperato, almeno in parte ma con costanti di tempo lunghe, attraverso una tenace opera di acculturamento della stessa Società; e questo è responsabilità precisa degli scienziati.

Un punto ulteriore su cui qui si è detto molto è quello dei rapporti tra Scienza - Tecnologia - Uso Finale, che nelle varie discipline mutano storicamente come peso degli elementi di questa fondamentale catena in cui è abbastanza comune credere un ordinamento gerarchico anche di importanza nel verso Scienza → Tecnologia → Uso Finale.

E così è in molte discipline, specialmente in quelle più moderne a forte contenuto scientifico anche per la tecnologia e per il prodotto finale (Elettronica, Nucleare, Farmaceutica, Carbochimica); ma ci sono state inversioni molto importanti nel corso della storia.

Un caso citato è quello della Astronomia, il cui sviluppo oggi è praticamente limitato all'aspetto scientifico e da questo condizionato mentre nell'antichità era l'uso finale l'elemento traente: per la misura del tempo, la costruzione dei calendari, l'esplorazione della terra. Se il sistema copernicano ha avuto

difficoltà ad essere accettato, nonostante la sua maggiore ricchezza di fatti interpretati rispetto a quello tolemaico, è perché le effemeridi dei pianeti nel sistema copernicano iniziale non erano migliori di quelle già affermate da tempo nel sistema tolemaico.

Talvolta l'elemento traente della catena è stata la tecnologia a cui ad esempio, con la costruzione di specchi, lenti e prismi, si deve lo sviluppo dell'ottica e dei suoi strumenti.

Un ultimo punto riguarda una domanda che sempre l'uomo si è posto di fronte a scoperte o invenzioni di carattere nuovo in settori cui mancante era l'esperienza.

Questa domanda è: quale futuro mi è riservato? Ed è sempre stata ragione di dubbi, di ansietà, come di irrazionali certezze in una alternanza tra pessimismi e ottimismi entrambi ingiustificati.

L'introduzione della polvere da sparo deve aver suscitato questo tipo di problemi, come l'invenzione delle macchine alimentate da energia non umana né animale, e ancora più recentemente i mezzi di trasporto, per finire con la bomba atomica e oggi con la manipolazione genetica. Quest'ultima, perché la più recente, appare a noi come la più straordinaria delle possibilità di rischio nella scelta tra bene e male; ma ai loro tempi anche le altre, di cui ho citato alcuni esempi, hanno certamente suscitato acuta attenzione.

La differenza è che essa non interessa, come le altre, l'uomo in senso generico attraverso un rischio statistico regolato da leggi di probabilità; ma il discorso vale per quell'individuo e per quella specifica ragione, ed è in grado anche di predeterminare un futuro individuo. Il problema, e con esso l'atteggiamento nei suoi riguardi, sta maturando, ed è auspicabile che questa volta la Comunità Scientifica riesca a mantenerlo a lungo sotto il proprio controllo.

A conclusione di questo molto lacunoso rapporto e in armonia con l'intento della riunione, possiamo fissare l'attenzione su alcune regole di comportamento dello scienziato.

— Mantenere l'indipendenza e l'autorevolezza della Scienza per mantenere o per ricondurre i problemi suscitati dal suo progresso, anche quelli con delicate implicazioni etiche, alla loro vera base scientifica; e in tal senso e su queste basi acculturare la Società Civile.
— Rendersi però conto che la Comunità Scientifica non è la unica voce ascoltata e spesso anzi è la più difficile da essere intesa. Il rimedio è nel mantenere il prestigio degli scienziati come voce chiara, non inquinata da motivazioni non scientifiche, e onesta nel riconoscere anche i limiti del sapere stesso.
— Aver sempre presente che la sequenza di evoluzione tra Scienza - Tecnologia - Uso finale è ora molto rapida e che si tratta di un sistema aperto in

cui l'enfasi può essere posta dall'esterno su qualsiasi elemento del suo sviluppo. Sono quindi da attendersi ritardi, corse in avanti, remore anticipazioni e scollegamenti la cui azione, se fuorviata, deve essere rigorosamente controllata con autorevolezza.

CLOSING ADDRESS OF THE BOLOGNA SESSION

GIAMPIETRO PUPPI
Professor Emeritus, University of Bologna

I have been given the task of summarizing the content of our discussions here in Bologna. I shall do this by directing your attention to certain points which, it seems to me, were raised with a certain vigour both as regards their intrinsic importance and the attention given to them.

I shall begin with the eternal problem of the dichotomy of knowledge between the Science of Man and the Science of Nature. I would say that this has been a factor not so much in knowledge itself as in the «practice» of knowledge, if it is true that «officially» knowledge is simply that which is possessed by those who know. Those who know were grouped, in the old organizational system of the University of Bologna and of the universities which followed this model, in two distinct structures: the University of the Legists and the University of the Artists. The former was dedicated to philosophical-juridical-historical knowledge as such, and to its systematic applications; the second, conversely, to scientific thought and to its applications in the domains of Natural Science and Medicine. This dichotomy has remained down through the ages, though the attention given to the two poles of knowledge has varied, and through a series of vicissitudes Natural Science, liberated from its subjection to Human Science as the all-inclusive philosophical systems declined, has acquired autonomy.

Two fundamental elements have contributed to this, in my view. First, the consolidation of a separate quantitative mathematical language, along with the awareness that it is through this language, and not through the qualitative philosophical one, that nature can be deciphered; in the second place, the

discovery of the fundamental laws which govern natural phenomena and which form an entirety which can be applied toward the unification of the many and diverse phenomenological laws, and ultimately toward the unity of scientific knowledge.

This unity of scientific knowledge tends to have a powerful antagonist in the fragmentation into disciplines and sub-disciplines at the practical level which the extraordinary development of scientific achievements has brought about. This is a process which appears to be one of divergence, at present, in spite of the continuous partial syntheses which have been made. In speaking of the unity of knowledge, and in order to avoid misunderstandings, it must be recognized that this unity becomes increasingly unthinkable in the strict sense (a sterile encyclopedism), and that it is only meaningful in terms of *common language, common methodology, structural analogies* in the various disciplines. In accordance with this precise definition, the unity of knowledge can also be pursued by the human sciences.

Let us now proceed to the second point, which is the responsibility of science and the responsibility of scientists. They are two concepts which can go to make up a unified whole in a closed world of savants, and they probably did so in the ancient priestly castes, in the academies of the classical world, in the medieval monastic communities and, more recently, in those spheres which were strongly characterized by the all-inclusive type of ideological approach. They are no longer a unified whole in that the new types of knowledge, while being sought by scientists, yet do not remain scientists' exclusive property nor even, in general, that of the scientific community as such. Immediately they move into the public sphere and become the common property of all who can make an applied use of them. Viewed in this way, scientists today have lost control. However, they can regain it, at least partially, albeit over a long period of time, by means of persistent efforts aimed at the acculturation of Society itself. And this is precisely the responsibility of scientists.

Another point on which much was said concerns the relationships among Science - Technology - End Use. In the history of the several disciplines, these relationships have varied in the importance they have possessed as links in this fundamental chain. It is commonly held that there is an order of rank and of importance in this chain which goes from Science to Technology to End Use. This is indeed the case in many disciplines, especially in the most modern ones where a strong scientific content extends to the technology and to the end products (Electronics, Nuclear Science, Pharmaceutics, Organic Chemistry).

However, there have been very important inversions in the course of history. A case which comes to mind is that of Astronomy. Today its development is mainly limited to and conditioned by the scientific aspect. In olden

days it was the end use which was the leading element — for measuring time, constructing calendars, exploring the globe. If the Copernican system had difficulty in getting itself accepted, even though it was richer in interpretations of facts than was the Ptolemaic one, it was because the planetary almanacs of the early Copernican system were no better than those which had long been serving in the Ptolemaic system.

At times, the leading element of the chain was technology. Thus, it was the construction of mirrors, lenses and prisms that was responsible for the development of optics and its related instruments.

A final point concerns a question which man has always asked when confronted with discoveries or inventions of a new type, in sectors where experience was lacking. This question is: «What will the future be like for me?» Always there has been cause to doubt, to worry, just as there has also been found an irrational confidence. In this alternation between pessimism and optimism, neither one was justified.

The introduction of gunpowder must have raised this type of problem, as did the invention of machines which ran neither on man-power nor on animal-power, more recent instances being new means of transportation, the atomic bomb and, today, genetic manipulation. The last on this list, being the most recent one, appears to us to be the one with the most extraordinary risk potential in the choice between good and evil. Yet, in their day, the others, such as those already mentioned, must also have been the object of acute scrutiny. The difference is that this time it is not a generic type of concern involving statistical risks regulated by laws and by probability. Now it is a question of the individual, and of specific circumstances, and perhaps the predetermination of a future individual. The problem, and the attitudes toward it, are coming to a head, and it is to be hoped that this time the Scientific Community will succeed in maintaining control for a long time to come.

As a conclusion to this very incomplete report, and in keeping with the intent of this meeting, we might fix our attention on a few rules of conduct for scientists. They should:

— preserve the independence and the authority of Science by taking in hand those problems which emerge from scientific progress — even those with delicate ethical implications — and leading them back to their true scientific base. In this way and on these foundations they can acculturate society;
— keep in mind, however, that the voice of the Scientific Community is not the only one that is listend to. On the contrary, it is often the one with the most difficulty in making itself heard. The remedy is to maintain the prestige of scientists as persons who should speak with a clear voice, untainted by non-scientific motivations, honestly admitting the limits of knowledge;

— always remember that the evolutionary sequence in Science - Technology - End Use is very rapid today, and that it is an open system where emphasis coming from the outside can be put on any aspect of its development. Thus we can expect to see delays, spurts forward, postponed hopes, disjunctures; and if these developments go astray, they must be controlled vigorously and with authority.

DISCUSSION

LICHNEROWICZ

Je veux faire brièvement deux remarques. La première consiste à dire combien j'ai apprécié l'exposé synthétique de notre ami, qu'il s'agisse de son contenu ou de sa remarquable forme. S'il m'est permis, je ferai une profession de foi: Je suis un ennemi résolu de cette «philosophie des deux cultures» qui, depuis la dernière guerre, a envahi un certain champ de pensée. Je doute de l'existence d'une culture dite «générale» qui n'aurait ceci de général que d'être et de se vouloir radicalement non scientifique.

Je veux dire aussi ma méfiance devant l'entreprise qu'on a appelée «*théorie générale des systèmes*». Dans des domaines précis, je fais confiance aux approches contemporaines concernant les systèmes dynamiques, certains systèmes informatiques ou aléatoires. Nous avons ainsi beaucoup appris et des choses difficiles. Par contre, je mets en cause l'intérêt présent de l'entreprise «systémique»; son ambition même me semble la condamner à la vanité. Malgré des efforts certains, je ne connais pas, à l'heure actuelle, un seul énoncé, théorème etc... en théorie générale des systèmes qui ne soit pas trivial du point de vue théorique et qui soit intéressant du point de vue des applications. Ici c'est l'épithète «général», et la fausse abstraction correspondante, que je mettrais en accusation.

A propos de l'avenir de l'humanité, je dirai que je pense comme beaucoup d'entre nous ici, que ce qui nous importe est une vision de l'avenir de la personne humaine. Peut-être nos amis biologistes sont-ils un peu trop «partis pour la gloire» dans leurs visions futuristes. Cependant, en ce qui concerne le futur de l'humanité, ce sont les grands risques biologiques qui sont de beaucoup les plus importants. Ils sont prévisibles depuis quelque trente ans et c'est sur eux que nous aurions dû réfléchir humblement depuis longtemps.

GERMAIN

Je voudrais rapidement donner mon sentiment sur certains thèmes de l'excellent exposé de conclusion que nous venons d'entendre.

Premièrement, nous assistons à une fragmentation des disciplines, aussi bien dans nos sciences que dans les sciences humaines et sociales. Face à cette fragmentation de l'esprit, où trouver «l'unité de l'esprit»? Dans la pluridisciplinarité, l'interdisciplinarité? Je ne pense pas que cela soit la voie. L'unité de l'esprit, pour moi, c'est une conquête jamais terminée; sans doute l'objectif principal de notre existance et qui demande, contrairement aux disciplines qui dissocient en quelque sorte le réel, une vision globale des choses sur laquelle chacun risque et vit sa vie.

Un deuxième point c'est la nécessité d'introduire certaines distinctions entre science et technique, d'une part et entre technique et pouvoir économique d'autre part. Le professeur Puppi a mentionné ces trois aspects et je lui en suis très reconnaissant. Il y a bien évidemment des relations étroites entre science et technique et il y a des relations entre technique et pouvoir économique. Mais chacun de nos pays essaie d'être économiquement le meilleur, de battre le voisin, de vendre plus de produits qu'il en achète; au total comment le circuit se boucle-t-il? Alors, en accord avec Lichnerowicz, je crois que nous devons promouvoir l'idéal de la science tel qu'il a été vécu autrefois, même si nous sommes parfois nous aussi tentés de «vendre» ce que nous faisons. Nos amis ingénieurs et techniciens, sont engagés par le pouvoir économique dans une espèce de bataille dans laquelle nous n'avons rien à faire. Bien que nous soyons liés à eux, nous devons leur rappeler quel est notre idéal.

Troisièmement, Monsieur Puppi a employé le mot «inculturation», qui me paraît être le mot clé chaque fois que l'on veut essayer de faire pénétrer dans une culture, sans la démolir et pour l'enrichir, quelque valeur universelle. Née au coeur d'une réflexion catholique, sur la transmission des valeurs judéo-chrétiennes ou gréco-latines dans d'autres cultures tout à fait différentes, cette perspective d'action doit être aussi la nôtre si nous voulons faire pénétrer l'idéal de la science, comme valeur universelle, dans toutes les cultures sans les violenter. Nous devons trouver le moyen de leur faire comprendre que la démarche scientifique n'est pas destructrice de culture alors qu'une certaine démarche économique peut l'être.

Quatrièmement pour réussir cette inculturation, cette greffe scientifique sur la culture des pays en voie de développement, la durée est nécessaire. Monsieur Puppi a eu raison de le souligner. Les hommes n'ont pas la possibilité biologique et culturelle de s'adapter aux évolutions si rapides que nous imprimons à notre technique. On ne prend pas assez en compte cette durée. Les gens

du nord sont des gens pressés même s'ils ont de bonnes intentions. Mais c'est quelquefois avec les bonnes intentions qu'on prépare des catastrophes.

PUPPI

Merci, Monsieur Lichnerowicz et Monsieur Germain, pour avoir eu l'amabilité de me citer, mais je veux rassurer M. Lichnerowicz que je n'ai jamais pensé à une théorie générale des systèmes. Peut-être vous avez un terme meilleur que ça pour dire qu'on va reconnaître qu'il y a des lois de comportement dans certaines structures de différentes disciplines, qu'on peut donc reconduire une certaine façon de voir les choses. Merci à M. Germain, je crois qu'il m'a attribué plus que j'ai dit, mais en tout cas je le remercie.

THE RESPONSIBILITY OF SCIENCE

DAY FOUR
30 OCTOBER 1988

RESPONSIBILITY OF SCIENCE AS ADVISER TO GOVERNMENTAL STRUCTURES

HANS TUPPY
Institute of Biochemistry, University of Vienna (Austria)

Scientific and technical factors increasingly influence all important political issues. Therefore every branch of government (executive, legislative and judiciary), and government on all levels (national, regional and municipal), must take science-based assessments into account in policy formulation and decision-making. There is no question that politicians require high-quality advice in matters and areas such as education, public welfare and health, new technologies, energy, human reproduction and demography, agriculture and forestry, space research and, naturally, national security and arms control.

In most countries there do exist large and growing scientific and technical bureaucracies and agencies. In addition to them, however, a scientific advisory system is desirable and, in most countries, available, which aims at connecting government with the scientific and technological communities through the agency of outstanding scholars and scientists. In most countries advisory committees have been established, be it standing committees or *ad hoc* committees. Academies of science give advice, commissions make assessments; they have taken the tasks of alerting, of monitoring, of warning, of making suggestions, solicited or unsolicited. This counselling capacity provides intriguing opportunities to influence political planning and action, and places great responsibility on those scholars, scientists and experts who individually and collectively perform such advisory functions. Indeed, these scientists and experts may bring into the political scene a wealth of experience and wisdom, independence of thought, critical views, disinterestedness and wideness of outlook.

I would say that in general the involvement of scientists in political affairs has been positive, and that politics on a national and also international scale would be much worse off if, in the past and present, the voice of science, of eminent science and scientists, had not been heard.

However, science and politics do not mix well. When science and politics meet, when science advice is given to government, this is beset with great difficulties, on the side of those expected to give and on the side of those supposed to take advice.

There are frustrating examples in many countries where extremely qualified advice has been given by the best and most conscientious scientists, but has been in vain. Advice has been neglected for one reason or another: for the reason of short-term political advantages, for ideological reasons, partisanship, or misconceptions of those planning and deciding, or merely because those consulting with scientific experts were interested in publicly asserting that they had scientific advice, rather than in taking the advice seriously into account. In cases where the advice given or the advisory commission as such did not conform to the ideas cherished by those who should take the advice, the former were dismissed altogether and not consulted again. Often advisory scientists have been appointed from the very beginning on the basis of political compatibility and loyalty to the reigning powers in order to eliminate controversy and criticism. On the other side, the requirements for performing an advisory function wisely, effectively and responsibly are stringent and not easy to conform to. Scientists, however outstanding they may be, are true experts in one field only, or even in less than a whole field; they should not trespass the limits of their competence which, however, they often do. The reliability and credibility which they have in one field should not be exploited in other areas where they do not have available the expertise that would be necessary. This warning is the more important since most of the problems put to scientists for advice are rather diversified or even exceedingly complex, and require for tackling them the cooperation and interaction of experts in several fields, sometimes in so many fields that they can hardly be accomodated in committees of workable size.

The scientists concerned should be ready, and they should even be obliged, to defend within their professional communities and among the scientists working in the same and related fields, the views and statements which they present to political instances, thereby testing whether these views deserve support and confidence. The scientists engaged in advisory functions should have enough political experience and insight to understand the nature and scope of the governmental issues to be dealt with and should, on the other hand, be as uncontaminated as possible by personal political ambition and bias.

Most public policies or actions involve issues for which science does not provide unequivocal answers. In such cases, scientific honesty requires that matters not be falsely declared as scientifically established, when in reality they are not. When firm ground is lost, when objective and reliable knowledge gives

way to guesswork, scientific honesty and reliability require that this be declared and not concealed.

Ethical and moral questions bring an increasingly broader dimension into contemporary science advising, and the scientists are expected to raise their voice also in those matters which are explicitly ethical in nature. But even matters which may appear strictly technical at first sight very often have important ethical implications. I wish to emphasize that scientists are not experts in the field of ethics. Scientist are not superior to other citizens in this respect, apart from the fact that they have learned and are accustomed to follow problems to their roots and ramifications. Nevertheless, scientists cannot and should not dismiss the ethical dimension of scientific developments, options and potential actions.

What is required, then, from the scientists when they defend human life, freedom and dignity, when they take sides for the good future of our globe, when they get implicated in matters of international welfare, peace and freedom? What is required from them is that they disclose the set of values on which their judgements, their warnings and proposals are based, and that they not confound scientific fact on the one hand and values on the other. If they do confound, if they do not declare their set of values, they rightly lose confidence and may rightly be considered partisans rather than true scientists.

To conclude, the advisory function of scientists and scientific commissions with regard to governmental policies and actions is a matter of particular responsibility and delicacy. If science and scientists are not to lose credibility, if their claim to be reliable and accountable is to be upheld, the scientific community must give strong support to those of its members who engage in advisory functions and must try to impose on them the ethical rules of scientific thought and work.

DISCUSSION

MÖSSBAUER

I would like to congratulate Professor Tuppy on this clear analysis of a very difficult subject, but I would like to make some additional remarks from the point of view of a scientist, things which I am sure he is aware of. In our countries such as Austria or Germany, which are non-nuclear powers and where the government is less dependent on scientists than in those countries where they have important military applications, we have a phenomenon where a

number of what I call pseudo-scientists, people of low qualifications, spend their whole time advising governments on issues like ecology or nuclear power. We have a large reservoir of these, and they have the advantage that they can do it full time. Now as a scientist, one must perform these advisory functions on the side, and one has to spend most of one's time working in the scientific areas which are our main duty. So, in advising governments we have to compete with these people who give ideologically biased advice to their governments. This gives us a very complicated and difficult job, especially since the general public, which is uninformed, tends to pay much attention to the noise that is made by such pseudo-scientists.

TUPPY

I fully agree. Our experience points to the fact that such pseudo-experts do not defend their theses within the scientific communities. They prefer to seek the support of non-scientific groups which are emotionally manageable and are appealing groups to politicians. I would say, however, that even in my country, where the debate on nuclear power has been very lively, governmental actions would have been even worse if good scientists had not raised their voices.

PULLMAN

Professor Tuppy has given us a very beautiful picture of an ideal scientific adviser. I wonder whether anybody would be able to give us a parallel picture of an ideal politician. I would like to ask Professor Tuppy a question: what would you prefer, a government of politicians advised by scientists, or a government of scientists advised by politicians?

TUPPY

If scientists formed a government and were advised by politicians, but without having experience in politics, they would be complete failures. Scientists have not usually learned, in their careers, to take decisions for action.

PULLMAN

What about a government composed of one politician and one scientist in each important job?

TUPPY

The latter might be advantageous in my opinion. That's a good combination. However, I am convinced that a government purely scientific in nature would be incapable of dealing with huge problems. Nor have scientists, generally, sufficient public appeal. They usually haven't the kind of leadership which is necessary to motivate the population to move in a certain direction, even in a good direction. But I feel that a combination of men of action and men of thought, men of ideology and men who restrict ideologies to their place, would be a very good thing.

WEISSKOPF

We should be grateful for the clear presentation by Professor Tuppy of the problems of scientific advice. He is one of the rare examples of a scientist as a member of a government. I wish there were more of them. That's also the reason why he can speak so well, and be so well-informed, about these problems. In the United States there are too few scientifically trained people in the government. The scientists do not have the inclination to get into the political business; they prefer to do science. I admire Professor Tuppy, who has temporarily given up his scientific activities in order to do something very important.

Perhaps you have overstated the case of ethics versus science. It is true that science cannot make ethical judgements, but science in itself carries an ethics. Scientists are ready to admit that they were wrong when facts or arguments require it. We are able to come to the conclusion that you are right and I was wrong. This is rarely so among politicians. In this respect the scientific community can have an important ethical impact on political discussions.

But then let me come to another point. As you said so correctly, the scientific problems that the government faces are really so multi-dimensional and complicated and non-scientific in many aspects, that necessarily science cannot give unambiguous advice. You said correctly that the scientists should admit that. The trouble is that the public hears differing opinions among the scientists. In America this is the case about SDI, or about nuclear policy. Often the scientists think that their conclusions are purely scientific, which is not always the case. They will not admit — scientists are humans too — that they really haven't *all* the wisdom, as people expect of them. Now the trouble with this is that the public is getting very discouraged. If they see several important scientists having completely different opinions about a well-defined subject, then their confidence in science is diminished, as we have witnessed in the United States. The public says, «Oh, the scientists don't agree among themselves, so

what is all this talk about science being an unambiguous yes or no?» Of course, even within science it isn't so, but we agree to a great extent on the fundamental issues, although not on those issues that are mixed with politics. This problem has already very much diminished the impact of sciences on the government in the United States, to the detriment not only of the country but of the whole world. How can we avoid this? How can we re-establish the confidence that the public had in science which is definitely diminished by these problems?

We face the problem of how to get more scientists in the government. How does one convince people to sacrifice their work and join the government? The government too must understand that there should be a scientist and a politician in every office, as was proposed. It seems utopian, but maybe it should be our aim to reach such a situation.

TUPPY

I very much feel, like Professor Weisskopf, that the appearance of science in public is not as positive as it should be because of much open dissent among the scientists. In my opinion, the best way is for commissions of experts to first deliberate — not in public but in their own sphere — and there try to come to more or less agreement before they have this knowledge and advice transferred to government and to the public by outstanding people who have both prestige and the right understanding of how to put things in public. Such a two-step procedure has actually been adopted very often. For instance, in the United States the National Academy of Science has set up many commissions which give most pertinent advice. The Royal Commissions in Great Britain, headed by an eminent personality, have done excellent work, and have definitely influenced politics.

WEISSKOPF

It is true that the commissions appointed by the Academies did very good work. However, I am not sure that they had much influence. As you said yourself, in many cases it didn't work. I would like to make one more remark about comparing European governments with the American scene. I do feel, in spite of the difficulties, that there is much more political participation of scientists in America than in Europe, perhaps sometimes even too much. There should be more participation here in Europe, where there seems to be an attitude among scientists of 'it's none of our business' — the ivory tower attitude. I hope that this will change, and I am sure that your example, Tuppy, will help.

MINTZ

We seem to be discussing two aspects of responsibility of science as adviser. One stems from the prerogative of the government to request advice from scientists, and the other stems from the initiative of scientists and the responsibility of scientists to render advice. These have had very different histories in my own country, the United States. Science advice requested by the government originated formally in the time of President Truman, and was very strong for a period of time. In recent years it has been very weak and lacking in the initiative and responsibility and respect that it deserves. The advice rendered by scientists on their own initiative has not occurred very frequently, not even on the part of the National Academy of Sciences in the United States, which undertakes most of its projects at the request of the government or some arm of the government. Perhaps one of the most important and most influential groups rendering advice on its own initiative was the group of atomic scientists that originated shortly after 1945, the Association of Atomic Scientists which published the Bulletin of Atomic Scientists. I think it had an extremely important influence in airing opinions and controversies, and even making it clear that there were controversies and differences of opinion among scientists themselves — for example, the different views held by Edward Teller and many other atomic scientists. So my question to you, Professor Tuppy, is: in the event that a government neglects its responsibility to seek advice from scientists, is it not preferable for scientists, somewhat in the manner that you yourself have just propsed, to organize themselves as an advice-rendering body and, in connection with the problems that Professor Weisskopf has raised, to create a forum for themselves, rather than to speak solely as autonomous individuals?

TUPPY

I agree that science must not wait until government asks for advice, and that scientists should organize themselves. I am not certain, however, that one forum will suffice and be competent in all respects. The problems are so diversified that, according to what issue is at stake, you have to draw on the experience of different scientists.

PAVAN

I am following this discussion with great interest and I am not sure that we can give general advice for every country. I am afraid if we decide, or if

the government decides, to designate one person to give advice, even if he has under him or with him a group of other colleagues, we may imagine a situation like we had in Russia with Lysenko, which is an extreme case, but we may fear such a situation. I think we, as scientists, should be very active in the giving of suggestions to the government. Take the example we have in Brazil, where we have a very strong society for the advancement of science, and this society is very critical of the government. They discuss there not only pure science or applied science, but also rational science and political sciences, giving advice, criticizing or going along with the goverment. This society has always been very strong, and even during the twenty years when we had a military government in Brazil, this society was critical of the government. Even during the time when we had the strongest dictatorial attitude of the military government in Brazil, we had an annual meeting for one week of ten thousand, fifteen thousand people, and at least half of what we did there was criticizing the government. Even then, this annual meeting was supported by the government. They paid for more than half of the meeting costs, and yet it was the only place in Brazil where criticism could be made of the government and the government tolerated it.

I think scientists should not expect the government to invite them to meet officially and to give suggestions. That's all right, but we should have an outside, independent body that would represent the attitude of the entire group of scientists, rather than a special group. A special group may be in favour of what is modish. For instance, it is fashionable, at present, to sequence the DNA of the human genome. However, it might be better for scientists to seek another subject rather than man for performing such sequencing. When fashion reigns, even among scientists, it can be very dangerous. The best thing to do, I would say, is to form a kind of association like that which the group of nuclear scientists formed. It was very good for the government to know what they thought. The best people should get together, agree on decisions, and give suggestions to the government. I am very much afraid of one person acting alone, but I am totally in agreement with having an association to advise the government on scientific matters.

RUNCORN

I find Professor Pullman's idea of a government of politicians and scientists quite unrealistic. I am sure that something like that in Plato's republic attracted many people, but it's impossible in a modern democracy, as I've no doubt he knows. In Britain, during the war, out of dire necessity politicians,

scientists and the military learnt to talk to each other and cooperate with each other. That was true in the United States and in other countries. That generation, of course, is almost gone and one can see, certainly in my country, that scientists have got to learn again how to cooperate with Whitehall, with higher civil servants and politicians, and I think that one has to recognize that there is a gulf between them which has to be bridged. The scientist tends to look at long-term issues, the politican and the civil servant is very much concerned with immediate issues, and that is a very great difficulty which one has to face. Certainly, scientific advice in Britain on the economy was somewhat of a disaster. Undoubtedly, the labour government of Wilson was convinced that if it put a large investment into science, there would immediately be an upturn in the British economy. It didn't happen, of course, and as a result, I think that scientific advice was later discounted by politicians. Perhaps with the increasingly recognized threats to the environment, scientists and politicians will learn again to talk to each other and collaborate, but I think one has to recognize that there is a gap. I might just illustrate it by mentioning that our Secretary of State for Education, who is a most intelligent man and who writes poetry, was involved in a discussion on medical education. One of my friends said it was clear that people were not getting very far in the discussion, and then he realized that it was because Baker thought that medical professors did not have patients, that they simply taught their students in the way that an arts professor would. There is a gap to be bridged. I think it is very valuable for experience in different countries to be brought together, and we have very much to learn from how these matters are approached in other countries.

MÖSSBAUER

One thing that surprised me is the emphasis on advice to the government. I think that one should also take into account advice to the opposition because the opposition, not being in power, can sometimes make the most remarkable statements about scientific questions, and they are not criticized in the way the government would be. The opposition should also have scientific advisers, and these advisers should be consulted when matters of a technical or scientific nature are discussed, so that the opposition can make sure that they are at least listening to some reasonable advice. This can be quite important, because sometimes the opposition comes into power through these statements that have no foundation in fact.

ECCLES

I want to speak on the need for science training for political leaders — not just science advice to political leaders, but their actual science training. It can give rise to an imaginative policy that is based on a rational evaluation of problems of all kinds and not just of scientific problems per se.

Margaret Thatcher, for example, was well-trained in chemistry at Oxford. Recently the Royal Society of London set up a Committee for Science Policy and appointed Margaret Thatcher chairman of the Committee, and she acts in that responsibility in two committees of the Royal Society of London. So that is quite a remarkable happening, that the Prime Minister becomes chairman of Committees for the Royal Society.

MALU

Monsieur le Président, je ne sais pas si vous l'avez remarqué: nous venons de discuter longuement sur le sujet scientifique, conseillant soit le gouvernement, soit l'opposition, comme le suggérait Monsieur Mössbauer, mais personne n'a dit sur quel sujet les scientifiques devaient intervenir. Implicitement, bien entendu, du moins je l'espère, c'est sur des sujets ayant une composante scientifique importante. Sinon, le scientifique étant citoyen comme les autres, il n'a ni plus ni moins de droit pour qu'il soit tenu compte de son opinion. C'est là une première remarque qui me parait fondamentale.

La seconde est que les scientifiques deviennent aujourd'hui fort spécialisés. Et lorsqu'ils discutent entre eux, il est souvent très difficile d'arriver à un consensus. Je vous cite un exemple personnel: je fais partie du Conseil Scientifique de l'Agence Internationale de l'Energie Atomique. Après Chernobyl, nous nous sommes réunis pour discuter de l'avenir des centrales nucléo-énergétiques. Les opinions étaient fort divergentes; et, finalement, les décisions qui ont été prises étaient beaucoup plus dictées par des intérêts économiques existants que par des critères strictement scientifiques ou techniques. Alors, je me permets de tempérer vos ardeurs, Messieurs, en vous disant que nous pensons tous que nous sortons de la cuisse de Jupiter, mais nous sommes des citoyens comme les autres.

GERMAIN

Des hommes de science donnent des conseils au gouvernement à plusieurs niveaux. D'abord, les Agences gouvernementales. Il arrive souvent, qu'à la tête

d'une Agence, soit appelé un scientifique; ce dernier agit en tenant compte, naturellement, des intérêts de l'Agence. Ensuite, un ministre peut appeler une personnalité ou une commission pour le conseiller; les avis donnés le sont dans un cadre donné, dans des perspectives imposées. Il y a encore le cas de nos Académies nationales. Leurs avis sont formulés en toute indépendance et avec le souci du long terme; et souvent à leur propre initiative et non à la suite d'une question posée par le gouvernement. Est-il souhaitable ou non d'avoir un scientifique comme ministre, ce n'est pas évident. Mais l'expérience que nous avons actuellement en France montre qu'il n'y a pas lieu d'y être systématiquement opposé.

Le profeseur Weisskopf a souligné le trouble créé dans la population lorsque des scientifiques émettent des idées différentes. C'est pourquoi, les Académies peuvent jouer un grand rôle. L'expérience de la nôtre est assez remarquable. Sur des questions délicates, donnant lieu au départ à des opinions opposées, nous avons toujours, après bien des discussions, réussi à obtenir, sur un rapport transmis au gouvernement, une approbation à soixante-quinze ou quatre-vingt pour cent. A ce moment-là, l'avis donné a une valeur certaine.

Il y a donc bien des manières pour les scientifiques d'intervenir, et je crois que c'est une bonne chose. On ne peut imposer à un scientifique qui est ministre de se comporter comme un scientifique qui est Président de l'Académie des Sciences. Chacun doit faire son travail du lieu où il se trouve. Au total, les scientifiques peuvent avoir un très grand poids.

BLANC-LAPIERRE

Je voudrais d'abord dire que j'ai suivi ce débat avec un très grand interêt parce que j'ai eu pendant deux ans la responsabilité de présider le Comité Consultatif de la Recherche Scientifique et Technique en France. Il est bien évident que nous sommes tous d'accord pour que l'influence scientifique se fasse sentir de façon plus forte dans les prises de décision gouvernementales; je crois qu'il faut aussi que nous soyons conscients des limites du domaine de la science. Je résumerai ma position en reprenant la proposition provoquante de Monsieur Pullman, de faire un gouvernement d'hommes politiques et de scientifiques, et ma question serait de lui dire: «Croyez-vous que vous avez atteint l'exhaustivité, si vous vous bornez à ajouter des scientifiques aux politiques?». Prenez, par exemple, les problèmes d'éducation: il y a des composantes qui ne sont pas uniquement scientifiques; prenez aussi les problèmes sociaux: les sciences sociales se développent, mais je ne crois pas que les prises de décision politiques dans ce domaine puissent être uniquement soutenues par des concepts que, à l'heure actuelle, nous pouvons baptiser de scientifiques.

ABRAGAM

I would like to call your attention to a side issue. Personally, I have never been asked by any government to give advice — that was my good fortune, but if you want the government not to do bad things or disastrous things, one way is to educate the public. What we find is that the ignorance of the general public in developed countries is appalling, absolutely appalling; you can make them believe anything. I'll give you just one example. In our country, and I suppose it's the same elsewhere, there are far more astrologists than astronomers, and they make very much more money. Even in non-democratic countries, but especially in democratic countries, the government cannot do completely without public opinion, and you have to educate the public. You have to eradicate at least some of the more stupid notions, and I know it's uphill work. It takes time, it takes education, but I think that if we want the government to act in a reasonable way, we have to educate the public. It's a vast problem, but I think this is an issue which is quite germane to the problem of advising the government.

THIRRING

Professor Tuppy has expressed so clearly what I wanted to say in my intervention the other day, that I cannot possibly contradict him. Yet there is a certain point which I think is dangerous. He has quite correctly said that as scientists we have some expertise and knowledge in our field, but in other fields we are generally not better than anybody else. Now this may lead to the attitude that we will work for the government and give them advice on what we are asked for, but questions of ethics we'll leave to them because we think we are not competent. This attitude probably leads to the situation we are presently living in and which Pope John Paul II criticizes, namely that more scientists work for governments in the world than work for science, and so more scientists actually work for the destruction of mankind. During the Nazi time, this attitude that you had to do what the government said and leave to them the questions of ethics, had terrible consequences. So I think we should not consider ourselves as first and foremost scientists and only in the second place as second-rate amateurs in ethics, but we should consider ourselves first as human beings with our responsibilities, and then in second place as scientists.

TUPPY

Ethical questions concern everybody, including scientists, and scientists are not worse in matters of ethics than others. What I wished to stress, however,

was that they are not, so to say, an elite which is privileged to decide in these matters. I agree that there are certain aspects of ethics which help scientists to be in a better position than others. Professor Weisskopf has already referred to this. Scientists are used to taking more global views that are less restricted with regard to partisan interests. They go more into the depth of a matter, and they ask themselves the question what their activity is good for. More and more scientists ask the question why, not only in relation to the objects they observe, but also why they are themselves doing what they are doing. So they have a good approach to ethics. But we have also heard that scientists may ethically be quite out of keeping with what we feel is right. We have heard about Lysenko. We know that scientists are engaged in the arms race. We must not be confident that scientists as scientists will be ethically on the right road. What I stressed was that you should not confound science with ethics. Scientists should take ethical matters seriously and should try to do their best and declare what their values are. I think that's very important. It would be difficult for many unethical scientists to defend their values, and it's good to know why people are on what side in ethical matters.

RICH

I only want to add a point about my experience in the United States. I was for several years a member of the National Science Board in Washington where we discussed the role of science — this is a board appointed by the President and it is the governing board of the National Science Foundation, but it also considers broadly the questions of the intersection of science with the government. There have been at various times pressures in the United States for the development of a Department of Science. I think more thoughtful people have resisted that for the following reason: the importance of science is such that it cannot be limited to the activities of one Department. In fact, our feeling is that all branches of the government should and indeed must employ science in a variety of ways. Therefore to essentially pull science apart from the other Departments of the government is counterproductive. What we try to do in this board is, in fact, to introduce the activities of scientific advisory groups and the incorporation of science within all of the various branches of the government because it is very difficult to find any activity of government which cannot profit by having scientific analysis or contributions in a variety of ways. This is, of course, a very large component in some Departments, smaller in others, but nonetheless pervasive.

The American scene is both encouraging and discouraging. The encouraging part is that as one looks at the various Departments in the government,

there is in fact a strong support for the use of scientific activities. Those reports that Beatrice Mintz mentioned that the National Academy of Sciences draws up, are frequently drawn up in response to requests from different agencies of the government, and they come from all over the government, not just one or two agencies. That part is encouraging. The discouraging part is the almost complete absence of any understanding of science at the higher levels of the government and that, I'm afraid, is a reflection of the fact that we have by and large failed to educate the populus generally. It's not only that there are more astrologers than astronomers. The situation is more grievous than that. I went into a bookstore in Harvard Square which is in Cambridge, a well-educated area, and I looked in the science bookshelf and there was astrology next to astronomy. I asked the clerk, «Why is astrology here?» He said, «Well, it's with all the sciences». In other words, this apparently well-educated person didn't understand the difference. So I think we have a very large educational task. We can only hope that in the upper reaches of government, science education helps. However, let me say that sometimes it's counterproductive. If I look at some of the heads of government who have done the best as far as the use of science in their government, they're often people without scientific training, and if I look at other governments, where some of the heads of state have had scientific training, I see that in fact they do very poorly in terms of utilizing or developing science. So it's not clear to me how to make that kind of coordination, but our chore certainly is to educate the public more broadly.

LEPRINCE-RINGUET

Je voudrais faire quelques remarques à la suite de ce qui a été dit.

Premièrement: je suis tout à fait d'accord avec ce que Germain a dit.

Deuxièmement: est-ce que, au gouvernement, il faut mettre des scientifiques? Faut-il en mettre comme ministre de la Recherche, par exemple?

Je crois que ce n'est pas mauvais d'avoir un scientifique dans le gouvernement. Actuellement, nous avons comme Ministre de la Recherche, un homme de science qui est modeste, qui ne passe pas à la télévision; mais au sein du gouvernement, je pense qu'il doit donner un avis intéressant. Parmi les Ministres de la Recherche qui n'étaient pas des scientifiques du tout, certains d'entre eux ont été de bons ministres, parce qu'ils se sont informés.

Certainement, les scientifiques ne sont pas faits pour faire de la politique. La politique, c'est la leçon du compromis. Nous, nous avons dans notre éthique d'être ouverts aux phénomènes, aux faits que nous ne connaissons pas mais que nous détectons. Avant tout nous avons besoin d'avoir une très grande hon-

nêteté scientifique, c'est à dire de reproduire les choses, de refaire les expériences, d'attendre assez longtemps pour publier quelque chose. C'est exactement l'opposé de ce que fait le politicien, l'homme politique, qui doit souvent, au contraire, très vite faire des compromis. Donc participer à la vie politique n'est pas du tout dans notre forme de tempérament, dans notre formation et dans notre éthique.

Ensuite, quant à l'information des hommes politiques: bien sûr, il faut que les politiciens soient informés, mais trop souvent ils n'en ont aucune envie.

Autre remarque: les scientifiques de l'énergie atomique, les Commissaires à l'Energie Atomique (j'étais Commissaire à l'Energie Atomique à ce moment-là), n'ont pas été consultés pour le lancement de la bombe atomique française.

Autre remarque encore, qui touche celle d'Abragam sur l'éducation du public, sur l'astrologie en particulier. Il est absolument certain que la télévision a une action considérable. Supposez que la télévision — ce qui s'est passé — présente un quart d'heure bien ficelé, d'astrologie avec Mars, Saturne, Venus, la conjonction, etc. Cela agit profondément sur la population française. Par contre, si vous avez un quart d'heure sur les naines blanches, sur tout ce que l'astronomie a découvert avec toute l'intelligence accumulée des siècles des astronomes, ça peut avoir une action aussi, mais pour pouvoir porter un jugement là-dessus, il faut avoir une certaine formation rationnelle, scientifique, et ce sont les enseignants qui doivent donner cette formation du jugement. Dans la télévision, tout ce qui est scientifique, para-scientifique, faussement scientifique, etc., tout cela a la même valeur, comme disait Rich tout à l'heure. C'est donc au cours de l'enseignement, dans les classes, avec des enseignants capables de le faire, qu'il faut former le jugement des jeunes. Sans cela ils croient n'importe quoi.

Enfin, pour former et informer le public, il ne faut pas que les scientifiques se réunissent en conclaves sur un sujet sur lequel ils ont des opinions totalement différentes, car le public dira: ils ne sont même pas capables de s'entendre. Dès ce moment-là, le public ne croira plus du tout les scientifiques. D'un autre côté, si un scientifique un peu attrayant passe à la télévision, il a une influence très grande. Il y en a un, par exemple, avec une barbe superbe, qui parle d'astronomie chez nous. C'est ce genre d'individu, de personnalité qui peut avoir une influence sur la formation du public en matières scientifiques. Il faudra donc que chez les scientifiques on distingue et on désigne des personnes qui soient capables de bien passer à la télévision, d'être attirantes. C'est eux qui donneront le message scientifique le plus valable actuellement. Pensez que dans trois ans nous aurons cent ou cent cinquante chaînes que nous pourrons écouter et observer. Alors il se peut très bien qu'il y ait des chaînes avec une vocation plus scientifique, et des personnalités attirantes, jeunes, intéressantes, qui passionnent le public.

PULLMAN

Je voudrais revenir à une proposition faite par Monsieur Weisskopf et qui n'a pas reçu assez d'attention, à savoir, la détérioration de l'image de la science auprès du public. Certains auteurs en ont parlé, mais peut-être n'ont-ils pas vu le problème sous cet aspect-là.

Il n'y a pas si longtemps, on pouvait dire que la science et la société étaient des amoureux. Maintenant, elles sont mariées de façon indissoluble, et il est très important que l'image de la science auprès de la société soit améliorée.

Ce n'est pas désespéré, comme cela semble paraître. Dans la nouvelle génération de jeunes on peut constater un intérêt croissant à venir visiter par exemple un laboratoire. Chaque fois qu'on fait une journée ouverte, il y a une affluence formidable de jeunes.

Il y a peut-être une tendance à revenir vers une considération plus respectueuse, plus enthousiaste envers la science. C'est quelque chose que nous devrions étudier avec soin. Je crois qu'il y aurait intérêt à consacrer une de nos séances à la réflexion sur la manière dont nous sommes capables d'améliorer l'image de la science auprès du public. Il faudra analyser à fond, peut-être même par une sorte de sondage, quelles sont les raisons qui ont produit cette détérioration de l'image de la science — il y a des raisons militaires, écologiques, économiques. Je crois que par une réflexion conjointe (et on voit ici des tas d'idées qui germent à chaque instant) nous trouverons un moyen organisé, peut-être selon les lignes indiquées par Monsieur Leprince-Ringuet, à remonter cette pente. Il est certain que nous pourrions mieux influencer le gouvernement dans la mesure où l'image de la science auprès du public sera meilleure. Si le public est pour la science, approuve la science, cela nous aidera à faire valoir nos points de vue auprès des autorités qui nous gouvernent.

ETHICS AND HUMAN EXPERIMENTATION

PERCY C.C. GARNHAM
Southernwood, Farnham Common, UK

On two previous occasions, I have addressed the Academy on the ethics of experiments on man and animals: in 1975 on the use of man and primates in scientific research and in 1978 on the general responsibilities of the scientist in regard to such experimentation. The first paper was largely devoted to animals, and I made the comment that the ethics of human experimentation are another question. This, however, needs further attention and the present paper has tried to cover the problem in special reference to my own experience in biomedical research.

The ethical question stems from the Hippocratic Oath as extended by the modern codes (e.g., the Tokyo revision [1975] of the Helsinki Declaration [1964] as amended in Venice, Italy, in 1983). Two considerations are fundamental: does the project have a humanitarian basis, or is it to satisfy the curiosity of the worker, and apparently devoid of practical value?

Today, I intend to present the aspect from two points of view: (1) to mention a few personal, ethical problems that arose in the course of my research, and (2) to describe briefly recent ethical recommendations in the United Kingdom and France, respectively.

Fifty years ago in Kenya, I started to work on the one remaining lacuna in the life history of malaria parasites of man and monkeys, viz., the course of development of the sporozoite in the body, after the mosquito bite. Early in 1947, I showed that the early development of these (*Plasmodium kochi*) in African monkeys took place in the parenchymal cells of the liver. Later in that year, I returned to England to join forces with Colonel Shortt, FRS, who was working on the same problem. Our preliminary experiments (1948) on rhesus monkeys showed that the simian parasite (*Plasmodium cynomolgi*) developed in liver cells, 8 days after the monkeys had been bitten by infected mosquitoes. This monkey parasite resembles closely the form responsible for benign ter-

tian malaria (*P. vivax*) of man. We were anxious to confirm that a similar cycle occurs in the human liver.

A human volunteer was therefore required and the ethics of such an experiment had to be carefully considered. Fortunately, malaria therapy of the hitherto fatal disease of general paralysis (of syphilitic origin) had been introduced by Wagner-Jauregg in Vienna in 1922, and centres had been quickly opened in various countries in Europe and the United States of America. Important malaria therapy clinics were established in Horton, England, by S.P. James, FRS, and Shute; in Milledgeville in the U.S. by Jeffery and Young, and in Bucharest, Rumania, by Ciuca. The cure of nearly 40% of the patients with G.P.1, accompanied by malaria research on the largest scale was the outcome; ethical problems were minimal or non-existent.

Our own experiment (1948), however, required the introduction of immense numbers of the sporozoites of *P. vivax* into the patient with general paralysis. He was bitten by 2000 infected mosquitoes and inoculated intravenously with the salivary glands of another 200. Eight days later, a biopsy of the liver (by open operation) was taken by Mr. Radly-Smith, surgeon of King's College Hospital. The timing of 8 days was chosen as the result of experiments carried out on several hundred soldier volunteers by Sir Neil Fairley, FRS, (1945) (a future collaborator in our experiments), who showed that the prepatent period was 8 days (in other words, after the parasites had matured somewhere in the body though the actual site was unknown). The ethics of Fairley's work had been limited to simple verbal consent, but our own experiment needed a careful protocol, including the informal consent by the patient and his wife, and the approval of the Chairman (Professor Macintosh) of the London School of Hygiene & Tropical Medicine, and the Superintendent (Dr. W.T. Nicol of Horton Hospital). The experiment was successful and revealed that the sporozoites developed in the liver, like the forms found in monkeys in the first experiment.

The next experiment (1951) involved the use of a volunteer in order to ascertain the details of the life history of *Plasmodium falciparum*, responsible for the most virulent type of malaria (with an annual mortality rate of over a million). Of the several volunteers, Mr. L.H. Howard, of the Ministry of Civil Aviation of London, was chosen. With the approval of Sr. Wilson Jameson, Chief Medical Officer of the Ministry of Health, and of Professor James Macintosh, Dean of the London School of Hygiene and Tropical Medicine, and after the formal consent of the healthy volunteer, the experiment was performed. 770 mosquitoes, infectd with *P. falciparum*, were allowed to bite him, and 140 hours later a biopsy of his liver was taken, and a portion of liver excised, by Mr. Naunton Morgan of University College Hospital. Mr. Howard made a rapid recovery (as had the former case) and later Mr. Howard's noble act was

recognised by the award of the M.B.E. A second volunteer (a technician of Sir Neil Fairley's) was used in this experiment, as confirmation of successful transmission, by the inoculation of blood from Mr. Howard (at the end of the expected incubation period). Eight days later, this volunteer also exhibited parasites of *P. falciparum* in his blood. Examination of the liver sections revealed schizonts with a surprisingly quite different morphology from those of *P. vivax*. Their cycle in the liver occupies 6 instead of 8 days.

The third malaria parasite of man is the species which causes quartam malaria (*P. malariae*), which sometimes is thought to have been the cause of Oliver Cromwell's death in 1660. Fortunately, chimpanzees are susceptible to this species, and we were able to subistitute these apes in place of man, to elicit the details of the life history. I do not want to discuss now the ethical problems arising from the use of the surrogate host — a rare animal which is in danger of extincion. The liver cycle was found to last 15 days.

The fourth type of human malaria is caused by *P. ovale*, an uncommon parasite limited to certain tropical and subtropical countries, in the Old and New Worlds. I was most anxious to complete our knowledge of the life history of *P. ovale,* which might throw light on the mysterious geographical distribution. We encountered difficulties in this last experiment (1958), in which the same ethical problems arose. I had to wait for over a year, before acquiring a strain of the parasite, but eventually (in 1953) I received a telephone call from the Liverpool School of Tropical Medicine, to say that a Roman Catholic priest from Liberia had just been admitted to hospital, suffering from *P. ovale* malaria. Two patients in succession were infected from his blood, and some blood of the second (a woman with nephrosis) was sent to London, where it was inoculated intravenously into myself in the hope that enough gametocytes (the stages required for infecting mosquitoes) would develop in order to infect the hundred or so with which I was to be bitten. Unfortunately, only a few became infected and my blood was inoculated into Dr. Ralph Lainson, FRS, a volunteer working in my department. Again the result was unsatisfactory and his blood was passed to Dr. Robert Bray, with a poor result, as was the case also with the fourth volunteer — Dr. F.I. Awad — an Egyptian student also working in my laboratory. This was unsatisfactory too and we then inoculated the blood into two «general paralytics» in Horton Hospital who required malaria therapy. Transmission by mosquitoes succeeded in the latter, but only feeble infections resulted. Finally, success occurred when Dr. James Williamson (a Scotsman, working temporarily in my department) allowed 18 of the infected mosquitoes to bite himself and an excellent infection followed. Nearly a thousand mosquitoes were fed on Williamson at the peak of gametocyte production, and 77% became infected in their turn.

Now came the crucial and heroic stage of the experiment. My Chief Technician, William Cooper, for several months had been begging to be allowed to participate. He was accordingly bitten by 750 of the above batch of mosquitoes, on 3 successive days, and then submitted to the removal, 9 days later, of a piece of his liver by Mr. H. Wolfs, FRCS, Surgeon of University College Hospital. In the sections we found the exoerythrocytic stages, and Cooper (still in hospital) was so excited that he insisted that a microscope should be brought to his bedside for him to see the hitherto unknown stage, and then — for he was an excellent artist — to paint pictures of this stage. After a short attack of pneumonia, he recovered completely.

The consent of the Ethical Committee was unanimously given for all these experiments. Thirty years later it would not have been so easy: the use of human volunteers, experiments on animals, and also the legal requirements for vivisection have been made much stricter, and the anti-vivisectionists (even our own students) resort to most unpleasant and even injurious actions.

I shall give a brief summary of the restrictions which are required today. An example is taken from my old Department in the London School of Hygiene and Tropical Medicine, now in charge of my successor, Professor Wallace Peters, who has shown me the protocol of an experiment in progress on leishmaniasis, a cosmopolitan disease, which still ravages large parts of the tropics and subtropics.

The project is a clinical trial of a vaccine to protect people against *Leishmania major,* which causes severe skin lesions and deformities. The live vaccine is prepared from the non-pathogenic *Leishmania arabica* (like Jenner's use of cowpox to vaccinate against smallpox). The first stage of the experiment is being carried out on volunteers at the London School of Hygiene, and the second in the field, in Saudi Arabia. The volunteers are selected from healthy male adults, preferably residents of Saudi Arabia, where the disease is prevalent and who would therefore be likely to benefit if the procedure proves successful. The volunteers are free from chronic disease like tuberculosis, allergies, previous infection of *Leishmania,* history of HIV positivity or known carriers of hepatitis viruses.

The volunteers are fully informed of the potential hazards, they then sign the consent form, which indicates that they may withdraw from the trial at any time. After vaccination with *L. arabica,* each volunteer will be given a written statement setting out the aims, methods, anticipated benefits and any discomfort that may ensue.

The volunteers who become positive to the «leishmania test» showing that they have been successfully immunised against *L. arabica,* will be challenged with the virulent *L. major.* Any who remain negative will also be inoculated

with this parasite as a control, and also two other volunteers who have not been inoculated with *L. arabica.* A careful follow-up (fortnightly) is to be made for 1 year and any volunteers who have developed the disease will be given full treatment. The general practitioner of each volunteer will be kept fully informed and asked to certify that he has no objection to the study.

The third phase will be conducted in highly endemic sites in Saudi Arabia and similar informal consent forms (in Arabic) will be duly signed. If the results are satisfactory, an eradication campaign of vaccination is likely to be introduced by the Public Health Authorities of the country.

Finally, I should like to give two examples of modern attitudes to research involving human volunteers. The first is that of the Royal College of Physicians of London (1986), and the second is that of the Académie Nationale de Médecine of Paris (1988).

The English report emphasizes the need for approval by an Ethics Committee (preferably with some lay members), which should attempt to define the «risks» involved and ensure that the «risks» should not be more than «trivial» or «minimal». Financial reward of the volunteers is not essential, except for reimbursement of expenses. Certain groups should be excluded, e.g., pregnant women, children, the elderly and the mentally handicapped; but prisoners, colleagues, and service personnel may be acceptable as long as details of the proposed experimentation are *fully explained,* and a written account is provided. There is an obligation to protect the volunteers from harm and preserve their rights, e.g., to withdraw from the study at any time. (It is remarkable that the following statement, nevertheless, is included in the report: «When a volunteer leaves the study and exercises his right not to give a reason, *no payment need be made*»). The possibility that the research may entail «ill-health» of the volunteer can never be eliminated, so binding commitments to provide compensation must be made.

The French report is on much the same general lines. It stresses the desirability (and indeed the common practice) of the research worker to carry out the experiment on himself before using volunteers. Again, the conclusions in this Report are related to two essentially different types of research: therapeutic trials and experiments on healthy volunteers. In regard to the latter, it begins with the statement «Medical tradition, on ethical grounds, condemns (without ambiguity) all experiments on healthy man», but it continues with the proviso that this principle can exceptionally be waived after the approval of the Ethical Committee (composed of scientists and others, familiar with the subject of the research). It is essential that «Free Consent» of the volunteer is obtained, the potential risks explained and the progress of the experiment described to him throughout its course. The Report of the Ethical

Committee guards itself by stating that it gives its advice and opinions without having actual responsibility or the power of either formal approval or of prohibition. It is the experimentor himself who is ultimately responsible, legally and morally.

In this paper I have concentrated on only a single aspect of ethics, viz., research on volunteers to ascertain unknown details of the life history of certain pathogens which cause important human disease, with a view to the designation of methods for their elimination. You are all probably aware of the intense activity today to produce a vaccine against malaria in which similar ethical points are at issue.

Before concluding this rather incompatible paper in this high-power symposium I want to thank our President for all kindness in the last 18 years of our association in the Academy. I have long been familiar with the work of his famous father, Carlos Chagas (the great discoverer of many new ideas in tropical medicine). I have enjoyed the friendship of his dear son, Carlos, who is responsible for the immense progress in science in Brazil and indeed in the whole world. Long may it continue!

REFERENCES

FAIRLEY, N.H. «*Trans. Roy Soc. Trop. Med. Hyg.*» *38*, 311-328 (1945)

GARNHAM, P.C.C. «*Trans. Roy. Soc. Trop. Med. Hyg.*» *40,* 719-722 (1947).

GARNHAM, P.C.C. «*Commentaria*» *3,* 1-12 (1975).

GARNHAM, P.C.C. «*Scripta Varia*» *Science and the Modern World* (Part 1) 67-69 (1978).

GARNHAM, P.C.C., BRAY R.S., COOPER, W., LAINSON, R., AWAD, F.I. and WILLIAMSON, J. «*Trans. Roy. Soc. Trop. Med. Hyg.*», 49, 158-167 (1955).

JEFFERY, G.M. «*J. Nat. Mal. Soc.*» *10,* 337-344 (1951).

LORTAT-JACOB, J.-L. «*Bull. Acad. Natle. Méd.*» *172,* 487-494 (1988).

LUPASCU, J., CONSTANTINESCU, P., NEGULICI, N., GARNHAM P.C.C., BRAY, R.S., KILLICK-KENDRICK, R., SHUTE, P.J. and MARYON, M. «*Trans. Roy. Soc. Trop. Med. Hyg.*» *61*, 484-489 (1967).

ROYAL COLLEGE OF PHYSICIANS OF LONDON, *Research on Healthy Volunteers,* «*J. Roy. Coll. Physicians*», *20,* 244-257 (1986).

SHORTT, H.E. and GARNHAM, P.C.C. «*Nature*» *161,* 126 (1948).

SHORTT, H.E. and GARNHAM, P.C.C. «*Trans. Roy. Soc. Trop. Med. Hyg.*» *41,* 785-795 (1948).

SHORTT, H.E., FAIRLEY, N.E., COVELL, G., SHUTE, P.J. and GARNHAM, P.C.C. «*Trans. Roy. Soc. Trop. Med. Hyg.*» *44,* 405-420 (1951).

WAGNER-JAUREGG, J. «*J. Nerv. Ment. Dis.*» *55,* 369-375 (1977).

DISCUSSION

MALU

Ce problème d'éthique dans l'expérimentation médicale est, bien entendu, fort important. On tend actuellement à le résoudre en constituant un Comité d'Ethique. C'est ce que le professeur Garnham a rappelé. Mais ce faisant, on déplace en fait la problématique au niveau de la constitution de ce Comité. Forcément, pour des raisons de politique, c'est toujours un moyen terme qui est visé, ce qui fait que le Comité en question a tendance à déboucher sur des solutions de compromis qui ne satisfont pas nécessairement l'ensemble ou des parties de la communauté nationale.

Alors je me demande si, pour sortir de ce dilemme, on ne devrait pas requérir que ceux qui demandent à faire ce genre d'expérimentations, puissent s'inoculer eux-mêmes d'abord.

MARINI-BETTÒLO

Je pense que le professeur Garnham a déjà fait lui-même ces expériences sur lui-même et que c'est un exemple. Mais c'est une question extrêmement délicate. Même le Comité Ethique ne peut pas toujours ôter toute responsabilité à l'homme qui fait l'expérience lui-même. La question des volontaires est encore plus grave, si, comme dans quelques pays, on emploie des personnes qui sont en prison, comme on l'a fait quelquefois. Mais en tout cas, il faudra que le Comité Ethique envisage même ces possibilités, et quelles sont les limites que l'on peut demander. Certainement, il y a des volontaires, mais si ces volontaires sont des prisonniers, la question devient encore plus difficile.

MINTZ

My question is very much related to the remark that Professor Marini-Bettòlo has just made and I'd like to address the question to Professor Garnham. The ethical dilemma which is so much at the heart of human experimentation is the problem of informed consent, isn't it? You of course address that question, but it's difficult, partly because frequently the subjects of human experimentation are not the élitist group that you describe but prisoners and other people who may have limited education. So the capacity of the subject to understand the risk may vary a great deal and even more than that; the experiment is inherently dealing with unknowns. That's why it's an experiment.

It's dealing with an inability to predict the risks that may occur. How does one regard this dilemma?

GARNHAM

I published my views on this in the Academy's *Commentarii series.*

(See P.C.C. Garnham, 1975, *Commentarii* Pont. Acad. Sci. Vol. III, no. 8, *Some ethical considerations regarding the use of man and primates in scientific research.*)

LEJEUNE

On a beaucoup parlé d'avoir des scientifiques dans le gouvernement. J'aimerais avoir des économistes dans les comités destinés à savoir si quelque chose est bon ou mauvais, car dans ce que j'ai pu lire sur les expérimentations humaines — je ne parle pas de ce qu'a fait le professeur Garnham, qui est la preuve que les scientifiques opèrent sur eux-mêmes — ils sont à la fois dévoués et prudents, mais très souvent les expériences qui sont proposées le sont sur l'homme, parce que c'est moins cher d'opérer sur l'homme que sur l'animal. Et je pense qu'il y a là un horrible scandale — et ce ne sont pas les Comités d'Ethique qui le résoudront — car, très souvent, les Comités d'Ethique ne sont fabriqués que pour changer la morale. Et il me semble que d'abord, il faudrait démontrer que l'objet d'étude envisagé est définitivement irréalisable en dehors d'un essai sur l'homme, et c'est très rarement le cas.

CHAGAS

If there are no comments, I would like very much to make a small comment because for about 20 years sometimes this comment comes back to me. This is a problem of a country which produced a very good vaccine against streptococcus and then vaccinated 700 children and took 700 other children and did not vaccinate them in order that they could from a control. Naturally, as it happened, those who were vaccinated had a very small number of cases of endocarditis compared with the others. Was it right to choose the 700 who were to be vaccinated but to exclude the other 700? In my opinion, if the vaccine had been effective, it should be given to all, but then there would be no scientific control. In my country, there were many experiments on a vaccine against what my father called American trypanosomiasis. One good researcher injected this vaccine into himself and then injected the same vaccine into what

he called volunteers. Some of the volunteers were paid, and I don't believe very much in paid volunteers. Others were his assistants who were under the influence of his prestige. Happily the vaccine comprised attenuated trypanosomes, which did not produce the disease. In the early stage of vaccination against typhoid fever I know of a very similar case, in which typhoid fever developed in some of the volunteers. So this is a problem which I think is very important. What is really a volunteer? We can influence volunteers by money, by pressure, by incentives, and also by personal prestige. It's difficult, as a scientist, sometimes to oppose this sort of experiment. On the other hand, it's also very difficult to analyze the real ethical aspects which are involved. So I am happy that Professor Garnham raised this question.

THE ROLE OF THE ACADEMY IN THE DEVELOPMENT OF NATURAL DRUGS FOR THE BENEFIT OF HUMANKIND

SALIMUZZAMAN SIDDIQUI
H.E.J. Research Institute of Chemistry, University of Karachi, Pakistan

As a result of studies in the alkaloidal constituents of *Rauwolfia serpentina* during the 1930s we obtained nine new alkaloids; namely, ajmaline, ajmalinine, ajmalicine, isoajmaline, neoajmaline, serpentine, serpentinine, along with two weak bases m.p. 220° and 234° from the neutral fraction of the alcoholic extract. On mild hydrolysis the base melting at 234°, which was not assigned any name, yielded an acid and a base. In 1952, Schlittler *et al.* reported the isolation of this base from the «oleo resin» fraction and gave it the name reserpine. Reserpine later acquired worldwide reputation as the main hypotensive and sedative agent of Rauwolfia.

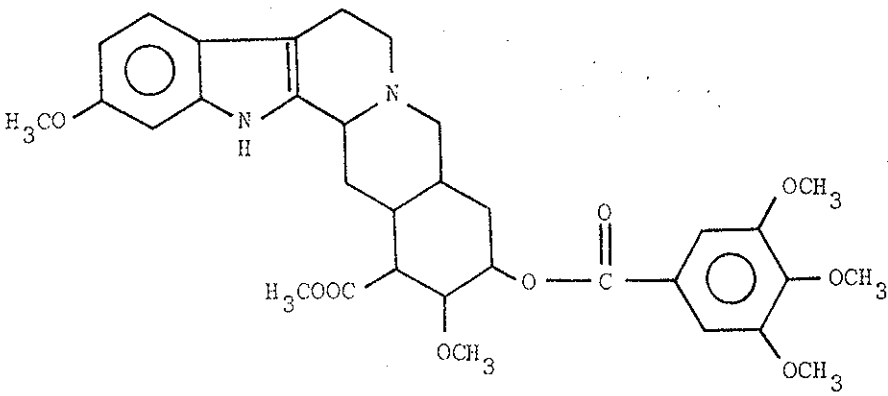


Fig. 1. Reserpine

As a result of clinical experience over a long period, however, it was noted that its extended use in the treatment of hypertension produces heavy depressions in about 50% of patients, leading in many cases to suicidal tendencies and schizophrenia. On account of this complication, which is due to the dual activity of reserpine as a hypotensive and a sedative, a large number of derivatives of reserpine were prepared with the object of eliminating or reducing either one or the other of these two actions, but none of those reported by different workers have so far come into therapeutic use.

The pharmacological investigation of the antiarrythmic activity of nitroajmaline revealed that it is more than twice as active as ajmaline. Profiting from this finding, it appeared of interest to extend the nitration studies to the reserpine molecule in order to note any changes in its dual hypotensive and sedative central depressant action.

Due to the extreme susceptibility of reserpine to resinification and formation of tarry material on its reaction with nitric acid, a great deal of difficulty was experienced in working out the optimum experimental conditions for this reaction. When the nitration of reserpine was carried out in glacial acetic acid at 18-20°C with a reaction period of about 4-6 min., three position isomers of mononitroreserpine were obtained. In the course of these studies it was noted that the experimental conditions in respect of the variables of concentration of reactants, temperature, duration, and the speed with which the reactants are brought together are highly critical. If these conditions are not meticulously observed, there is either failure of the reaction or formation of tarry material. For instance, if the optimum proportion of nitric acid (eight moles) in glacial acid (Merck) is added slowly drop by drop with mechanical stirring at 20°C to a solution of reserpine in glacial acetic acid, reserpine nitrate crystallises out and there is no formation of a nitro derivative of the base. On the other hand, when under the same conditions the reaction mixture is quickly run through a burette and allowed to stand for 4-5 min, the initial yellowish colour of the reaction mixture changes over to red and then deep red. On quenching the reaction at this stage by pouring into crushed ice, and working it up in the usual manner, 1-nitroreserpine, m.p. 146°C (dec) is obtained in a yield of 40-50%, 12-nitroreserpine, m.p. 231°C (dec) 10-12% and 9-nitroreserpine, m.p. 253°C (dec) only in minute quantities in the form of carmine red prismatic rods.

A bioassay for possible carcinogenicity of reserpine was conducted by the National Cancer Institute, N.I.H., USA, by administering the test chemical in feed to F344 rats and B6C3FI mice. It was concluded that, under the conditions of the bioassay, reserpine was carcinogenic in male rats and in mice of both sexes, producing three different kinds of cancers. It was further added

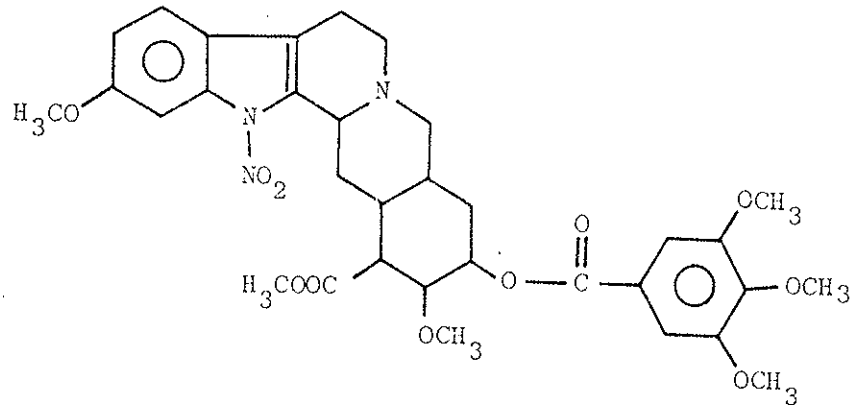


Fig. 2. 1-Nitroreserpine

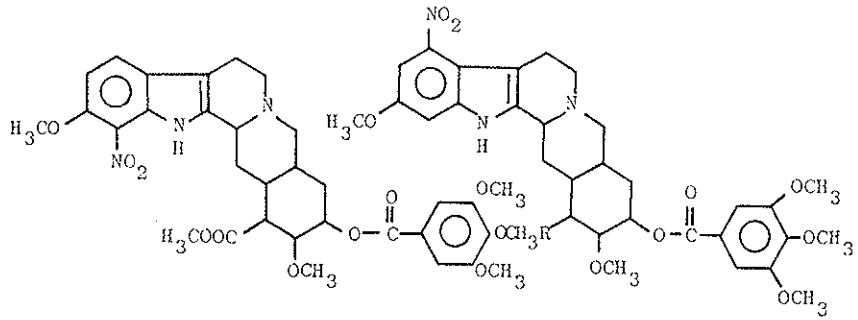


Fig. 3. 12-Nitroreserpine and 9-Nitroreserpine (R = $COOCH_3$)

that reserpine was not carcinogenic for female rats, but they may not have received a high enough dose for maximum test sensitivity.

Taking these studies into account, nitroreserpines have now been submitted to the National Cancer Institute for their carcinogenicity testings and the results are keenly awaited. If it turns out that nitroreserpine(s) are not carcinogenic, though strange, it would be a significant finding and would possibly lead to the development of anti-hypertensive drug(s) which are free from carcinogenic properties of reserpine.

DISCUSSION

MARINI-BETTÒLO

We must always congratulate Professor Siddiqui for having discovered many years ago reserpine which was a turning point in the treatment of many mental illnesses and not only of hypertension. We must also congratulate him for continuing even now his research in this field, by preparing a certain number of derivatives. I think that this demonstration he gave of reserpine and its derivatives is quite good because we may always have some doubts about these new molecules that are formed.

Now I would like to ask Professor Siddiqui: he has prepared nitro-derivatives, but are there also some products of reduction, that is, the corresponding amino derivatives, and was their action tested and if yes, what are the effects of these compounds?

SIDDIQUI

On reduction 1-nitroreserpine gives back reserpine instead of the corresponding amino derivative. 12-nitro-derivative, however, afforded the 12-aminoreserpine, but the yield did not allow to undertake its biological testing.

The substances which were obtained as a result of these reactions have been sent to you for investigation, to you personally; you are forgetting.

CHAGAS

Thank you, Professor Siddiqui. It's always a great honour to have you here with us.

DE GIORGI

Je voulais dire que, à côté du problème de l'expérimentation correcte, il y a aussi le problème de l'usage correct des choses qui ont été correctement expérimentées. C'est peut-être le plus difficile.

On a parlé des pesticides; certains amis qui connaissent la chimie m'ont dit que les armes chimiques qui ont été utilisées dans les villages kurdes dans ces derniers mois, ont été très voisines des pesticides. Alors, un problème que nous devons considérer, est le problème de développer quelque forme d'anti-

corps culturel contre le mauvais usage des inventions qui ont été faites avec les meilleures intentions et avec la plus correcte expérimentation.

Et pour ces choses, il est nécessaire, certainement, comme Monsieur Lejeune l'a dit, d'éduquer le public, mais il est nécessaire aussi d'éduquer la communauté scientifique et la communauté culturelle. Par exemple, à propos de l'usage des armes chimiques, je connais une certaine réaction en Italie, mais seulement dans les universités de Pise et de Lecce. Je ne sais pas s'il y a eu quelques réactions dans les universités des autres pays du monde. Je serais heureux de savoir que, dans d'autres pays, la réaction a été plus forte qu'en Italie.

Le problème, à mon avis, est de développer ce type d'anticorps culturel qui a été découvert plusieurs milliers d'années auparavant par les anciens: la sagesse. Par exemple, le Livre des Proverbes qui date, je crois, de mille ans avant Jésus-Christ, parlait de cette sagesse qui était en même temps l'ordinatrice du monde physique et aussi l'ordinatrice du monde éthique. Le problème est de développer, dans des formes différentes, cet esprit de sagesse que les anciens appelaient philosophie — l'amour de la sagesse et, dans la divulgation, faire comprendere que toute l'information scientifique que nous pouvons donner aux autres, a une valeur dans la mesure où elle naît d'un véritable amour de la sagesse.

Il faudra nous éduquer pour éduquer les autres. Les deux choses doivent toujours marcher ensemble. Il n'y a pas de bon maître qui n'ait rien appris de ses relations avec ses élèves. Je pense que ceci, et les méthodes pour le réaliser, pourraient être le sujet de réflexion et de réunion pour notre Académie et d'autres académies.

Sur le problème spécial des Kurdes on a réagi d'une façon plutôt faible: des télégrammes aux Ministres des Affaires Etrangères et aux Chefs de Gouvernements. Ces problèmes exigent des moyens plus efficaces.

A CRITICAL SYNTHESIS OF THE PLENARY SESSION

JÁNOS SZENTÁGOTHAI
Dept. of Anatomy, Semmelweiss University, Budapest, Hungary

Professor Chagas, dear colleagues: Having been asked to give an overview of these exciting days — a great and, I am afraid, undeserved honour — I find myself in a most difficult situation, because I have to agree with almost everything that has been said. The dilemma is, of course, how to agree at once with different people who seem to disagree on a couple of fundamental issues. If we find ourselves in such a dilemma in Hungary, some rabbinical story would invariably turn up; we have in my country quite a tradition in such parables. The story runs that a rabbi famous for his great wisdom is asked to mediate between a quarreling couple. First the husband visits the rabbi and tells him about his grudge against his wife. The rabbi tries to console him by saying: you are quite right, my son, I know your wife is a terribly garrulous woman, but you still have somehow to live with her. Soon it is the wife's turn to tell her side of the story. The rabbi tries to pacify her by saying, you are quite right, my daughter, your husband is a very difficult, conceited, and self-righteous man, but I still advise you to get along with him peacefully. The rabbinical student, overhearing his master, asks him in private how come, most reverend rabbi, that you agree with both parties, what is the logic? The rabbi, stroking his beard, finally says, you are completely right, young colleague! So here is my predicament.

In the short time available, I cannot mention all the important questions that have been raised, but hope to be able at least to touch briefly upon some of the highlights of the discussion.

Let me start with an issue that is very close to my own heart, the importance of basic science research. Professor Weisskopf, in his plea for more recognition for and support of efforts in the basic sciences, has articulated the need of humankind for a better understanding of the laws of nature and of

human social mechanisms as the only token not only of progress, but even for survival under the circumstances that we will be facing in the near future. Professor Weisskopf himself and several of the other speakers have pointed out two main obstacles that stand in the way of the much needed progress. One of the major obstacles is the lack of motivation in the younger generation to take up basic science as a career. A major factor in this is the erosion in modern societies of the prestige of the teaching profession. This erosion can be experienced at all levels, from universities down through colleges, secondary and primary schools — to the kindergarten level. One major factor of this erosion is the increasing separation between teaching and research mainly at univesities and so-called «pure» research institutions. Technical development in teaching (various audiovisual, computerized, do-it-yourself programs, etc.) may be spectacular in many parts of the world, but this seems only to increase the speed of decline in the prestige of teaching. This is reflected in the low salaries in the teaching professions, which have reached unskilled labor levels in many of the eastern Socialist countries.

Professor Moshinsky has cited the example of Japan, where the reputedly high level of science teaching in primary and secondary schools may be in a causal relation with the spectacular economic success of modern Japan. This may be so, but I can still remember my youth as assistant at Budapest University, when we used the expression «Japanese science» with typical «Western» feeling of superiority for the unimaginative, overpragmatic, pedestrian, although exacting and painstaking approach of our Japanese colleagues. Today, when the success of Japanese science and technology will soon be matched by similar spectacular development in South Korea, Taiwan, Hong-Kong, Singapore, and probably within the lifetime of our younger contemporaries also in mainland China, we will have to become more humble, and may become motivated to undertake a more circumspect and trenchant analysis of the sociological and other human factors involved in the apparent success of some contemporary societies.

The erosion of the prestige of basic research in Caucasian societies is not unrelated to the widespread anti-science mood of large segments of our populations. This is only partially due to the two apparent major factors: the great publicity given especially in juvenile subcultures to irrational beliefs, symbolism, ritualized practice (from beliefs in astrology, paranormal phenomena, spiritism, etc., down to so-called «satanic cults»), and the disenchantment of post-industrial societies with the dubious benefits of modern industrial civilization (danger of an atomic holocaust, a global environmental catastrophe, etc.). We have to realize that progressive secularization of modern societies, erosion of the traditional ethical values proclaimed and upheld by the major religions of

the world, emerging irrational fundamentalism and increasing intolerance, significantly contribute to anti-science sentiments throughout the industrialized world.

The problems of the developing countries have been mentioned repeatedly during these days. A major issue, of course, is the population explosion in many parts of the world. The developed part of the world, inhabited mainly by populations of Caucasian origin, have solved — actually oversolved — their demographic problem by having achieved zero population growth, or — to be correct — by having reached a stage where the population is decreasing. Nobody knows at what point such an involution becomes irreversible. It is therefore important that such societies should not believe themselves entitled to impose programs upon other societies that are still in the stage of population explosion. The demographic explosion almost invariably produces serious environmental problems. The deforestation of large parts of the globe, paralleled by acid rain damage in the regions of moderate climate, in combination with increasing pollution of the atmosphere, the ground, and the ocean, including that of fresh water resources, may turn into a runaway vicious circle in the whole biosphere. Still not sufficiently known changes in the outer layers of the earth's atmosphere are a serious threat for the global environment. We do not know whether or not the recent major irregularities in the world climate are already the first signs of an irreversible change for the worse.

World science and industrial capacity would still be able to cope with all present problems if they were rationally applied. Instead of using these resources in the interest of humankind, the industrially developed part of the world takes the worst possible route by supplying weapons to underdeveloped societies, supporting thereby antidemocratic repressive governments with military equipment that at the very best serves only prestige purposes. This is tantamount to keeping up long outdated and potentially dangerous industries at home and forbidding the underdeveloped parts of the world to make the first steps in the right direction. Both add fuel to continued and increasing damage to the global environment. The developing nations are reponsible for finding solutions to ttheir own problems. They are undoubtedly entitled to aid — mainly in technology and knowledge — but should depend less on charity and handouts from the developed part of the world. First of all, they should not repeat the mistakes that the developed part of the world made in the past. Time is running dangerously short.

While thinking of the underdeveloped countries, we should not forget about another very rapidly increasing gap between the two major blocks of the so-called industrially developed world. It is being increasingly realized in the countries directly concerned that Marxist doctrine, especially as implemented under

the influence of Joseph Stalin — in spite of quite considerable initial success — cannot cope, in the long run, with the economic requirements of modern society. It still remains an open question whether the widening gap in the standard of living — primarily in production of commodities, food-stuffs and services, both in quality and in quantity, is due primarily to the lack of democratic freedom and personal incentive or, conversely, whether it is the planned economy itself that led to the present predicament in the Eastern block.

But I am seriously convinced that the worst possible strategy of the West would be to insist on a strategy that would take advantage of their own superiority in informational and management technology in order to bring the east to its knees. I cannot judge questions of security — they have to be decided by the people involved — but the insight into the counter-productive nature of the cold war confrontation and the dwindling expectations for a «world revolution» on the Eastern side is genuine enough, so that I would judge the historical situation mature for major changes towards more peaceful cooperation. Conversely, the dangers of stockpiled atomic weaponry — sufficient for several times «overkill» — are still too large for the «strong hand» as a realistic alternative strategy.

The issue of the «two cultures» has been mentioned by some of the speakers. Although there is undeniably a certain convergence between natural and social sciences and the humanities in the sense that various aspects of the latter can be quantifield, mathematical or theoretical systems models can be created, abstract mental constructs can be formalized, etc., we still cannot explain away the problem as non-existent. Whether we like it or not, we have to live with this aspect of our present civilization. The age-old paradigm of brain mind relationship is one of the truly interdisciplinary fields that have been discussed repeatedly by this Academy. First, almost 25 years ago, in 1964, in a Symposium, the transcript of which has by now become an international classic in its field under the title «Brain and Conscious Experience» (1965). Later, various specific aspects of the problems have been discussed at smaller symposia. Finally, the present status of the whole problem, although with stronger emphasis on the biological substrata, has been re-examined by an international symposium held in the four days between Oct. 19 and 24. The lion's share of the credit has to go to Sir John Eccles for a whole lifetime of courageous struggle with this most fundamental question of our culture, which is undoubtedly the crucial point of the so-called «two cultures». We might disagree in the wording of our ultimate conclusions, but we certainly all agree in our basic concern for human values and for the dignity of man's unique position in the universe. In this context, I have to return very briefly to the grave danger caused by the wide coverage given in today's mass media (mentioned already

when relating the loss in prestige of basic science research and its teaching) to irrational and absurd pseudoscience concepts, beliefs, and practices. I can only reiterate my conviction that this is merely a symptom of, as well as a surrogate for, the eroded basic value system of our civilization.

This leads me to the last and probably most important issue raised in this conference, that of ethics. I am happy to find myself in strong agreement with most of what has been so articulately and artistically expressed by Professor Lejeune. Also, I too live in the strong belief that the Judeo-Christian ethic is the supreme manifestation of a natural ethic, especially if at least that part of humankind to which the Holy Writ was primarily addressed would live up to its spirit. At the same time, we have also to be realistic in the sense expressed by Professor Pullman and have to reckon with the hard facts of real life of the XX century, now about to step into its concluding decade. As I can see it, we are in great need of mutual tolerance and humility to recognize and to respect human values wherever we may encounter them and whatever their source.

Although there will probably be some specific occasion to express our gratitude towards and appreciation of our beloved President Professor Carlos Chagas, let me conclude this modest summary with my words of my most sincere thanks.

FORMULATION OF THE DECLARATION OF THE PONTIFICAL ACADEMY OF SCIENCES ON CHEMICAL WARFARE

The afternoon of the final working session was devoted to the discussing and the preparing of a text to be presented to the Holy Father at the Solemn Audience on the following day, by means of which the Pontifical Academicians could express their concern about the production, the stockpiling and the deployment of chemical weapons.

The Academicians, listed here in alphabetical order, who participated in the discussion were: ABRAGAM, BLANC-LAPIERRE, CHAGAS, DE GIORGI, GARNHAM, LEJEUNE, MALU, MARINI-BETTÒLO, MINTZ, PAVAN, PULLMAN, RICH, SIDDIQUI, SZENTÁGOTHAI, WEISSKOPF.

Two versions of the document were prepared. The French text, Declaration de l'Académie Pontificale des Sciences sur la Guerre Chimique, *was included in the address of Professor Chagas to the Holy Father at the Solemn Audience on 31 October 1988. The English version,* Declaration of the Pontifical Academy of Sciences on Chemical Warfare, *was prepared in a form suitable for general dissemination. Both texts will be found at the end of this volume as* Appendix I.

THE RESPONSIBILITY OF SCIENCE

DAY FIVE
31 OCTOBER 1988

THE PIUS XI GOLD MEDAL AWARD

The Pius XI Gold Medal was established by Pope John XXIII on 28 October 1961 on the occasion of the 25th anniversary of the founding of the Pontifical Academy of Sciences. The award commemorates the Founder of the Academy, Pope Pius XI, who reconstituted the Academy under its present name in 1936.

Recipients of the Pius XI Gold Medal Award are young scientists who have already achieved international recognition. The winner of the award in 1988 was Dr. Luis A. Caffarelli, a mathematician who is at present a member of the Institute for Advanced Study in Princeton, New Jersey. Dr. Caffarelli, who was born in Argentina, and who received his Ph. D. degree from the University of Buenos Aires, has been a professor at the University of Minnesota, the Courant Institute and the University of Chicago.

During the Solemn Audience granted by the Supreme Pontiff to the Pontifical Academy of Sciences on 31 October 1988, Dr. Caffarelli received the Pius XI Gold Medal from the hands of the Holy Father.

THE 1988 RECIPIENT OF THE PIUS XI GOLD MEDAL DESCRIBES HIS WORK IN MATHEMATICS

LUIS A. CAFFARELLI
The Institute for Advanced Study, Princeton, N.J., U.S.A.

I have been asked to describe my work. I studied in the school of Caldéron of real analysis and completed my Ph.D. in Buenos Aires. In 1973 I went with a fellowship to the University of Minnesota. There, I attended a very beautiful course given by the late Hans Levy, one of the powers of analysis in this century, and was very much taken by the work he was doing.

At the time, Hans Levy, in collaboration with Guido Stampacchia, was working on free boundary problems.

Free boundary problems can be more or less described in the following way. A free boundary problem is a problem in mathematical physics where

some quantity changes, discontinuously, behaviour. For instance, if one is studying a flow of a liquid in a pipe, then the boundary of the flow is perfectly determined *a priori*. It's given to you. It's just the boundary of the pipe. It's the shape of the pipe. But if one is studying a liquid jet coming out of a nozzle, then it is part of the problem to find the boundary of the flow, to find the air-water or the liquid-liquid interface. The difficulty of this type of problem is that it is highly non-linear. There is no way of studying it by superposition methods. Let me remind you that the classical way of studying, for instance, the heat equation, the equation for diffusion of heat or other close to linear equations, is by superposing particular solutions. In free boundary problems, that's not possible. One has to have a completely different way of studying the flow and the interface.

For several years, I studied free boundary problems. Let me give you some other examples of such problems. For instance, an ice-water mix, a solid-liquid mix is another typical free boundary problem. You drop a piece of ice in water and how the surface of the ice shrinks with time, is not prescribed. It is part of the problem to find how the heat diffuses in the water part, how the heat diffuses in the solid part and at the same time you have to find and study the geometrical properties of the water-ice interface. Another problem of that type is gas flow in a porous medium. If one puts a concentration of gas inside a porous medium, and lets it flow freely, the gas has a finite propagation speed. It will not instantaneously cover the whole medium. Differing from the heat equation, which has infinite propagation speed, the gas flow equation degenerates and represents the fact that gas is flowing at a finite speed and there you have, as your free boundary, the advancing gas front.

These problems are interesting from the mathematical point of view for two reasons. The first reason is that when the mathematical model is posed, you assume that these moving surfaces are very smooth surfaces and from there describe their behaviour. But then when you try to find the actual solution, it's very hard to control what happens at the surface. The other reason why these problems are interesting is for accuracy in computer simulation. In other words, if you try to simulate, for instance, an ice-water mix, even if you are able to compute the temperature, it's many times very hard to be able to deduce from your numerical estimates on the temperature where the interface is really located, because the temperature, for instance, could be very close to zero and still be in a liquid region. So computing the temperature very close to its real value doesn't let you know where the interface really is, and to be able to have reliable methods of computation, you have to know enough about the geometry of the problem to be assured that the phenomenon has some stability. You have to be able to estimate from knowing how close your tempera-

ture is to the real one, how close your estimate of the position of the ice is to the real one.

That was in a sense the purpose of the studies I conducted at Minnesota for about, I would say, seven or eight years: the regularity and geometric properties and stability of problems with free boundaries.

In the early 80s, I went as a professor to Courant Institute. Contrary to Minnesota, which allowed me to conduct my work quietly and take my time, Courant is a very exciting place in the middle of Manhattan. Scientists from all over the world are constantly passing through and giving lectures, and ten different matters are discussed every day. So there I had a chance to develop other interests. There are two particular things I like from that stage of my work. One is my work with Kohn and Nirenberg on the Navier-Stokes equation. The Navier-Stokes equation is a model for the evolution of viscous flow. When you study the flow of liquids you can consider the simplest model, ideal liquids, where there is no viscosity, that is, no interaction between two layers of flow running parallel; and then the next stage of difficulty is to study viscous flows where in some sense parallel layers of flow interact and the molecules trap each other and cannot run freely. Since this model was posed, it has not been decided if three-dimensional flows are regular, that is, if this model predicts that the speed of the flow will always remain finite, or it will become infinite. It still is an open question and it's part of the ongoing research in trying to describe turbulent flows.

Leray in the '30s constructed some kind of solutions to the problem which were very weak. It was hard to say from his construction if the speed becomes infinite or not. What we did was to show that the speed could become infinite on, at most, a very small set, on less than a curve evolving in space-time. So really you wouldn't see it, by any reasonable observational means. As I said, it is still open whether these singularities do exist at all, but there are some recent very nice counter-examples of Vladimir Shefer, consisting of solutions to the equation with an external force which always goes against the flow, so it's supposed to brake in some sense the flow, and nevertheless having singularities as close to a curve as you want. So, I think we have elucidated the nature of the flow, how regular it could be.

The other work I like was the collaboration with Nirenberg and Spruck on fully non-linear equations. Fully non-linear equations are in some sense again related, philosophically, with free boundary problems. It is, however, a very different problem. As I said, the classical approaches to studying solutions of differential equations are variations of the linear method, superposition of solutions or continuous deformation of solutions. In the whole theory of linear or quasi-linear equations you try to construct your solution as superpositions

of elementary ones, and if the superposition is not again a solution, at least the error is small enough that you can control it. Fully non-linear equations are those equations where, if you superpose two solutions, the disturbance that you create is as large as each one of the solutions. There is no possibility of controlling them. For instance, we were interested in Monge-Ampere-type equations. These are equations where you try to construct surfaces for which some relations on the curvatures are prescribed. Curvatures are a way of measuring how a surface bends. If you look at the surface from its tangent plane, you want to measure how the surface curves with respect to its tangent plane in different directions. There are different mathematical ways of measuring how a given surface curves, and one of the outstanding, classical problematics in mathematics is to globally reconstruct a surface just from knowing at every point how it is curving. For a curve in the plane, the problem is very reasonable. If you know at every point how a curve is curving, you can reconstruct it as a whole. For surfaces in space, the problem is much more delicate, because you are only giving a curvature number and you are going in many different directions. In other words, a surface could curve according to that number because it curves very little in one direction and a lot in a perpendicular one, or could curve the same way in both directions. So it is a much more delicate problem to reconstruct a hypersurface in space, just by knowing, for instance, its mean curvature or its Gauss curvature or one of the many different measures of curvatures. In fact, it's already a difficult problem to decide from the data you are given if that is enough to prescribe the surface.

This has been an ongoing work for several years now, and we have developed a general approach to constructing the surfaces in fully non-linear cases by continuous deformation.

Finally, a word about my ongoing research. I think there are several areas of interest. Probably the one which is easier to describe is again related to free boundary problems, or minimal surfaces, and is the study of singular perturbation problems. Let me give an example: when you study flame propagation, you can have a model where you assume a sharp interface for the separation between the flame and the part that is to be burnt. This sharp surface will then be a free boundary problem where some quantity changes discontinuously. But if you look at the phenomenon with a closer and closer eye, what you really have is a one-parameter family of models where the transition between the advancing flame and beyond is a narrower and narrower front. In other words, at the limit, when you let your parameter go to zero, what you find is this sharp free boundary. So in that problem you want to know not only whether the limiting model presents a nice stable sharp interface, but you would also like to know if the approximating models in some sense converge in a strong enough

fashion to the limiting problem. You would like to know whether, as your parameter goes to zero, the transition between the flame and the complement is a smooth narrow strip that shrinks into your limiting sharp change. You would like to know if this is a stable phenomenon that doesn't wiggle up and down constantly. There are a host of problems of this type, as you can imagine, in any area of fluid mechanics.

This is more or less a description of my work and my interests.

I want to thank you very much for having chosen me for this honour. I am particularly proud of it because I know personally several of the members of the Academy and they are scientists whom I hold in very great respect. Thank you again.

RECIPIENTS OF THE PIUS XI GOLD MEDAL AWARD SINCE ITS INSTITUTION

Since its establishment in 1961, the Pius XI Gold Medal has been awarded to fourteen young scientists of international stature coming from five continents:

1961 Robert Burns Woodward (U.S.A.) for research in organic chemistry (reproduction for synthesis).

1962 Bengt Erik Andersson (Sweden) for research on nervous mechanisms concerning thirst and hunger.

1963 Aage Bohr (Denmark) for important studies and discoveries in nuclear structure and atom structure.

1964 François Gros (France) for research on action mechanisms of antibiotic agents.

1966 Allan Rex Sandage (U.S.A.) for research on the cosmic distance between galaxies.

1970 Haruo Kanatani (Japan) for research on the growth and the reproduction of starfish.

1972 György Némethy (Hungary) for research in physical chemistry (intermolecular forces).

1975 Stephen William Hawking (U.K.) for research in the theory of «black holes».

1976 Lucio Luzzato (Italy) for research in haematology and malaria.

1979 Antonio Paes de Carvalho (Brazil) for basic cardiac research (physiology of the miocardium).

1981 Jean-Marie Lehn (France) for research in physical organic chemistry (photochemistry).

1983 Gerard 't Hooft (Netherlands) for research and a successful attempt to obtain renormalizable theories for vector particles.

1986 Elizabeth Anna Bernays (Australia) for research in the fields of ecology and entomology (plant-insect interactions).

1988 Luis A. Caffarelli (U.S.A.) for research in fluid dynamics, free boundary problems and non-linear equations.

TRIBUTES TO THE OUTGOING PRESIDENT OF THE ACADEMY, CARLOS CHAGAS

On 31 October 1988 Professor Carlos Chagas formally retired from the office of President of the Pontifical Academy of Sciences which he had held since 1972.

Speaking on behalf of their colleagues, two senior Academicians conveyed the thanks and the appreciation of the Membership to the outgoing President.

FAREWELL ADDRESS TO PRESIDENT CHAGAS

JOHN C. ECCLES

President Chagas, Madame Chagas, Fellow Academicians,

It is my privilege as the Senior Pontifical Academician at this Plenary Session, to speak on behalf of the Pontifical Academicians on the occasion of the departure of President Carlos Chagas after sixteen years of distinguished leadership.

I have known Carlos for over thirty years, having visited him in 1959 at the Conference he organized on electrogenesis at his institute in Rio. Later we were both elected to the Pontifical Academy in the same year, 1961. In 1964 he participated in the Study Week I organized, "Brain and Conscious Experience".

In 1972 Professor Chagas was chosen by Pope Paul VI to be the President of our Academy. This is not the occasion to speak of the difficulties that President Chagas had to resolve in the first months of his Presidency, and so he opened up the way to the most successful years of the Academy, 1972-1988.

We should recognize the very important role of Study Weeks, which have been in World Class in many important scientific fields. I quote some I know well:

1978 - Nerve Cells, Transmitters and Behaviour

1982 - Recent Advances in the Evolution of Primates

1983 - Pattern Recognition Mechanisms
1988 - Principles of Design and Operation of the Brain.

In closing, I give on behalf of you all, special tribute to Professor Chagas for the enlightened and benevolent leadership of his sixteen years of Presidency.

MESSAGE À CARLOS CHAGAS

LOUIS LEPRINCE-RINGUET

Nous voulons témoigner à Carlos Chagas, au moment où il quitte la présidence de l'Académie Pontificale des Sciences, après seize années dans cette haute fonction, notre estime, notre admiration, notre affection. Il a conduit l'Académie avec foi, motivation, courage, avec une vitalité, un sens de l'adaptation aux besoins de notre temps, qui ont provoqué l'admiration de tous.

Nous sommes heureux de voir aujourd'hui une Académie florissante, équilibrée, comme elle ne l'a jamais été, entre les diverses disciplines et les chercheurs de toute la planète, capable de manifester sa vitalité par "Semaines d'étude" de très haut niveau, de grandes réunions internationales sur des sujets aussi actuels, angoissants et passionnants que "la responsabilité de la science", sujet immense sur lequel nous venons de nous pencher.

Vous possédez une double nature: scientifique naturellement et aussi diplomatique puisque vous fûtes ambassadeur à l'UNESCO et dans d'autres hautes institutions internationales. Cette double nature vous a permis de trouver les voies complexes de la réussite, car vous avez mené votre action, difficile et exigeante, dans des conditions souvent peu favorables, malgré une santé parfois fragile et des déplacements fréquents et fatigants, toujours disponible, toujours ouvert aux suggestions de nos confrères, toujours attentif aux incidences des décisions et des choix.

De leur part puisque, avec Sir John Eccles, je suis le plus ancien ici présent (un peu plus jeune que lui dans l'Académie, un peu plus âgé de naissance), je vous dis "Merci" avec une grande et respectueuse affection, sans oublier Madame Chagas, constamment auprès de vous, toujours souriante et bienveillante, et vos très charmantes filles, venues aujourd'hui vous entourer.

Mais nous ne nous quittons pas et, dès la prochaine réunion, nous vous retrouverons dans la chaleureuse fraternité que vous avez si bien créée.

REPONSE DU PROFESSEUR CHAGAS AUX HOMMAGES DES ACADEMICIENS PONTIFICAUX

Mes chers amis, j'avais l'intention de simplement présenter un sommaire de ce que je pensais que notre séance plénière avait donné de meilleur. Mais il m'incombe d'abord de vous remercier, Sir John et Louis Leprince-Ringuet, pour ces paroles qui ont été tellement applaudies qu'on peut dire que vraiment, elles ont représenté l'opinion de l'Académie.

Je n'ai rien fait d'important. J'ai eu de la chance, et la chance compte beaucoup dans une vie. La chance peut être — et pour moi elle l'était certainement — un don de Dieu. D'abord je suis né avec un nom qui m'a favorisé énormément dans ma vie scientifique. Etant le fils de celui qui a découvert par lui seul toute l'histoire naturelle d'une maladie (maladie qui attaque de nos jours au moins neuf millions en Amérique latine), ce nom a toujours été un bon visa qui m'a ouvert les portes de beaucoup de laboratoires, de beaucoup d'universités.

Une autre chance était celle de passer une année dans la brousse brésilienne, en dirigeant un hôpital. C'est là que j'ai connu ce que sont les êtres humains. Je pense que l'on ne peut pas vivre si on ne connaît pas ce que c'est qu'un être humain — un pauvre, un misérable de la brousse, quelqu'un qui n'a pas un sou, qui n'a pas où dormir, et qui vous enseigne tout de même que la vie est le plus grand don de Dieu. Ces misérables étaient tous des hommes de foi, et c'est là que j'ai apris la foi. Dans les pires catastrophes ces misérables vous disent: "Dieu viendra nous secourir". Cela me rappelle les paroles de Jean Paul II quand il a dit que l'humanité ne doit pas s'enorgueillir tellement des grandes avances scientifiques et techniques, quand il y a des milliards de misérables au monde.

Une autre chance encore a été celle d'être professeur à un très jeune âge. Il y avait une place, j'ai fait un concours, je l'ai réussi, donc je n'ai pas été obligé d'attendre ou de faire la course à la chaire. D'autre part, être professeur à vingt-six, vingt-sept ans est aussi quelque chose de très lourd, parce qu'on a des obligations qu'on doit soutenir, qu'on doit faire avancer. Je pense que quelques uns des éloges généreux, excessifs qui ont été faits ici, sont la conséquence du fait que j'ai eu la responsabilité de diriger des gens qui étaient presque de mon âge quand j'étais encore très jeune. Et c'est comme cela que j'ai organisé l'institut où je travaille encore.

Ensuite — et c'est là que commence ce que Leprince-Ringuet a appelé ma vie diplomatique — j'ai été mis en contact avec les organisations internationa-

les. J'ai vu des serviteurs de ces organisation qui étaient vraiment dévoués à un idéal. Mais j'ai aussi vu de la part des gouvernements, qu'ils soient de droite, de gauche ou du centre, un égoisme nationaliste qui empêche que les organisations internationales font ce qu'on attend d'elles. Tout cela m'a enseigné beaucoup de choses. J'ai été à l'UNESCO pendant quatre ans. C'était cela aussi une chance pour moi, car un gouvernement militaire s'installa au Brésil, et je ne pouvais pas accepter certaines des mesures de ce gouvernement militaire; la dignité humaine devait être respectée. Donc, si je n'avais pas eu cet "exil d'or" à l'UNESCO, j'aurais dû m'exiler d'une façon beaucoup plus difficile. C'est à l'UNESCO que j'ai appris ce qu'était le Brésil parce que, à distance de dix mille kilomètres, je voyais tous nos problèmes, toutes nos difficultés, et je les voyais mieux là que siègeant dans mon laboratoire.

Il faut dire aussi que j'ai eu deux chances dans l'organisation de la recherche dans mon pays. L'une de ces chances a été le fait que, un jour, un mécène est venu me trouver, et m'a donné tout son appui — un appui que j'ai eu jusqu'à sa mort. C'était un type de mécène qui n'existe plus. Je pouvais lui dire que j'avais besoin d'un certain appareil qui coûtait deux mille dollars, et il m'envoyait un chèque sans demander un reçu pour en faire des déductions dans ses impôts.

L'autre chance était d'avoir l'aide de la Fondation Rockefeller qui, pendant dix ans, nous a donné de l'argent (ou "seed money" comme on dit). Pour les pays en voie de développement, cet "argent semence" est extrêmement important, parce que cela nous permet d'envoyer des gens à l'étranger ou d'acheter un appareil très cher.

Donc les chances se sont succédées, jusqu'à un certain moment quand j'étais à l'Organisation Mondiale de la Santé où je présidais le Comité de Recherche. Avec ma femme je revenais d'un long voyage, arrivant à notre petit appartement à quatre heures du matin. A huit heures on me téléphonait (et notre numéro de téléphone n'était pas dans le bottin) pour dire que le Nonce apostolique désirait me voir à midi. Je me suis donc présenté à la Nonciature à midi. Le Nonce, qui est actuellement le Cardinal Lambertini, me dit: "Le Pape vous invite à être le Président de l'Académie des Sciences". Cela m'a tellement bouleversé que j'ai commis la gaffe de lui demander: "Vous êtes sûr?".

C'est donc comme cela que je suis venu à Rome, et cette merveilleuse aventure humaine, qu'ont été ces seize ans, a commencé. A partir de ce moment j'ai dû organiser ma vie (sans trop de dogmatisme rigide) dans mes trois familles — ma famille civile de Rio, la famille de collaborateurs à mon institut où il y a à peu près soixante-dix chercheurs à plein temps, et la famille que vous êtes tous, parce que vous êtes tous mes sœurs et mes frères. Je vous remercie beaucoup.

THE RESPONSIBILITY OF SCIENCE

CONCLUSION OF THE PLENARY SESSION

CONCLUDING REMARKS ON THE 1988 PLENARY SESSION

CARLOS CHAGAS

I believe this was the best Plenary Session that we have had so far. The subject was indeed ripe for our discussion.

Some points were brought up which are of an extreme importance for developing countries. It was emphasized that developing countries cannot develop themselves if they do not cultivate basic sciences, and if they do not establish centres of excellence. Otherwise a new colonialism which is very much enhanced by the economic power of the wealthy sectors of our societies will become established. I feel that the new technological colonialism is as dangerous as the political one, and perhaps more so. It creates what I have called in my brief presentation a uniform world, and a uniform world is going to destroy what is the most important thing within every nation — its creative power, its initiative, its creative intelligence. At the same time that developing countries import goods, they will also be importing other elements which even now can be observed: I see, for instance, that some of the great writers of the developing countries are abandoning the traditions of their countries and of their culture to write novels which can be adapted for show-business — for cinema or TV.

On the other hand, how can we develop our intelligence without giving the greatest attention to basic sciences? Of course if, for example, we have in my country men or women who can obtain the Nobel prize, well and good,

but what we really need is for a majority of the people who are working in science to increase their knowledge. It is by an increase of knowledge that they will necessarily bring about an increase in the quality of life. It is a mistaken idea that economic power will always upgrade people's living standards and quality of life. Such was the thesis expounded at the 1963 United Nations conference on science and technology for development of which I was Secretary General. Even if this may have been so, the improvement has been so meagre that such a thesis cannot be defended as the only way in which we can increase the quality of life. Quality of life depends upon the joy of living, and it is not material possessions alone which will increase the joy of living.

In our sessions we have also spoken of the need to improve the universities. This, I think, is not enough. One of the responsibilities of science is to bring about a scientific humanism which will change the structure of our societies. To do this, it is necessary to change the rigid structures we find in the universities in many parts of the world, especially in the developing countries where they tend to copy the universities of the more developed countries. The universities that are set up in the developing world must not only take what is useful from abroad (and advanced science is the most appropriate thing to take in this connection), but they must also keep in touch with the reality, the traditions, spirit, and customs of the country itself.

We have discussed a great many subjects which I need not enumerate here, as they have been beautifully presented by Professor János Szentágothai, and they will be available, moreover, in the published proceedings. One point, however, I should like to stress: it is essential to keep the autonomy of each country in the fields of science, technology and culture. Each country has the right and the duty to be itself.

Science, I am convinced, can do a lot for the common good. Not science as it is done by those scientists who have regrettably acquired a "fortune complex", but science as a leverage for human benefit, science as it is practiced by those who believe it is important to know what is going on in the fields of philosophy and theology. In saying this I am not speaking as a religious man, but as a lay scientist. I believe that working for the good of humanity is the duty of every scientist, of whatever religion, creed, race or region.

Another point to keep in mind is that science and technology are to be defended. Our discussions touched on this many times, and on the necessity of combatting the anti-scientific movements which are so prevalent today. This too is a responsibility of science.

I would say that the lesson which we should take away with us is that although the responsibility of science is sometimes thought to lie in very small and limited areas, gradually it will be seen to extend to more and more fields.

It will be recognized that this responsibility is to be exercised in cooperation with dignity, in cooperation with the respect for human rights, in cooperation with the observance of complete freedom. Certainly, the responsible practice of science has as its initial goal the pursuit of knowledge, but it is equally certain that its ultimate goal is the pursuit of the happiness of each individual woman and man.

SOLEMN PONTIFICAL AUDIENCE AT THE CONCLUSION OF THE 1988 PLENARY SESSION OF THE PONTIFICAL ACADEMY OF SCIENCES

On 31st October, at the conclusion of the 1988 Plenary Session, Pope John Paul II received the Pontifical Academicians, members of the Curia and of the Diplomatic Corps at a solemn audience held in the Sala Regia in the Vatican Palace.

The Holy Father's allocution, which was pronounced in French, is printed below, as is the discourse which Professor Chagas addressed to the Pope on behalf of the Academy.

In the course of the solemn audience, Professor Luis A. Caffarelli received the Pius XI Gold Medal from the Holy Father.

At the end of his message to the assembled Academicians, John Paul II thanked Professor Chagas for his leadership of the Academy during the preceding sixteen years, and called upon Professor Giovanni Battista Marini-Bettólo to take office as the new President of the Pontifical Academy of Sciences.

ALLOCUTION DA SA SAINTETE PAPE JEAN PAUL II

Monsieur le Président,
Messieurs les Cardinaux,
Excellences,

1. Je suis heureux de saluer les Membres de l'Académie Pontificale des Sciences, à l'occasion de la session plénière où a été traité le thème de la responsabilité de la science. L'importance de cette rencontre est soulignée par la présence des Cardinaux et des Chefs des Missions diplomatiques accréditées auprès du Saint-Siège. Je les remercie de cette marque d'intérêt pour les travaux de l'Académie.

Cette assemblée plénière a lieu à la suite de la semaine d'étude au cours de laquelle deux groupes d'experts venus du monde entier ont débattu d'une part sur «l'agriculture et la qualité de la vie», et d'autre part sur «la structure et la fonction du cerveau».

Au sujet de l'agricuture, les experts ont pu établir un large bilan où les aspects scientifiques et techniques du problème rejoignent finalement les aspects

éthiques. D'une part, la recherche scientifique a permis un développement considérable de la production alimentaire dans le monde. A l'échelle globale, la production agricole serait aujourd'hui suffisante pour subvenir aux besoins de l'humanité entière. Cette constatation soulève par contraste le problème dramatique de la faim et de la malnutrition dans le monde. Certes, il faut tenir compte des obstacles physiques et matériels, tels que les grandes différences de fertilité suivant les régions. Mais la répartition très inégale des ressources alimentaires n'a pas suscité jusqu'ici une politique d'ensemble, ni des projets assez efficaces pour que la production agricole bénéficie à tous les peuples et à tous les hommes. Encore une fois, nous devons observer que le problème du développement requiert avant tout une volonté politique et une action de nature éthique et culturelle, comme je le disais dans l'encyclique *Sollicitudo Rei Socialis*. La clé de tout développement humain est à trouver dans un effort généreux de solidarité entre tous les groupes et tous les hommes et les femmes de bonne volonté. A bon droit, vous avez souligné que les interventions nécessaires en cette grave question doivent respecter les personnes et leurs traditions propres, c'est-à-dire dépasser le plan strictement économique et technique pour tenir compte des principes de la justice sociale et du développement authentique de la personne humaine.

2. Un second groupe de savants a fait le bilan des études sur le cerveau humain et ses admirables fonctions. Les recherches permettent de mieux connaître aujourd'hui les structures et les processus organiques qui servent de base aux opérations cognitives et affectives de l'être humain. Mais, au-delà de toute observation empirique, apparaît le mystère de l'esprit, irréductible aux supports biologiques mis en œuvre dans le comportement de l'être intelligent ouvert à la transcendance. Devant ce que l'on connaît maintenant du cerveau, le croyant ne peut oublier les paroles du Livre de la Genèse: «Dieu modela l'homme avec la glaise du sol, il insuffla dans ses narines une haleine de vie et l'homme devint un être vivant» (Gn 2, 7). En termes anthropomorphiques, l'antique récit de la création évoque bien le lien intime de l'organe et de l'esprit en l'homme. Aussi était-il opportun que des savants confrontent les résultats de leurs études expérimentales avec la réflexion de philosophes et de théologiens sur le rapport entre l'esprit et l'appareil cérébral. Niels Stensen, dans son «Discours sur l'anatomie du cerveau», avait déjà dit du cerveau qu'il était «le plus beau chef-d'œuvre de la nature».

3. Vous avez voulu vous associer à la célébration récente de la béatification de Niels Stensen, ce grand savant qui a cherché, dans toute sa vie et dans toute son œuvre, a réconcilier les divers ordres de la connaissance qui font la grandeur de l'être humain. Votre Académie, conjointement avec le Danemark,

a voulu que le souvenir de cet événement demeure et soit commémoré par une plaque apposée dans ses propres locaux. Je tiens à exprimer à la nation danoise et à l'Académie ma vive gratitude pour ce geste.

4. Aujourd'hui, ayant présent à l'esprit l'itinéraire que parcourut Niels Stensen au long de sa vie, je voudrais y relever quelques éléments qui contribuent à approfondir le sens, la valeur et la responsabilité de la science. Ce savant explora les merveilles de la nature, particulièrement dans les domaines de l'anatomie, de la physiologie et de la géologie. En poursuivant ses études sur les phénomènes naturels, il ne perdait jamais de vue ce qui transcende la nature elle-même et, tout en portant son attention sur l'infiniment petit et sur les données mesurables, il demeurait sans cesse ouvert aux grandeurs qui dépassent toute mesure.

Pour lui, la synthèse de la connaissance réunit les données recueillies grâce aux expériences sur la nature et les valeurs qui, bien qu'inaccessibles à l'expérimentation sensible, font partie de la réalité. Stensen était profondément attiré par la beauté de l'univers physique, mais plus encore par les valeurs spirituelles et la noblesse du comportement humain. Il étudiait avec soin les certitudes d'ordre mathématique, mais il était tout autant attiré par d'autres certitudes d'ordre historique, moral et spirituel.

5. La science expérimentale suscite une légitime admiration, et l'Eglise encourage volontiers les recherches des savants qui nous aident à comprendere les énigmes de l'univers physique et biologique. Mais la science expérimentale d'épuise pas toute la connaissance de la réalité. Au-delà du visible et du sensible, il existe une autre dimension du réel, attestée par notre expérience la plus profonde: c'est le monde de l'esprit, des valeurs morales et spirituelles. Au-dessus de tout, il y a l'ordre de la charité, qui nous relie les uns aux autres et à Dieu dont le nom est Amour et Vérité.

Même avec la fragilité de sa condition de créature, l'homme garde en effet l'empreinte de l'unité divine originelle dans laquelle toutes les richesses sont unies sans confusion. Dans le monde sensible, ces richesses semblent dispersées et amoindries, mais elles n'en rappellent pas moins, particulièrement en l'homme, l'image de l'unité véritable du Créateur. Cette image est celle de la Vérité elle-même.

Telles sont les caractéristiques de la synthèse globale qui établit l'unité du savoir et qui inspire, par voie de conséquence, l'unité et la cohérence du comportement. Il s'agit là d'une unité à construire en permanence, en fonction des caractéristiques dynamiques de la vie.

6. Mon prédécesseur, le Pape Pie XI, dans un des premiers discours qu'il adressa à l'Académie Pontificale des Sciences après sa reconstitution, développa longuement le thème de la vérité. Il disait qu'il est important de concevoir et d'affirmer la vérité, mais qu'il est encore plus important de rappeler que «celui qui *fait* la vérité vient à la lumière» (Jn 3, 21). Telle est la règle fondamentale de la pensée et de l'action qui transforme toute œuvre en un reflet visible de la vérité. C'est en s'inspirant de cet idéal que Pie XI nomma, en 1936, les soixante-dix premiers membres de l'Académie rénovée, les ayant invités à en faire partie eu égard à l'importance de leurs études scientifiques originales et à leur haute qualité morale, sans aucune discrimination ethnique et religieuse. C'est ainsi que s'expriment toujours vos Statuts et c'est dans le même esprit que je vous invite à poursuivre vos travaux et vos recherches.

7. Le Pape, aujourd'hui encore, demande à votre Académie de contribuer à «faire la vérité», c'est-à-dire à rechercher l'unité du savoir dans la solidarité scientifique internationale, dans la solidarité humaine, dans l'ouverture à toutes les valeurs, pour le bien de l'homme.

Certes, comme savants, vous avez à appliquer rigoureusement les règles propres à chacune de vos disciplines pour aboutir à des conclusions valides et vérifiables par tout autre spécialiste dans vos domaines. Mais, tout en respectant les nécessités de l'abstraction méthodologique et l'autonomie de chaque discipline, vous êtes invités à examiner les résultats de vos recherches à la lumière des autres sciences. Tout savant est aujourd'hui appelé à participer à une patiente recomposition des connaissances humaines. Il y va de l'avenir de l'homme et de la culture.

Votre Académie, qui est internationale, présente une caractéristique propre: elle a d'une part le devoir de travailler en lien avec la communauté scientifique internationale et, d'autre part, elle est appelée à collaborer avec les organismes de l'Eglise afin de leur fournir des éléments utiles dans le champ de leurs compétences.

C'est dans cet esprit que je voudrais renouveler aux illustres Membres de l'Académie la requête que je formulais lors de l'audience du cinquantenaire, en les invitant à promouvoir des propositions concrètes pour favoriser à tous les niveaux la collaboration interdisciplinaire. Tout en poursuivant vos programmes spécialisés, il serait utile aussi que vous élaboriez des projets conjoints de recherche, en concertation étroite avec d'autres organismes culturels, scientifiques et universitaires du Saint-Siège. L'Eglise a besoin de vos recherches pour approfondir sa connaissance de l'homme et de l'univers. Elle compte également sur vos études pour affronter les graves problèmes techniques, culturels et spirituels qui touchent à l'avenir de la société humaine. D'avance, je

vous remercie de votre apport indispensable à notre approfondissement commun de l'énigme de l'homme et de son destin, dans l'ordre de la création et dans l'ordre du salut.

8. Avant de terminer, je désire saluer très spécialement Monsieur le Professeur Carlos Chagas qui, au terme de seize années de présidence, quitte des responsabilités auxquelles il a fait face avec tant de distinction, de générosité et de désintéressement. Je tiens à lui rendre un hommage tout particulier, en prenant acte de l'œuvre considérable accomplie sous sa conduite. Grâce à lui, l'Académie a connu un développement important quant au nombre de ses membres et à la diversité des pays d'où ils viennent: on peut maintenant parler d'une représentativité universelle. Sous son impulsion, l'Académie est devenue le centre d'une continuelle activité, prenant contact avec les autres Académies et avec les savants de nombreux pays, abordant des thèmes importants dans le domaine des sciences historiques, par exemple les études sur Galilée et Albert Einstein, dans le domaine des sciences fondamentales, ainsi les recherches sur la cosmologie, l'astronomie, les microsciences, la structure de la matière, l'origine de la vie, les processus biologiques, ou encore dans le domaine des sciences appliquées aux problèmes du monde moderne, notamment en ce qui concerne la paix et le désarmement. On peut dire que les préoccupations importantes de notre monde actuel n'ont pas échappé à son attention. Aujourd'hui, le Saint-Siège remercie Monsieur le Professeur Chagas pour la vitalité qu'il a su communiquer à l'Académie, pour le rayonnement qu'il lui a donné, pour son action très appréciée grâce à laquelle l'Eglise est devenue beaucoup plus présente au monde de la science. Et je lui sais gré moi-même de bien vouloir continuer à la faire bénéficier de ses hautes compétences.

J'ai appelé Monsieur le Professeur Giovanni Battista Marini-Bettòlo à prendre la succession du Professeur Chagas. Il a collaboré activement aux travaux de l'Académie depuis plus de vingt ans; dans ses nouvelles responsabilités, je lui souhaite un travail fructueux. Je suis sûr qu'il poursuivra, avec l'aide des Membres de l'Académie, l'œuvre entreprise par ses prédécesseurs.

En renouvelant l'expression de mon estime pour les travaux de l'Académie et de ma gratitude pour le service qu'elle rend au Saint-Siège, j'invoque sur vous la Bénédiction de Dieu.

DISCOURS DU PRESIDENT DE L'ACADEMIE, PROFESSEUR CARLOS CHAGAS, A L'AUDIENCE SOLENNELLE PONTIFICALE

Très Saint-Père,

Au nom de l'Académie Pontificale des Sciences, je vous salue de tout cœur, pour le Xe Anniversaire de votre Pontificat. Dans les dix années passées vous avez éclairé et conforté la foi des croyants, et vous avez adressé à tous les peuples le message d'espérance et de foi de l'Evangile.

Nous avons suivi avec joie et admiration votre extraordinaire action en faveur de la compréhension et de la paix entre les nations, en faveur des hommes, des femmes et des enfants qu'une société matérialiste et malveillante rejette aux marges de la société.

Une heureuse coïncidence a fait que nos travaux, Semaines d'Etudes et Séance Plénière se réalisent au moment de la béatification de Niels Stensen, le savant danois mort en 1686, qui, aprés 1667, a parcouru un exemplaire chemin pastoral. Sa vie s'exprime par une pensée qui devrait constituer un principe de réflexion pour la connaissance scientifique: «Les choses qu'on voit sont belles, plus belles sont celles qui sont connues, mais bien plus belles encore sont celles qui ne sont pas connues et celles que nous ne connaîtrons jamais».

Pendant cette décennie, Saint-Père, vous avez appuyé votre Académie d'une façon totale. Je me permets de rappeler l'émotion avec laquelle nous avons écouté vos paroles sur Galilée le 12 Novembre 1979 au moment de la célébration du Centenaire d'Albert Einstein.

Je veux aussi vous exprimer notre reconnaissance pour votre souveraine approbation et pour votre appui, de retentissement mondial, à nos documents et à nos appels contre la guerre nucléaire.

L'Académie Pontificale des Sciences est profondément inquiète d'un grave danger menaçant l'humanité. Les agents de guerre chimique actuellement disponibles, combinés à des missiles, constituent de nouveaux engins de destruction de masse dont la puissance ne le cède qu'aux armes nucléaires.

A ce jour de nombreuses nations possèdent des installations industrielles capables de produire ces agents. Il apparaît que récemment des agents de guerre

chimique ont été effectivement utilisés. Cette situation nous semble alarmante et la communauté internationale n'a que faiblement réagi à ces événements.

Les savants de tous pays doivent soutenir tous les efforts en vue d'un traité international dont l'exécution puisse être contrôlée, bannissant la production, le stockage ainsi que l'emploi d'agents de guerre chimique. Il y a grand danger à retarder cette action.

Très Saint-Père, les Académiciens soutiennent avec force vos efforts contre la guerre chimique comme totalement immorale et contraire à l'éthique.

Pendant ces dix années vous avez suivi, très Saint-Père, le progrès de la science et de ses applications technologiques pour les orienter dans les chemins de la sagesse et du service à l'homme et à l'humanité toute entière. Le progrès scientifique et technologique est en lui-même une expression très élevée de l'intelligence humaine, et il peut coopérer aujourd'hui d'une façon exceptionnelle au progrès de l'humanité s'il obéit aux principes moraux et éthiques qui doivent guider le comportement humain, et sur lesquels vous veillez avec votre magistère.

Maintes fois vous nous avez enseigné que la Science doit être libre, mais qu'elle doit être toujours consciente de sa lourde responsabilité. C'est ce qui a conduit l'Académie à se proposer comme objet de sa réflexion au cours de la Session Plénière «La Responsabilité de la Science».

Permettez-moi, Saint-Père, de vous exprimer ma pensée au sujet d'un aspect de cette responsabilité. J'ose dire que le danger de la guerre nucléaire a été au moins ajourné — si non éliminé. Ce qui nous fait peur pour notre lendemain, c'est la destruction de l'environnement — à laquelle vous vous êtes référé vigoureusement dans l'encyclique *Solicitudo Rei Socialis* — et qui rendra presque impossible la vie humaine pendant le siècle futur. Il semble que 35.000 espèces animales et végétales vont disparaître avant la fin de notre siècle. La destruction de l'environnement est le résultat d'une action progressive et obstinée, presque invisible à son début, menée par la cupidité, le pouvoir économique et l'ignorance. Seulement vous, par votre voix, pouvez empecher le désastre écologique, et l'Académie est là pour vous servir.

A côté de la Séance Plenière, deux Semaines d'Etude viennent de se réaliser. La première, dédiée aux «Nouvelles tendances de l'agriculture et la qualité de la vie», a montré la complexité du problème, particulièrement important pour les pays en voie de développement sur lesquels, plus que n'importe aucun autre facteur d'ordre technique, pèse la dette externe. La collaboration de la technologie moderne avec les méthodes traditionnelles, le respect de la culture nationale, la coopération internationale, l'éducation à tout niveau, l'introduction des techniques du génie génétique, ont été quelques-uns des sujets sur lesquels les participants se sont penchés.

J'aimerais signaler encore l'importance donnée à l'utilisation de l'excès de la production agricole comme source d'énergie, au grave problème de la déforestation et en plus aux questions économiques et l'urgence de décisions politiques au plan national et international.

La deuxième Semaine d'Etude a traité «Les principes du dessein et de l'opération du cerveau». Elle a fait suite à une série d'études de votre Académie sur le cerveau, dont la première, réalisée en 1964, a marqué une date très importante dans ce domaine. Dans ces dernières 24 années d'extraordinaires nouvelles recherches sur la structure et le fonctionnement du cerveau, on a obtenu, grâce aux nouvelles technologies, des résultats d'importance extraordinaire, parmi lesquels la visualisation de certaines modifications du métabolisme vérifiées au cours du fonctionnement cérébral.

Toutefois nous sommes loin de connaître comment et par quels mécanismes le cerveau humain se distingue de celui des autres êtres vivants. Je pense que nous n'arriverons jamais à comprendre cette structure, la plus complexe et parfaite qui a été créée par Dieu, et qui ne peut être comprise que dans le contexte transcendant de l'esprit.

A ce sujet une Table Ronde multidisciplinaire a été organisée, avec la présence de théologiens, de philosophes, d'épistémologues, de psychologues, et de scientifiques, où l'action conjointe du cerveau et de l'esprit dans le cadre de nos connaissances, a été analysée.

Saint-Père,

Comme d'habitude, en chaque séance plénière, l'Académie Pontificale des Sciences attribue à un jeune savant la Médaille d'Or Pie XI. Cette année, et pour la première fois, un mathématicien l'a obtenue. Le professeur Luis Caffarelli, Argentin, est un jeune savant qui, grâce à son propre mérite a devancé les frontières de son pays, du continent où nous sommes nés tous les deux, et qui s'est acquis une renommée internationale. En vous remerciant de nouveau, je vous prie, Sainteté, de remettre à Luis Caffarelli la Médaille d'Or qui couronne son travail.

APPENDICES

APPENDIX I

DECLARATION OF THE PONTIFICAL ACADEMY OF SCIENCES ON CHEMICAL WARFARE

Two versions of the Declaration were prepared. The French text, which was included in the address of Professor Chagas to the Holy Father at the Solemn Audience on 31 October 1988, is as follows:

DECLARATION DE L'ACADEMIE PONTIFICALE DES SCIENCES SUR LA GUERRE CHIMIQUE

L'Académie Pontificale des Sciences est profondément inquiète d'un grave danger menaçant l'humanité. Les agents de guerre chimique actuellement disponibles, combinés à des missiles, constituent de nouveaux engins de destruction de masse dont la puissance ne le cède qu'aux armes nucléaires.

A ce jour de nombreuses nations possèdent des installations industrielles capables de produire ces agents. Il apparaît que récemment des agents de guerre chimique ont été effectivement utilisés. Cette situation nous semble alarmante et la communauté internationale n'a que faiblement réagi à ces événements.

Les savants de tous pays doivent soutenir tous les efforts en vue d'un traité international dont l'exécution puisse être contrôlée, bannissant la production, le stockage ainsi que l'emploi d'agents de guerre chimique. Il y a grand danger à retarder cette action.

Très Saint Père, les Académiciens soutiennent avec force vos efforts contre la guerre chimique comme totalement immorale et contraire à l'éthique.

The English version of the Declaration, prepared in a form for general dissemination, is the following:

DECLARATION OF THE PONTIFICAL ACADEMY OF SCIENCES ON CHEMICAL WARFARE

The Pontifical Academy of Sciences is deeply concerned about a grave threat facing mankind. Chemical warfare agents are now available which, in combination with ballistic missiles, create new weapons of mass destruction second in power only to nuclear weapons.

At present numerous countries have industrial facilities capable of producing these agents. Recently there has apparently been significant use of chemical warfare agents. We feel this is an alarming situation, and the international community has responded only feebly to these events.

Scientists of all countries should support all efforts toward a verifiable international treaty banning the production, stockpiling as well as the use of chemical warfare agents. There are severe dangers in delaying this action.

The Academicians strongly support the Pope in his pursuit of the fight against war and in his condemnation of chemical warfare as a totally unethical and immoral activity.

Appendix II

ACTIVITIES OF THE PONTIFICAL ACADEMY OF SCIENCES FROM THE 1986 PLENARY SESSION TO THE END OF 1988

Plenary Session: *Fiftieth Anniversary Celebration of the Founding of the Pontifical Academy of Sciences*, 27-30 October 1986.

Presentation of the award, *The Pius XI Gold Medal*, to the biologist Elizabeth Anna Bernays, 28 October 1986.

Study Week: *Aspects of the Uses of Genetic Engineering*, 19-23 October 1987.

Study Week: *A Modern Approach to the Protection of the Environment*, 2-7 November 1987.

Study Week: *Large-Scale Motions in the Universe*, 9-14 November 1987.

Study Week: *Agriculture and the Quality of Life; New Global Trends*, 17-22 October 1988.

Study Week: *Principles of Design and Operation of the Brain*, 19-24 October 1988.

Round-Table: *Brain Research and the Body-Mind Problem; Epistemological and Metaphysical Issues*, 25 October 1988.

Plenary Session: *The Responsibility of Science*, 27-31 October 1988.

Presentation of the award, *The Pius XI Gold Medal*, to the mathematician Luis A. Caffarelli, 31 October 1988.

Ceremony of presentation and unveiling of *a plaque in honour of the Danish scientist, Blessed Niels Stensen*, placed in the Academy at the initiative of a committee representing several Danish institutions, 10 December 1988.

Appendix III

PRINCIPAL RECENT PUBLICATIONS OF THE PONTIFICAL ACADEMY OF SCIENCES

PUBLICATIONS RELATIVE TO THE PONTIFICAL ACADEMY OF SCIENCES, AND TO THE HISTORY OF SCIENCE

Pontificia Academia Scientiarum. Annuaire Général, mis à jour au 30 avril MCMLXXXVII, 1987, pp. 375.

The Activity of the Pontifical Academy of Sciences, 1936-1986, G.B. Marini-Bettòlo, Scripta Varia 66, 1987, pp. 243 (Also published in Italian as Scripta Varia 71).

Discourses of the Popes Pius XI to John Paul II to the Pontifical Academy of Sciences, Scripta Varia 66, 1986, pp. 201. (Also published in Italian and in French as Scripta Varia 64 and 65).

Pontifical Academy of Sciences. The Building, Gabriela Delfini Filippi, 1986, pp. 66. (Also published in Italian and in French as *La Sede,* and *Le Siège*).

Cinquantenaire de la fondation de l'Academie Pontificale des Sciences. Compte-rendu et Actes de la Session Plénière et des Célébrations, 27-30 Octobre 1986, Scripta Varia 73, 1988, pp. 435.

Documenti del Processo di Galileo Galilei, Sergio M. Pagano ed., Scripta Varia 53, 1984, pp. 280.

Galileo Galilei e gli Orientamenti Esegetici del suo Tempo, Rinaldo Fabris, Scripta Varia 62, 1986, pp. 44.

Federico Cesi nel Quarto Centenario della Nascita, Enrico di Rovasenda and G.B. Marini-Bettòlo, Scripta Varia 63, 1986, pp. 47.

Federico Cesi e i Primi Lincei, (exhibition catalogue), Città del Vaticano, co-edition Pontificia Academia Scientiarum - Bibliotheca Apostolica Vaticana, 1986, pp. 107.

Blessed Niels Stensen and His Memorial Plaque in the Pontifical Academy of Sciences, (extra serie) 1989, pp. 43.

NEUROLOGY, MEDICINE AND THE LIFE SCIENCES

Developmental Neurobiology of Mammals, Working Group, June 3-7, 1985, Scripta Varia 59, 1987, pp. 481.

The Artificial Prolongation of Life and the Determination of the Exact Moment of Death, Working Group, October 19-21, 1985, Scripta Varia 60, 1986, pp. 114.

The Interaction of Parasitic Diseases and Nutrition, Study Week, October 22-26, 1985, Scripta Varia 61, 1986, pp. 352.

Molecular Mechanisms of Carcinogenic and Antitumor Activity, Working Group, October 21-25, 1986, Scripta Varia 70, 1987, pp. 489.

Immunology, Epidemiology and Social Aspects of Leprosy, Working Group, May 28—June 1, 1984, Scripta Varia 71, 1988, pp. 212.

Research on Pathogeny of Mental Retardation in Trisomy 21, Jérôme Lejeune, Commentarii Vol. III, n. 31, 1988, pp. 18.

NATURAL AND PHYSICAL SCIENCES AND THE ENVIRONMENT

Energy for Survival and Development, Study Week, June 11-15, 1984, Scripta Varia 57, 1986, pp. 615.

The Impact of Space Exploration on Mankind, Study Week, October 1-5, 1984, Scripta Varia 58, 1986, pp. 364.

Remote Sensing and Its Impact on Developing Countries, Study Week, June 16-21, 1986, Scripta Varia 68, 1987, pp. 676.

Persistent Meteo-Oceanographic Anomalies and Teleconnections, Study Week, September 23-27, 1986, Scripta Varia 69, 1988, pp. 662.

Large-Scale Motions in the Universe, Study Week, November 9-14, 1987, Scripta Varia 76, 1988, pp. 604.

A Modern Approach to the Protection of the Environment, Study Week, November 2-7, 1987, Scripta Varia 75, 1989, pp. 606.

Agriculture and the Quality of Life. New Global Trends. Conclusions, Study Week, October 17-22, 1988, Documenta 24, 1990, pp. 33.