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科学・技術研究の国際的規模：その展望と考察

ＥＣ委員会第XII総局長
ローマ大学教授　パオロ・マリア・ファゼラ

Professor Paolo Maria FASELLA

is awarded HONDA PRIZE together with all the privileges and honours pertaining thereto,

in recognition of his outstanding research work in the field of life science and its applied areas; and, also, in recognition of his extensive international activities which contributed greatly towards harmonious development between men and science in this modern world.

Biography and Positions

1930	Born in Rome, Italy
1954	M.D., The University of Rome
1963—1965	Associate Professor, The University of Rome
1965—1968	Associate Professor, The University of Parma
1968—1971	Full Professor, The University of Parma
1971	Full Professor, The University of Rome
1975—1977	President of the European Molecular Biology Conference
1982—1985	President of the International Union of Biological Sciences
1981 to present	Director General of the Directorate General XII for Research, Science and Development and the Joint Research Center, Commission of the European Communities
1982—1985	Member of the "Working Group on Technology, Growth and Employment" establshed by the Summit of Industrialized Countries
1985 to present	Representative of the Commission of the European Communities in the EUREKA Group of High Officials

He is Currently:

Director General of the Directorate General XII for Research, Science and Development and the Joint Research Center, Commission of the European Communities

* Member of the New York Academy of Sciences
* Member of the European Molecular Biology Organization
* Representative of Standing Committee of Assessment and Priorities of International Council of Scientific Union

Recent Monographs

— Rat Brain monitoring by near-infrared spectroscopy: an assessment of possible clincial significance
— X-Ray Absorption Near Edge Structure (XANES) Determination of Calcium Sites of Troponin C and Parvalbumin
— Non-invasive infrared monitoring of tissue oxygenation and circulatory parameters
— Interaction of aminotransferases with other metabolically linked enzymes
— Closing remarks of the proceedings of the symposium "The Revolution of New Technology",4-7 October 1985
— Ethical Issues in predictive medicine, Rome, 11-15 April 1988

ファゼラ氏の受賞は、生命科学とその応用分野において、卓越した研究業績と、これを基盤として、現代社会における人間と科学技術の調和ある発展のために、国際的な幅広い実践的諸活動を展開してこられた功績によるものです。

●学歴および経歴

1930	イタリア、ローマ生まれ
1954	ローマ大学卒業(医学)
1963～1965	ローマ大学准教授(生物学)
1965～1968	パルマ大学准教授(生化学)
1968～1971	パルマ大学教授(生化学)
1971	ローマ大学教授(生化学)
1975～1977	ヨーロッパ分子生物学会議　会長
1982～1985	国際生物学連盟(ＩＵＢＳ)会長
1981～	欧州共同体(ＥＣ)委員会　第Ⅻ総局（研究開発並びに共同研究センター）総局長
1982～1985	先進国首脳会議設立の「テクノロジー、成長、雇用に関する作業グループ」メンバー
1985～	ユーレカ計画　欧州共同体(ＥＣ)委員会代表

同氏は現在、欧州共同体(ＥＣ)委員会第Ⅻ総局（研究開発並びに共同研究センター）総局長を務めるかたわら、
—ニューヨーク科学アカデミー会員
—ヨーロッパ分子生物学機構(ＥＭＢＯ)メンバー
—国際学術連合の評価・審査の常任委員会代表
も、兼任しておられます。

●近年発表の論文

—近赤外線分光学によるラットの頭脳の観察・臨床面における重要性の評価
—トロポニンCとパーバルブミンの　ルシュウム位置へのXANESの定量
—代謝により結合した酵素とaminotransferases　の相互作用
—シンポジウム「新テクノロジーの改革」(1985年10月)の会報の後書き
—予防医学における倫理的問題

The International Dimension of Scientific and Technological Research: Prospects and Perspectives

SPEECH OF PROF. P.M. FASELLA

JAPAN, NOVEMBER 88

Mr. Honda
Amb. Shimoda
Mr. Minister
Ladies and gentlemen

It is a great honour and a great responsibility to address you tonight. I wish to thank the Honda Foundation for the honour and you all for your presence.

It is one of the tenets of Mr. Honda that technology must respond to recognized needs; the same should be said of many human activities, including research. This presentation concerns what, in my own view, are increasing needs for international collaboration in science and technology.

Science and technology are by their very nature transnational: collaboration and open competition have greatly contributed to their accelerated development over the last three centuries.

World-wide publication of results and ideas, their critical discussion, confirmation and further use by fellow scientists, recognition of priority and originality, protection of intellectual property through author's rights and patents, have enormously stimulated growth, assured validation, and encouraged practical exploitations.

During the last decades Science and Technology have become more valuable from the economical, social, political and militar point of view; they have also become more expensive, interdependent and complex. This has several effects on international collaboration.

The increased "value" of science and technology induces individuals, companies, and countries to be more "jealous" of their research results and to impose constraints to their free circulation because of economic and/or military reasosns.

Are new systems necessary to assure protection of inventions without losing the benefits of openness? Should patent and author's right legistlation be revisited?

What is the correct equilibrium between collaboration and competition in research? What is the impact of dual use technologies?

These problems were raised at the 1987 O.E.C.D. meeting of Research Ministers, and are presently analyzed by that organization. The increased "cost" of research favours the development of international collaboration beyond the traditional "scientist with scientist" interactions. Indeed, some individual projects have become so expensive in financial terms and so exacting in the quality and quantity of knowledge and know-how, as to make international collaboration a "conditio sine qua non". This has been particularly necessary in Western Europe where individual countries, though very advanced are not large enough to support alone some big science projects.

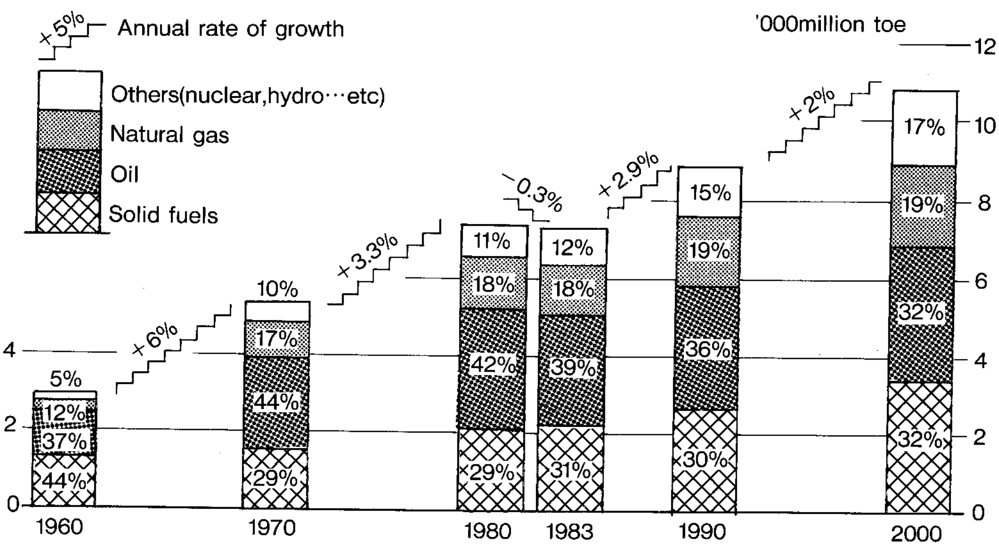
Several examples of successful EUROPEAN ventures could be given, ranging from CERN (Comité Européen pour la Recherche Nucléaire) which recently demonstrated the existence of particles Z°, W+ and W-, to ARIANE which brought Western Europe into space.

The European Community (EC) Programme on Controlled Nuclear Fusion is an interesting case. The 12 Member States of the E.C. plus Sweden and Switzerland, have decided to pursue together this very ambitious, very long-term, very difficult but also very promising programme, the ultimate goal of which is the development of a cheap, universally available, environmental-friendly source of energy. Honda Prize recipients U. Colombo and Nishizawa would agree on the interest of pursuing the controlled nuclear fusion approach to the long term satisfaction of energy requirements (cf. fig. 1).

Fig-1 Energy 2000

A reference projection and alternative outlooks for the European Community and the world to the year 2000

WORLD GROSS ENERGY CONSUMPTION*
(by sources)



WORLD GROSS ENERGY CONSUMPTION*
(by regions)

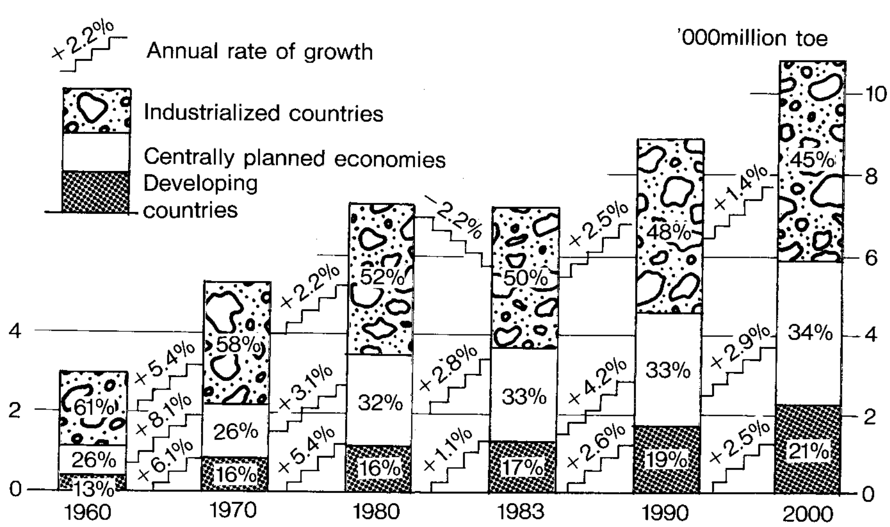
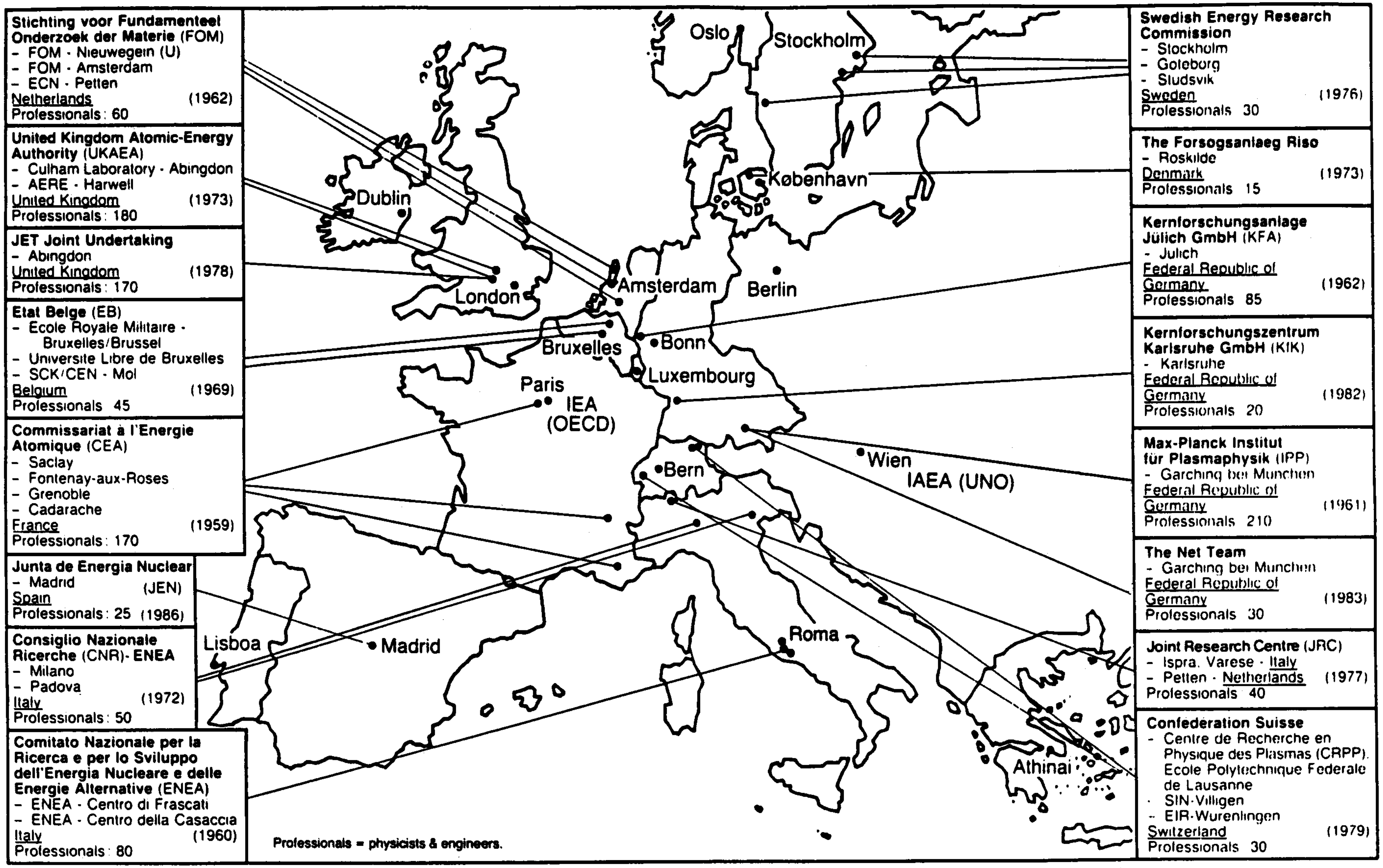


Fig.2 Location of fusion laboratories in Europe



The scientific and technical problems posed by controlled nuclear fusion are formidable. In the present approach, two isotopes of the gas hydrogen, namely deuterium and tritium, must be heated to more than 100 million degrees (a temperature 10 times higher than that of the sun!) for the duration of seconds and at a density of 10^{20} particles per cubic meter!

Containment cannot obviously be achieved in a simple vessel (no material would withstand that temperature) but through very intense magnetic fields which confine the hot gases in a doughnut shaped space, called Tokamak. Heating is achieved in a number of ways, including the circulation of a very intense current (5 M ampère) around the doughnut.

The structure of the E.C. Fusion Programme is worth noting. Unlike CERN, where all the facilities are concentrated in one center at a yearly cost of about 500 million $, in the fusion programme the resources (of a similar level) are invested half in one large machine (JET = Joint European Torus) hosted by the UK near Oxford, and the other half in severl Research Centres localized in "associated" laboratories of the Member States, where work, essential for the common effort and complementary to that of JET, is carried out with the participation of all Member States (cf. fig. 2).

The programme is successful; JET is presently the largest torus in the world, and remains quite competitive even after the Japanese J.T. 60 started functioning in 1987. The progresses made worldwide in demonstrating the "physical" feasibility of controlled nuclear fusion are summarized in fig. 3 and 4). The next steps (demonstration of "technical" and then of "economic" feasibility will be more expensive and exacting. Yet, the perspective offered are such as to attract the attention of political leaders at the highest level.

At the Summit meetings between President Reagan and 1st Party Secretary Gorbatchev in 1986 and in 1987 controlled nuclear fusion was proposed as a research area requiring "the joint effort", not only of the US, and the USSR but also of Japan and the European Community.

Under the aegis of the United Nations I.A.E.A., a detailed design of the next generation nuclear fusion reactor has now begun. Joint work is being carried out by a task force comosed by Japanese, Americans, Russians and West Europeans at the European Community-Max Planck Institute site of Garching, Federal Republic of Germany.

As far as I know, this is the first long-term collaborative effort among the four major industrialized powers of the world.

This "world-wide" interest in controlled nuclear fusion is indeed justified since it could provide a source of energy which would not contribute to environmental pollution and to the global climate change and green-house effect, which we shall discuss later. Relatively small amounts of "Fusion Fuel" would replace large amounts of polluting fossil fuel.

In the case of high energy physics and controlled nuclear fusion, it is the scale of the energy requirements which imposes concentration of the

Fig.3 How far away from Reactor Values?

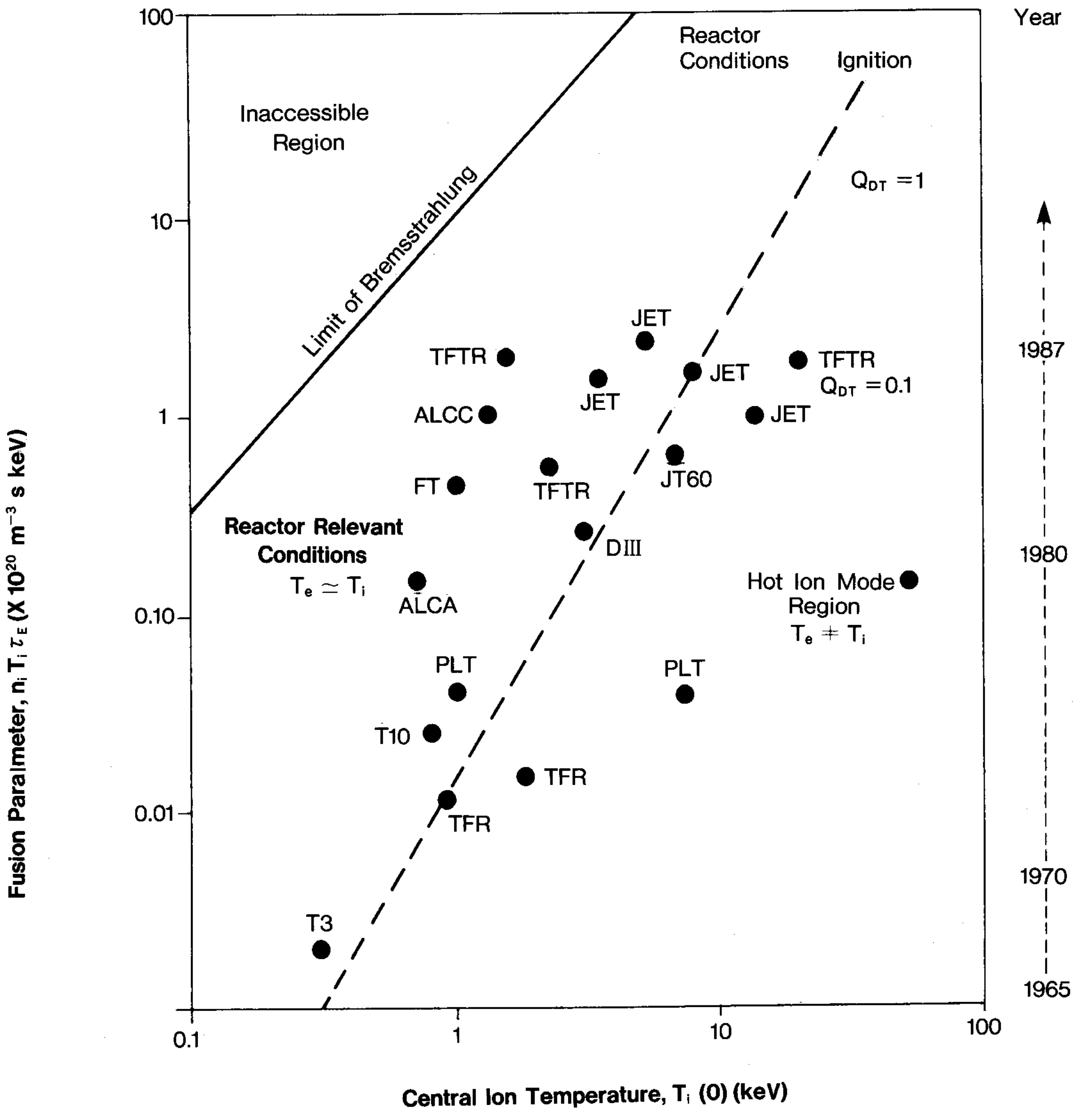
T_i —temperature in millions °C
n —density (particles/m^3)
τ_E—energy confinement time (seconds)

* * *

$n\tau_E T_i > 5\times10^{22}$ **for Reactor**

1970	$\sim 2\times10^{18}$ ····	25,000 times away
1980	$\sim 7\times10^{19}$ ····	700 times away
1983	$\sim 5\times10^{20}$ ····	100 times away
1988	$\sim 3\times10^{21}$ ····	17 times away

Fig.4



effort in one place. Politically, this poses the delicate problem of the choice of the site. A solution could become less difficult, if several large, joint, projects were considered together, so that each main participant could have the responsibility and advantages of hosting a project.

At present, new scientific ventures emerge which, because of their size and complexity, require international cooperation and, being "information intense" rather than "energy intense", do not have to be localized at one site but, thanks to the enormous development of information technology, can be pursued through highly coordinated networking among complementary research centres.

Biology, which is intrinsically "information intense", provides some example. The total elucidation of the human genome is perhaps the most striking of them. The difficulties are enormous, but so are the rewards. Each of the 10 trillions cells of the human body contains about 100,000 individual genes encoded by about 3 billions subunits of the large polymeric DNA molecules, the vectors of genetic information. The sum total of these "genes" corresponds to what is known as the human genome. Knowledge of the human genome is as necessary to the continuing progress of medicine as knowledge of human anatomy has been for the present state of medicine. Human beings, though basically similar have each individual features determined by small but significant differences in their genes. In the same species a gene can exist in different forms (polymorphism). It is the combination of different variants of the thousands of genes constituting the human genome that defines the genetic individuality of each human being. Deciphering not only the general structure of the human genome but the "particular" gene variants of single individuals will make it possible to define the genetic features of a person, including predisposition to disease.

The work to be performed is complex and tedious; it should consist of several phases involving the detailed physical mapping of the genome, the development of automated techniques for large scale cloning and sequencing, and finally, the sequencing itself.

The technical steps involved and proposed strategic approaches are summarized in tables I, II, III, IV.

The importance of studying the human gene has been well understood in many circles: a considerable effort for the automation of mapping and sequencing techniques is being carried out in Japan; the USA is considering spending 3.5 billion dollars for the next 10 years for work on the human genome under the leadership of Jim Watson, the Nobel Prize winner, co-discoverer of the double helix.

It would be a mistake to consider only the human genome at the expense of research on other species. On the contrary, several essential problems concerning the automation of techniques, the characterization of the key features of gene function, gene organization and gene evolution can find easier solutions from the sequencing of smaller genomes. Many laboratories in Western Europe are engaged in various aspects of genome research; however, the size of national programmes, even the largest, is not adequate to the scale of the problem. Pooling human as well as financial resources, task sharing, avoidance of duplication, common databanks and compatible bio-informatics are indeed necessary to collect and analyse the huge amount of information on which genome analysis rests.

One important part of the programme goes under the name of "Predictive Medicine". A pro-

Table I TECHNICAL STEPS FOR SEQUENCING GENOMES

–GENETIC MAPPING
–PHYSICAL MAPPING
–PRODUCTION OF DNA FRAGMENTS OF DECREASING SIZE
–SEQUENCING SMALL DNA FRAGMENST
–DATA TREATENT
–DEVELOPMENT OF SEQUENCING TECHNOLOGY
–MOLECULAR RULES GOVERNING STRUCTURE-FUNCTION RELATIONS
–APPLICATIONS IN MEDICINE AGRICULTURE AND INDUSTRY

Table II STRATEGIC GUIDELINES

–SEQUENCING SMALL GENOMES AS OBLIGATORY STEPS BEFORE TACKLING THE HUMAN GENOME.
–NETWORK APPROACHES SHOULD BE PREFERRED TO CENTRALIZED APPROACHES.
–HOWEVER CENTRALIZED DATE AND DAN MATERIAL REPOSITORIES ARE REQUIRED.
–GENETIC, SEQUENCING AND COMPUTER TECHNOLOGIES HAVE TO BE DEVELOPED IN PARALLEL.
–"SMALL SCIENCE" IS INDISPENSABLE FOR THE STUDY OF THE BIOLOGICAL FUNCTION OF NEWLY UNCOVERED GENES.
–TRAINING SHOULD BE LINKED TO RESEARCH ACTIONS.
–WORLD-WIDE COORDINATION SHOULD BE PROMOTED.

Table III HOMO SAPIENS

(3,000,000 Kbp –23 haploid chromosomes – less than 0.1% sequenced today)

----WHY HUMAN GENOME?

-ABOUT 50,000 GENES AND GENE PRODUCTS OF STILL UNKNOWN NATURE AND FUNCTION.

-FOR EARLY PREDICTION/TREATMENT OF HEREDITARY DISEASES.

-FOR IMPROVED PROGNOSIS AND PREVENTIVE TREATMENTS.

Table IV HOMO SAPIENS

----HOW TO PROCEED?

FIRST:

RESOLUTION OF THE GENETIC MAP IMPROVED FROM 10 TO 1 CENTIMORGANS

SECOND:

ORGANIZED DNA LIBRARIES

MEANWHILE:

-GENETIC, SEQUENCING AND COMPUTER TECHNOLOGIES.

-CENTRAL FACILITIES FOR DNA SAMPLES AND DATA ANALYSIS.

-SEQUENCES OF cDNA CORRESPONDING TO GENES OF PARTICULAR INTEREST.

THEN:

SYSTEMATIC SEQUENCING OF GIVEN CHROMOSOMES OR CHROMOSOME FRAGMENTS.

motor of this initiative, Jean Dausset, the recipient of the 1987 Honda Prize and of the 1980 Nobel Prize, recently stated, "predictive medicine is the first step in preventive medicine". The aim of the programme is to identify genes involved in disease, with a view to their isolation and structural analysis. Many diseases have a genetic component: they may result from the inheritance of a single defective gene (monofactorial) or from the interaction of multiple gene defects with environmental factors (multifactorial). Many common and debilitating diseases such as artery disease, diabetes the major psychoses, fall into the latter category. Predictive Medicine seeks to forecast susceptibility to diseases with a view to their early diagnosis and prevention, as well as to improved prognosis and, eventually, treatment (cf. table V and VI).

The scale of the problems posed by the elucidation of the human genome and its medical implications is such that a world wide concertation of effort may be in order. This includes task-sharing (different terms, each taking on one chromosome or a part of it), mutual access to data bases, sharing genetic markers, widening the correlation between gene structure and clinical conditions, as well as technological developments in automated analysis.

The development of a significant European programme on the elucidation of the genome should make world collaboration easier.

The enormous increase in genetic information — or rather some uses which could be made of it — does raise ethical questions. Personal privacy must be weighed against general health care; the ability to diagnose disease may outrun the possibilities of treating it; misuse could be made of genetic information in the choice of employees or in establishing a premium for health insurance. These and many other issues must be given serious and continuous attention. In these as in other areas, the progress of science and technology should be accompanied and, where possible, anticipated by ethical, social, and legal considerations. In 1984, Japan pioneered action in this field when it proposed and hosted the First Bioethics Conference of the "Summit of the Most Industrialized countries". Earlier this week, Mr. Nakasone opened a conference on bioethics chaired by Prof. Okamoto.

Such "ethical" problems should indeed be discussed at the "world" level, and not only within individual countries or groups of countries. The whole of mankind is concerned. Moreover, widely diverging legislation could distort competition among firms interested in the large market for high tech instrumentation and data banks which a widespread development of predictive medicine would create. On the other hand, the "culture" of each people must be respected when discussing such very delicate issues.

Having considered some problems posed by the increasing value and cost of research, it is worthwhile to examine a third set of problems created by the very nature of present "Science and Technology", namely mutual interdependence and complexity.

As Nobel Prize winner Ilya Prigogine outlined in his Honda Prize lecture, the scientific approach to complexity (which he pioneered) marks the second half of this century and opens new perspectives for the next.

Table V OBJECTIVE

PREDICTIVE MEDICINE PROGRAMME
(1989 - 1991)

-STIMULATION OF BASIC RESEARCH ON THE HUMAN GENOME LEADING TO IMPROVED:
-PRENATAL DIAGNOSIS OF GENETIC DISEASES
-EARLY PREDICTION OF CERTAIN DISEASES
-IMPROVEMENTS IN PROGNOSIS AND, EVENTUALLY, TREATMENT

Table VI PRIORITIES

PREDICTIVE MEDICINE PROGRAMME

(1989 - 1991)

1/ ADVANCED GENETIC TECHNOLOGIES
-HUMAN DNA COLLECTIONS
-NEW PHYSICAL MARKERS (RESTRICTION ENZYMES OR HYBRIDIZATION PROBES)
-PROBES FOR SPECIFIC GENETIC DISEASES
-NEW DNA LABELLING SYSTEMS
-AMPLIFICATION OF SPECIFIC GENES
-NEW CLONING TECHNOLOGIES AND SHUTTLE VECTORS FOR HUMAN GENES

2/ STUDY OF THE HUMAN GENOME
-PHYSICAL AND GENETIC MAPPING
(ESPECIALLY OF GENES ASSOSIATED WITH PATHOLOGY AND IMMUNITY)
-DATA HANDLING AND SOFTWARE DEVELOPMENT

3/ SETTING OF ORGANIZED HUMAN GENE LIBRARIES

Areas, which were too complex for science, can now be studied. Because of their very complexity, they often require international collaboration since the multiple and diverse competences involved or the huge number of data needed cannot always be found in a single country.

One such emerging area is Neurobiology. Mathematics, physics, chemistry, material and information sciences, meolecular and cell biology, physiology, zoology, medicine, psychology, linguistics and philosophy all contribute to the understanding of the higher brain functions such as memory, language and problem solving. The brain has been the subject of intense interest since it was recognised as the anatomical basis of intelligence, thought and feelings. The scientific study of the brain began in the early part of the last century when certain brain functions were pinpointed and the nervous tissue found to be composed of individual interconnected cells (neurons).

The brain of man is extremely complex. It contains more than 10^{10} cells, connected in a highly structured pattern through more than 10^{11} synapses. Information is processed through a series of highly nonlinear steps. In some key nerve centers a message is transmitted on the next relay only when the center itself receives a set of inputs coherent among themselves or with stored messages. Learning and memory occur through adaptive changes in cells, leading to more or less stable connections.

Much has been learned on the cellular and molecular physiology of the nervous system. Within neurons impulses are essentially carried as a wave of electrical depolarization of the nerve cell membrane. Between neurons, the message is transmitted by chemicals released at the extremity of a neuron and picked up at a "synapsis" by the receptors in the dendrites of adjoining cells.

Very many specific chemical and their receptors messengers have been identified. More are being discovered every year. The results of multiple messages on the behaviour of each cell is complex, since some messages re-inforce, others oppose each other. Repeated elementary contacts among cells could lead to learning by selective stabilization of the connection. The mechanisms that lead to such an assembly of billions of neurons into a very complicated system are only beginning to be understood.
Not only the components of the networks and their local interactions, but also the assembly structure and function of the networks must be elucidated.

Relative simple detailed models have been developed, which are amenable to mathmatical treatment and experimental verification. At the other end of the scale macroscopic connections among the main structures of the brain are being discribed.

The observation of the brain in-vivo using scanners based on advanced physical methods has been possible since the 1970's and has now greatly expanded allowing more resoltion in time and space. Computerized tomography, Nuclear Magnetic Resonance and infra-red spectroscopy as well as electro encephalography, allow the study of the living brain and revolutionize the diagoni-sis and treatment of many diseases from epilespy to arteriosclerosis, and brain tumors. Many of these developments have been possible by extensive trans-national collaboration involving industry as well as universities and research institutions. I have myself been involved in one such development. It concerned a relatively simple and inexpensive system for monitoring of brain blood supply and function by non-invasive IR Spectroscopy.

The new physical methods not only open new perspectives for the diagnosis and treatment of many diseases; they permit the study of the nervous system, including some highly specific chemical events, in the living brain. They allow therefore to combine the molecular, cellular and holistic approaches.

Neurocomputing requires special attention. Since the 1940's, parallels have been drawn between the functioning of the human brain and computing machines. Up to now attempts to emulate the brain have proved largely unsuccessful. In recent years, however, interest for neurocomputing is rapidly increasing. In the United States federal institutes universities and private companies are making important financial commitments.

Scientists hope that, guided by an understanding of brain functions, they can build a neurocomputer — a computer which is structured like the brain and which, like the brain, can learn by itself. Though relatively slow and quantitatively limited, the brain processes information with great efficiency, and it is envisaged that neurocomputers would be vastly superior to conventional machines. The brain differs from ordinary computers in several important ways including the ability to carry out simultaneous processing, connective learning and active reasoning. While computers have been trained to play chess at world level or to rediscover physical principles, they are a long way from being considered "intelligent", or provided with human-like intuition, not to mention "feeling" and "awareness".

An illustration of the diversity of skills of the human brain comes from an observation by the Japanese neurologist SASANUMA quoted by J.P. Changeux, of the Pasteur Institute, in his book

"The Neuronal Man". Vascular lesions on the left brain impair the use of the Kana alphabet much more than that of Kanji ideograms. The reverse is reported for lesions of the right side. It seems that the left brain develops skills in dealing with phonetic, linear, combinatory information, while the right hemisphere performs rather holistic functions and image recognition. As I once had the priviledge of discussing with Prof. Okamoto, it is tempting to speculate as to the effects which training of both hemisphers in young Japanese may have in their future activity.
Could they be better prepared to cope with the holistic recognition of compiex images and hence to deal with complex systems?

European laboratories are very active in neurobiological research and have to their credit several important discoveries.

The Commission of the European Communities has been supporting joint neurobiological research, and in particular the study of intercellular communication since 1984. The BRAIN (Basic Research on Adaptive Interlligence and Neurocomputing) initiative was launched in 1987.

- The development of connectionist models for neurocomputing — a mathematical way of simulating the brain's calculating capacity
- The design of a neurocomputer with learning abilities
- The study of the use of neural networks for data processing
- The determination of the level of complexity necessary for a computer to start to function in a similar way to the brain
- The study of the neural networks determining the relationship between the brain and the eye movement
- The study of dynamic connectionist models for the recognition of designs and graphs
- The investigation of sensorimotor strategies involved in visually guided arm movements in a view of possible application
- Application to robotics and computer vision
- The study of the basic operations involved in the cerebral cortex of primates in controlling a reaching movement.

Japan, besides promoting a multidisciplinary approach to neuroscience at home, has proposed it as a major area to be developed at the international level, in the frame of the Human Frontir Science programme. It is indeed a wise choice which could lead to significant progress through mutually advantageous sharing of tasks and pooling of research results on a subject of enormous complexity and of enormous interest. A successful development of the initiative will of course require a fair balance of giving and taking.

So far we considered cases where the usefulness of international collaboration is related to the size of the required research installations (as in the case of "fusion") or to the large amount of information to be collected and analyzed (as in the case of "genome" and "brain" research). It is worth now considering a problem which has a claim to broad international collaboration, because it is extremely complex, it requires large and expensive devices and, by its very nature, it concerns the whole world. I refer to the study of the global climate change.

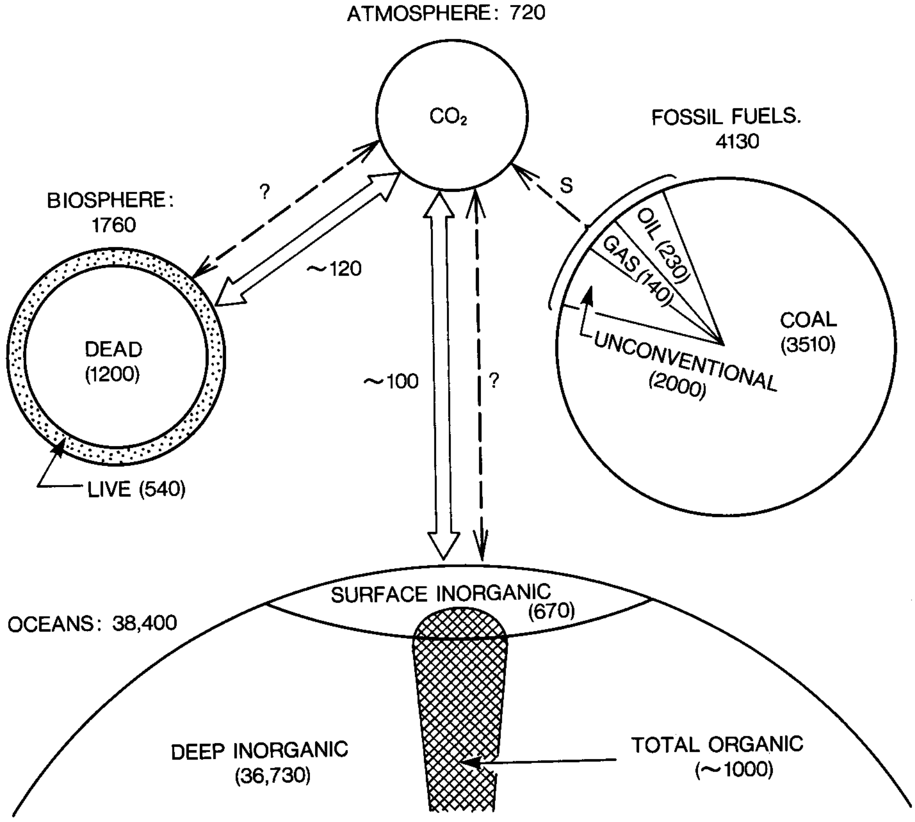
Environment results from the complex interaction of very many complicated sub-systems: the sun, the planet earth, the moon, the stratosphere, the atmosphere, soil, inland water, the sea, the biosphere and, more recently, human activities. Each must be analyzed and the mutual interactions of each component with the others must be studied in an integrated "system". A scientific approach to a problem of this complexity would have been unthinkable a few decades ago. progress in mathematics, physics, chemistry, biology and analytical methods (including remote sensing from space), as well as the huge present capacity to store and analyze information by advanced computing now make this approach possible.

Burning of coal and oil produces increasing amounts of carbon dioxide. Although the oceans, through complex processes involving phytoplancton, fix some of it, large quantities of carbon dioxide accumulate in the atmosphere, which now contains 15 — 20% more of this gas than in the preindustrial era. To make things worse, deforestation reduces natural recycling of CO_2 by terrestrial green plants. The CO_2 cycle is schematically represented in fig. 5.

Some of the solar energy which reaches the earth is radiated back into space as infra-red light. The presence in the atmosphere of excess CO_2 which is not transparent to infra-red light, reduces this irradiation. The corresponding energy is thus

Fig.1 Carbon Pools and Fluxes

Global carbon pools and annual fluxes. Sizes of pools (circles) and annual fluxes (arrows) are shown in gigatons of carbon. Dotted arrows represent additional fluxes due to human activities. Pool sizes are in true relative proportions, illustrating the relative dominance of oceans, and the "dead" biosphere (soil, humus) in the active carbon cycle.



Activity	Gt C/year
Forest clearing in the Third World	+ 3.6
Industriai use of wood	+ 0.3
Firewood	+ 0.3
Soil organic matter decomposition	+ 0.6
Reforestation	− 0.3
Regrowth in the tropics	− 1.0
Regrowth in temperate regions	− 0.5
Growth stimulation by CO_2	− 0.3
growth stimulation by NO_x	− 0.2
Total	+ 2.5

Pools	Quantity (Gt)a
Atmosphere	720
Oceans	38,400
Total Inorganic	37,400
Surface layer	670
Deep layer	36,730
Total organic	1,000
Terrestrial biosphere	1,760
Live	560
Dead	1,200
Fossil fuels	4.130
Coal	3.510
Oil	230
Gas	140
Unconventional	250
Gross fluxes per year	
Athosphere-ocean	100
Athmosphere-land	120
Fossil fuel combustion	5

One gigaton of carbon (GT C) $=10^{15}$ grams pool estimates rounded to nearest 10 Gt.

(WILLIAM C. CLARK AND CEC)

trapped as heat in the lower atmosphere and the planet is transformed into a gigantic green house. Besides CO_2 the accumulation in the atmosphere of other "green house" gases such as methane, nitrous oxide and fluorocarbons also contributes to this phenomenon.

It is generally thought that such heating will produce an increase in the mean temperature of the Globe of 1.5 to 4.5% over the next 50 years.

The change of climate resulting from such heating would have serious consequences for agriculture, while a significant rise in the level of the sea would result from the thermal expansion of the oceans, apart from melting of the large ice caps of the planet.

The problem literally has global dimensions; the search for preventive solutions is impaired by uncertainties on the extent of global heating, on the regional and seasonal features of the anticipated climatic changes, on the rates of green house gases production, on the role of the oceans and the biosphere as sinks or sources, on the possible shift of bioclimatic zones, on the rate of deforestation and finally on the consequence of policy decisions concering energy and industrial productions.

The problem is further complicated by the effects of other industrial discharges, such as those presumably connected with ACID RAINS which affect forests and the cycle of OZONE; the presence of this gas in the stratosphere shields the earth from U.V. light.

The main research requirements have been established, notably by the International Geosphere and Biosphere Programme of the International Council of Scientific Union, which issued a comprehensive paper at its September '88 meeting in Stockholm.

Eventually thousands of researchers and huge technological and financial means should be mobilized. Work should be well coordinated in order to be efficient and timely. Carrying out this work is a challenge to all concerned: scientists, technologists, industrialists and public authorities. The results of such a global study are badly needed in order to make the right decisions in environmental protection. In the absence of sound scientific knowledge, policies may be misguided and could improve uncecessary burdens while neglecting key actions.

At a recent meeting of the Bioethics Conference of Industrialized Summit, my attention was brought to the analogy between the present situation of "The Space Ship Earth" and the situation of Japan, when, in the Edo period, it was essentially sealed off from the rest of the world and its 30 million inhabitants had to husband their resources and their environment. At that time, an agriculturist KAMASAWA BANZAN (1659 — 91) developed the "theory of Land and Water". It was an exemplary approach to the problem of wise resource management; it did not confine itself to controlling rivers, lakes, soil and forests, but also considered socieconomic factors such as lawlessness, excessive burdens on the population and the optimal use of human skills. KAMASAWA was in a sense a precursor of "ecological economics" and of Mr. Honda's promotion of eco-technology.

It is indeed necessary that we all jointly seek a comprehensive, harmonious approach to our own self, to each other, to our common environment.

The research areas we discussed today as possible objects of international collaboration refer to this need.

Research on the human genome and on neurobiology should lead to a better understanding of what each of us is, while the study of the global climate change and the search for clean energy through nuclear fusion should make us aware of the impact which our actions have on the environment we share.

The decision of Mr. Honda, one of the leading world industrialists, to promote environmental-friendly technology is indeed most significant.
I know that many people and leaders on both sides of the Pacific and of the Atlantic share his vision.