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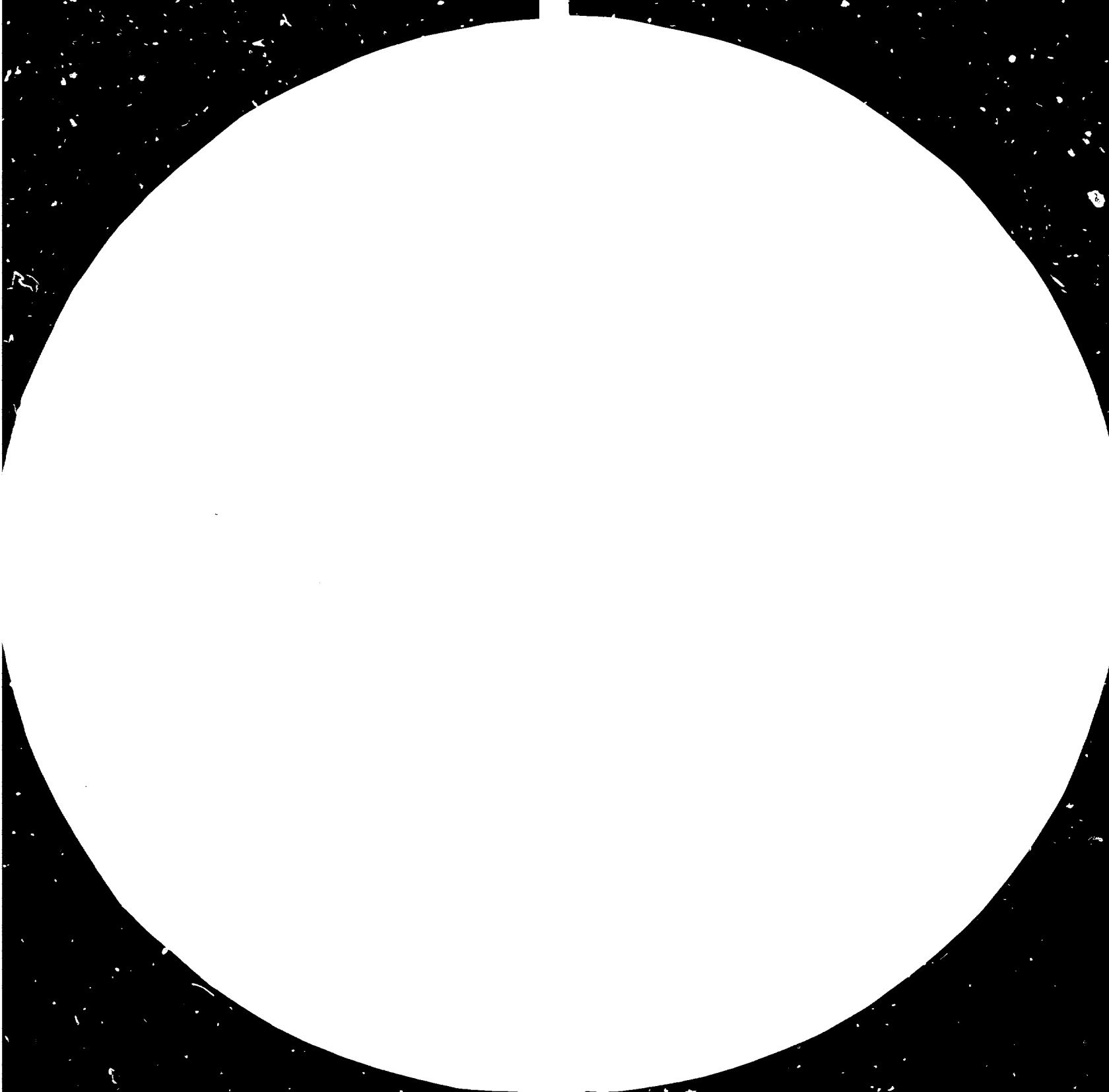

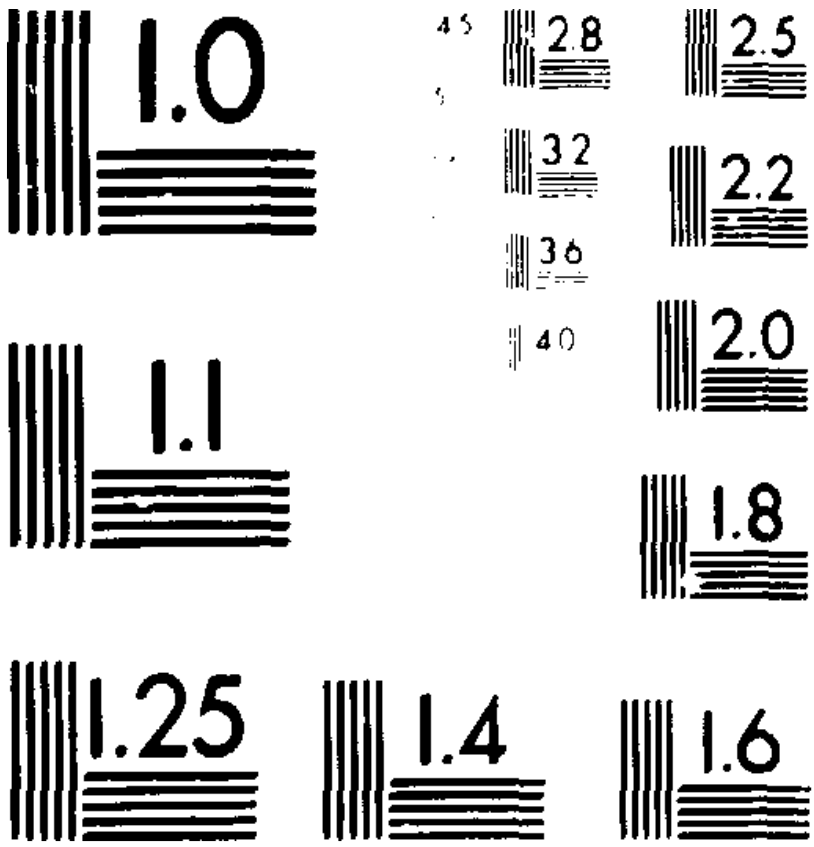

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BASIC INGREDIENTS REQUIRED FOR CAPABILITY BUILDING IN GENETIC ENGINEERING AND BIOTECHNOLOGY IN DEVELOPING COUNTRIES: SOME OBJECTIVES FOR THE INTERNATIONAL CENTRE FOR GENETIC ENGINEERING AND BIOTECHNOLOGY.

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INTRODUCTION

The new interest in biotechnology in the 1970s can be traced to a number of discoveries in different areas of research in molecular and cell biology. For example, in molecular genetics the discovery of the type II restriction enzymes greatly facilitated the manipulation of DNA molecules *in vitro*, now referred to as recombinant DNA or genetic engineering technology. In immunology the discovery that immunoglobulin (antibody) producing cells could be hybridised with tumour cells and that resultant "hybridoma" cells would continue to produce immunoglobulins and could be readily cultured made possible the production of monoclonal antibodies and gave new impetus to the use of immunological methods in many areas of biology. Many other key discoveries preceded and followed but these in particular played critical roles in stimulating interest in the new biotechnology. In 1976 the first genetic engineering company, Genentech, was founded in San Francisco, financed by venture capital, and in 1983 human insulin purified from genetically engineered bacteria was marketed in the United States. In that same year according to the US Office of Technology Assessment (OTA) more than $1 billion were invested in the commercialisation of new biological techniques by the private sector in the US and the US Government currently spends more than $500 million per year on research related to biotechnology. Japan, West Germany, UK, Switzerland and France, in that order, have also invested heavily in biotechnology. The OTA report considers that the US has a substantial lead. If this lead is maintained and carried through from the level of basic research to commercial realisation on the scale envisaged both by scientists and industrialists, the US and the other free market economies will have masterminded a new industrial revolution affecting many activities in medicine, agriculture, manufacturing industry and energy.

Most developed countries have been involved to various degrees in the basic sciences which gave rise to the new biotechnology and, following the lead set by Genentech in 1976, private industries or government agencies and sometimes consortia involving both the public and private sectors have set up companies making use of the pre-existing scientific knowledge and technological skills. However, some developed countries, where the basic sciences are not so strong, are faced with the possibility that they may not contribute significantly to the generation of the new biotechnology industry. Further, in 1981 a report for the United Nations Industrial Development Organisation (UNIDO) drew attention to the position of the developing countries (Narang 1981). It concentrated on the technology of genetic engineering and noted that the " recent scientific literature indicates that people in developing countries know little if anything about genetic engineering and the importance of recent advancements in research." This judgement implied that the developing countries will not benefit rapidly from the new biotechnology and that they will be beholden to international science and industry unless the problem is recognised and dealt with. The developing countries have been caught unawares and unprepared and must now set about building capability in biotechnology.

The UNIDO report (Narang 1981) suggested that the problem faced by the developing countries was on such a scale that international efforts would be required and it contained a proposal that " an international research and training centre should be established under the auspices of the United Nations". It envisaged that this facility would have three purposes: to help in the training of a core of professional scientists who would have the responsibility for furthering education and research in their own countries; to assist in the solution of particular research problems of developing countries by the application of genetic engineering; to conduct basic research in genetic engineering and the results to be shared with all interested countries. These basic ideas have led to a series of discussions organised by UNIDO over the last three years. The discussions involved scientists, industrialists, government officials and political figures in many different countries and eventually led to the establishment of the International Centre for Genetic Engineering and Biotechnology (ICGEB). This entity will have a crucial role to play in the transfer of the science and technology of genetic engineering and biotechnology (GEB) to the developing countries. It seems appropriate at this halfway stage with the ICGEB founded de jure but not de facto to record something of the process by which it has come into being.

This process reveals many of the difficulties faced by the developing countries in dealing with contemporary science and technology, it amply confirms the judgement that genetic engineering is not understood in developing countries and it suggests a series of steps which need to be taken to remedy this situation. In this paper the ideas behind the establishment of the ICGEB and the process of its formation will be described. Some proposals will be presented as to how, as a relatively small institution, it may undertake its task of facilitating the growth of genetic engineering and biotechnology (GEB) in developing countries.

EXCHANGE OF VIEWS ON GENETIC ENGINEERING AND BIOTECHNOLOGY IN RELATION TO DEVELOPING COUNTRIES. THE PROPOSAL TO ESTABLISH THE INTERNATIONAL CENTRE FOR GENETIC ENGINEERING AND BIOTECHNOLOGY.

The paper prepared by Narang was amongst those presented for discussion at a meeting convened in Vienna in February 1981 under the auspices of UNIDO, the International Federation of Institutes for Advanced Study, the Club de Geneve and the Foundation for the Reshaping of International Order. The meeting was attended by nine practising molecular biologists and microbiologists, as well as representatives from international groups and industry. The scientists concerned had close connections with developing countries. They set out:

(i) " to examine the implications of the advances in genetic engineering for the developing countries."

(ii) " to outline the nature of the technological capabilities to be built up by developing countries in order to take advantage of such advances."

(iii)" to examine the possibility of establishing a broad based international promotional and development facility for scientists and technologists from developed and developing countries to work together."

They concurred that international action was required and requested that UNIDO should undertake the responsibility of stimulating and co-ordinating a programme designed to foster GEB in developing countries. It was agreed that " there is a need for an international centre for genetic engineering and biotechnology." Their judgement was on the one hand that GEB was going to be extremely important for developing countries and on the other hand that there was a " relative lack of awareness in this field in many developing countries." Most of the scientists at this meeting had first hand experience of the state of GEB in both developed and developing countries and understood well the weakness of the underlying basic sciences in the latter. In effect, this report was both scientifically authoritative and culturally sympathetic. Given the scientific reputations of the scientists involved it was likely to be respected. The group suggested that UNIDO should prepare a report on the proposed centre, in effect widening the discussion to see if the idea of the centre which had come from experimental scientists would attract political and financial support.

In the following six months consultant scientists and UNIDO representatives visited 16 countries (both developed and developing) and some international organisations and conducted a very wide range of discussions with scientists, officials and political figures. They reported (UNIDO document IS.254) in October 1981 that there was widespread interest in GEB and support for the proposal that the ICGEB should be established. They noted " the

pervasive feeling that unless timely action is taken countries will stand to lose in the structural changes ahead." They identified at first hand the " great shortage of trained scientific and technological manpower in this field", the need for international exchanges and cooperation and for international advisory services at all levels extending from information on experimental protocols to discussions on the development of institutional and national policy. They observed the opportunities and the needs for regional collaboration. It was apparent that the ICGEB would have many more uses than were made explicit in the original proposal. More than that the report concluded that " only the setting up of such a centre will ensure the critical mass of international action and effort consistent with the wide ranging potentialities and implications of genetic engineering and biotechnology."

In reaching this conclusion it is evident in the report that the authors were anxious to emphasise some critical features of GEB. These had been referred to directly or indirectly in the two earlier reports, but at this stage they came more sharply into focus as the authors argued that the ICGEB was not just a useful mechanism to catalyse the transfer of GEB but that it was the " most practical and effective means of assisting, in an integrated fashion, the strengthening of national technological capabilities in this important field." They explained that genetic engineering and biotechnology represented a field which was remarkably wide and dynamic. One of the underlying sciences, broadly referred to as molecular biology, in which this group of scientists had been trained, has arguably grown more rapidly and extended more widely than any field of science in the last thirty years. Yet molecular biology is only a part of biotechnology which derives from a range of sciences extending from chemical engineering to genetics. The report noted that research and training in biotechnology cannot be sustained at the highest level unless a wide range of disciplines are represented. These scientists had first hand knowledge of the way research and training in molecular biology had thrived in the great research institutions of Europe and North America and they envisaged the creation of the ICGEB as sharing the essential characteristics of " transdisciplinarity" , " critical mass" , " internationality" and intellectual vigour but dedicated to the needs of the developing countries. They found that the international scientific community was " overwhelming" in its support for the Centre, but that it was concerned that the ICGEB would not succeed unless it established from the start a standard of excellence. " A sub-critical effort might rapidly erode ICGEB's attraction as a centre of excellence." Scientists would like to participate in the activities of the ICGEB but " the extent to which they actually do would depend on the location and facilities of the Centre" . The authors were acutely aware that the international scientific community of molecular biologists and others who understood the complexities of GEB would only support a scheme for the transfer of this science and technology if they were convinced of attention to standards which would be required to ensure its success.

The report addressed one other possible mechanism of facilitating technology transfer: networking. " The mere networking of

existing institutions will not have the desired effect in itself". Some countries, indeed most developing countries, have no institutions capable of contributing significantly to a network in GEB (as the field had been defined in the UNIDO Reports) and those that might conceivably be included were by implication considered not to be organised in a way that they could have given the necessary leadership or impetus in undertaking what amounts to a crash programme to invigorate developing countries with the science and technology of GEB.

In the case of a network of existing institutions the report noted that none of them would have the transdisciplinary character of the range envisaged for the ICGEB. Although it was not stated, it can be deduced from the report that many highly qualified scientists, who expressed doubts about the ICGEB meeting their standards of excellence, would not have given much thought to the idea of participating in a network of existing institutions. The transfer of GEB to developing countries will be accelerated much more effectively with the support of internationally respected scientists; the ICGEB seemed to offer a mechanism for enlisting this support in a way which networking could not match in this particular field.

Although the report did not see networking as an alternative to the ICGEB, the discussions certainly led to a broadening of the concept of the Centre and especially to much more detailed consideration about how it would be associated with existing institutions and how it should support the establishment and development of national and regional institutions specialising in GEB. It was proposed that the ICGEB should " promote networking of national and regional institutions engaged in genetic engineering and biotechnology so as to mobilise their efforts in the service of the developing countries." This and other references in the report were part of a theme which was to arise again at the Belgrade Meeting and which underlay many of the problems which arose at other times especially in regard to the location of the ICGEB. Developing countries have particularly strong national feelings, they display remarkable diversity in culture, geography, politics and so forth, and usually they have miniscule discretionary funds for investment in science. Networking, which implies the expenditure of money in one's own country, or at worst, within a region of common culture, is more desirable politically than the establishment of a single international centre, the financing of which was sure to be a most difficult matter and which might lead to the accrual of disproportionate benefits to the country in which the centre is located. Networking had other potential advantages in, for example, ensuring a greater degree of local control in choice of research programmes and providing a conduit for the transfer of knowledge and skills into each participating country. These matters were certainly regarded as extremely important in the report which emphasised that the ICGEB must establish close connections with national institutions for reasons of science, otherwise it would not be able to implant GEB in the different

countries. Networking, although not a substitute for the ICGEB, should be an important objective once the ICGEB was established.

The report outlined some roles for ICGEB in research and development, training, the promotion of co-operation including networking at national, regional and international levels, the provision of advisory and information services, the organisation of meetings, and the organisation of supplies of critical materials. The research programme was discussed, listing the fields within genetic engineering and biotechnology likely to be most relevant to developing countries. A training programme was suggested to be closely linked to the research programme. Trainees would be accepted on much the same basis as post-doctoral fellows to participate for a number of years in the research programme thereby gaining thorough experience. Additional trainees would be funded to go to other institutions . Trainees were to be chosen on the basis of their potential to create groups around them in their home countries, and with a " commitment made by the sending country" to provide adequate local facilities. The report had a range of imaginative suggestions which in themselves provided further justification for the ICGEB and generated some ideas on the constitution of the ICGEB and the scale of it in terms of space, personnel and financing. There would be a Board of Governors drawn from participating countries and a Board of Scientific Directors composed of eminent scientists. The scientific staff would consist of a Director, 30 scientists and 30 technicians, and would be able to train on site about 100 scientists in a five year period. Capital expenditure (excluding land and buildings which would vary greatly with location) would be $9.5 million and operating costs $29 million for a five year period (at 1981 prices).

The report had a last, short section discussing the location of the ICGEB, a matter which has perhaps done most to hold up the foundation of the ICGEB. It was noted that the facilities of the ICGEB would have a crucial effect on the ability to attract staff who in turn will determine the quality of the Centre. Four factors were listed for consideration when the location was being chosen - basic infrastructure, industrial environment, social infrastructure and national commitment.

The recommendations of the Report on the Establishment of an International Centre for Genetic Engineering and Biotechnology are shown in Table I.

THE BELGRADE MEETING ON THE ESTABLISHMENT OF THE INTERNATIONAL CENTRE FOR GENETIC ENGINEERING AND BIOTECHNOLOGY.

The UNIDO report " Establishment of the International Centre for Genetic Engineering and Biotechnology (ICGEB)" in November 1981 recommended that UNIDO should " follow up its initiative" and " pursue the question of the Centre vigorously' , enlisting the support of scientists, consulting with other international agencies and organisations, and negctiating with interested governments. It recommended that UNIDO should " convene a meeting of participating governments". In the following twelve months teams of UNIDO officials and consultants prepared more detailed plans for the statutes, staffing, research programmes, financing and other matters for consideration by a meeting of interested governments. Members of the UNIDO Secretariat discussed the ICGEB in many countries seeking political and financial support. There were indications from Mexico, Sweden, Ireland, France, Canada and Belgium of interest in supporting the establishment of the ICGEB, but it was clear that financial support for the ICGEB would be postponed until the nature of the Centre was more fully described and until it received substantive international political support. This political support emerged at the Belgrade meeting in December 1982.

The High Level Meeting on the Establishment of the International Centre for Genetic Engineering and Biotechnology was convened jointly by the Government of Yugoslavia and the UNIDO Secretariat. Representatives were invited from 35 countries where interest had been expressed in the ICGEB. Representatives came from 28 countries and 7 countries some not on the original list sent observers, as did 9 international organisations and one industry.

An introductory address was given by Dr. Abdus Salam, Nobel Prize Winner and Director of the International Centre for Theoretical Physics (ICTP) the first U.N. science centre established in 1960 under the auspices of the International Atomic Energy Agency (IAEA). He rejoiced at the prospect of a second U.N. science centre and continued the theme identified in the UNIDO reports. He referred to two theses; one, that " science transfer must go together with technology transfer if technology transfer is to be meaningful" and two, that " the best vehicle for both science and technology transfers were high level science and technology centres created and run by the United Nations Organisation." He argued that such centres give scientists from developing countries " opportunities to contribute scientifically on equal terms" and fostered idealism among scientists in the cause of the developing world. He saw too the need to protect biotechnology from the secrecy beginning to impinge upon it as industrial interest developed. His address echoed the ideas of the UNIDO consultant scientists. The ICTP in Trieste, established in Physics for the same reasons proposed for the ICGEB in Biology has been a success. Each year 2000 physicists, half from the developing countries, visit the ICTP. It is now financed mainly by the Government of Italy with other support from Sweden, Japan, Denmark, USA, FRG, the Netherlands, Kuwait and the

OPEC Fund, operating under the auspices of the IAEA and UNESCO.

The meeting was in overall terms highly successful. The great majority of the delegates spoke in favour of the idea of the ICGEB and the Conclusions and Recommendations (Table II) reflected this clearly. There was virtual unanimity that the ICGEB should be a " centre of high excellence' and strong sentiment that it should be located in a developing country (Table II, Paragraphs (iii) and (iv)). It was recognised however (Table II, Paragraph (iv) that the location had to be chosen with great care bearing in mind the need to attract outstanding scientists whose work would establish the quality and reputation of the ICGEB. It was also decided (Table II, Paragraph (v)) that preparations should be started to develop a network of affiliated " regional and/or national centres."

THE REPORT OF THE SELECTED COMMITTEE

It was decided to pursue the main outstanding matters of location and finance by asking interested countries to submit offers to UNIDO by 31st December 1982. A questionnaire was to be prepared by UNIDO and distributed to the offering countries with replies to be received by 20th February 1983. A broadly representative Selected Committee of scientists was to be established with members from Yugoslavia (host of the Belgrade meeting), Hungary (for the centralised economies), Sweden (for Europe), Nigeria (for Africa), Indonesia (for Asia), Argentina (for the Americas), China and UNIDO. This committee was to examine the replies to the questionnaires and then to visit each candidate country. It was to report on " its findings including the merits and demerits of the several locations offered from its point of view of realising the objectives of the Centre," the report to be presented to a Ministerial-Level Plenipotentiary Meeting. The terms of reference of the Selected Committee were wide covering physical facilities, scientific infrastructure, support services, finance and legal provisions, especially those related to the international character proposed for the ICGEB. I served as the UNIDO representative and as the Chairman of the Selected Committee. It considered offers from Belgium, Cuba, India, Italy, Pakistan and Thailand and visited these countries plus Sweden.

The Selected Committee had a unique opportunity to assess the prospects for the ICGEB from many different viewpoints in both developed and developing countries. Extensive discussions were held with political leaders, government officials, planners, administrators, scientists and students and the Committee received many written submissions and supporting material. Visits were made to universities, research centres, libraries, computer centres, industries and agricultural stations. For two and a half months as the Committee travelled its members listened, observed, questioned, analysed and discussed, accumulating a body of knowledge and forming opinions about GEB and developing countries.

(e) The political and governmental view.

In each country the Selected Committee was received by Cabinet Ministers and in three (Sweden, Cuba and Pakistan) by the Head of State. This level of political contact is a measure of the importance attached to the question of GEB in developing countries at this time. Science and technology have had very large effects on the developing countries perhaps most noticeably in medicine, and political authorities in these countries see the capacity of science and technology to solve major social and economic problems. Moreover it is certainly the case that if some of these problems are to be addressed through GEB the State has a much greater role to play than in developed countries given that the high technology private industrial sector is either weak or non-existent in most developing countries. The leaders of developing countries whom we met clearly expect GEB to be important in the future and are willing to support it. One question which emerged is whether they will be properly advised on the structures required for teaching and research in GEB, the kinds of research and development programmes, the costs, the time scales and the criteria for

success.

It was apparent in several countries that the expectations among some politicians were unreasonably high, that they had not been properly advised and were likely to end up supporting the wrong projects and the wrong people. I shall return to the set of problems underlying these observations later in the paper, as I see a major role for the ICGEB in providing objective advice on GEB to the authorities in developing countries. Allowing for these cautionary remarks, the message was clear that the prospects for GEB had been assimulated at high levels in government and that the small numbers of indigenous scientists trained in GEB had good contacts with senior politicians and officials. The UNIDO proposal to establish the ICGEB had obviously stimulated and accelerated the formation of these contacts. New planning boards were being established, policies were being formulated, new laboratories were being built, new courses were being designed, and scientists were being sent abroad to be trained, all with the immediate approval and sometimes close supervision of senior politicians and government officials. GEB now has a very high political profile in developing countries.

(b) GEB projects in developing countries.

The high political profile of GEB is certainly justified by the prospects for the application of GEB in developing countries, even if these prospects may be on a longer term basis than is usually accepted. In each developing country visited by the Selected Committee there were examples of how the new biotechnology might be applied with results in the near future. In Cuba the sugar cane industry is of vital importance. The primary products of molasses and sugar, rich carbohydrates could be more efficiently utilised. They are potentially valuable feedstocks for the industrial-scale enzymological processes which should emerge from the GEB revolution. The international cane sugar industry has been threatened by the industrialisation of one enzymatic reaction (the conversion of glucose to fructose by immobilised glucose isomerase), but this same industry should be revitalised by the application of similar processes. Moreover industrial-scale enzymological conversions should also be applied to the by-product of sugarcane, bagasse. It too is potentially a rich source of carbohydrate, mostly cellulose, which is convertible to sugars and ethanol. Research into these questions is discussed by Wu (1982). The impact of genetic engineering is already materialising with several reports on the cloning of genes for α-amylases, cellulases and β-glucanase. These are some of the enzymes which will be valuable in the catalysis of economically important conversions of polysaccharides. The newly-identified ligninase of Phanerochaete chrysosporium will be an important subject of research in this area.

In Pakistan there is a greater climatic range than in Cuba so the range of economically important crops is correspondingly greater. There are substantial opportunities to add food value to the crops through better utilisation of by-products through industrial-scale enzymology. Prevalent tropical infectious diseases will be more accurately diagnosed through the use of monoclonal antibodies and nucleic acid probes, and more importantly

novel vaccines developed by recombinant DNA will be introduced.

In Thailand striking data were presented to the Selected Committee on the incidence of thalassaemia and HbE, genetic disorders of the blood. These affect a very large percentage of South East Asians but can now in principle be diagnosed in unaffected carriers and in the foetus by using nucleic acid probes. These new techniques can lead to the near disappearance of these diseases, provided that they are made available in practical form, and that therapeutic abortion is socially acceptable. These and related genetic diseases are also widespread in East and West Africa and in Mediterranean countries . Another major line of interest in Thailand is malaria, unfortunately making a reappearance in many tropical countries. Genetic engineering is being used to study the surface of the malaria parasite in its different forms and there are prospects that a novel vaccine may be developed from this work.

In India there was substantial interest in the development of many novel vaccines. Leprosy remains an immunological puzzle and has been difficult to study partly because the causative bacterium Mycobacterium leprae is cultured only with extreme difficulty. It will be possible to clone M.leprae genes coding for surface antigens into E.coli and so to generate new reagents for the diagnosis and study of leprosy. These lines of research should also lead to novel vaccines, though here one should be cautious given the unusual features of the immune response to leprosy. New vaccines against tuberculosis, cholera, typhoid, polio, measles and hepatitis are also expected to be developed by recombinant DNA, as well as a set of vaccines against a variety of animal diseases.

These are merely a few reflections of many discussions on the applications of GEB anticipated in the four developing countries visited - in the short term. Long term prospects especially in the genetic engineering of plants were often considered but as in developed countries' many scientific observers were cautious in their assessments. In Cuba there was much interest in interferons and a very well-equipped and well-staffed research centre has been established - the Centre for Biological Research (CIB). Interferon is being produced from buffy coat by the Finnish method, and some clinical trials have been conducted. There is also an active research group working on the production of interferon by genetically-engineered E.coli. The Selected Committee were unanimous in their high assessment of the facilities' the personnel and the quality of the work, and this is the judgement which it is important to record. In my own opinion, which I believe was shared by other members of the Committee, the CIB was the best endowed laboratory which we visited in the four developing countries. It closely resembled similar laboratories in the U.S. and Europe, although it was small with less than 50 personnel, and it was working in virtual isolation. On the one hand it was an example of what can be and is being done in developing countries and on the other it demonstrates the need for an international centre such as the ICGEB to facilitate the transfer of new ideas and techniques which are emerging at a tremendous rate and which isolated laboratories have great difficulty in keeping abreast of.

(c) The research capacity for GEB in developing countries.

In general the research base in GEB, in particular in molecular genetics, in institutes and universities in each developing country visited by the Selected Committee was observed to be weak. In effect none of these countries presented substantial evidence of GEB research being conducted at a competitive international level. For the most part the research facilities were primitive, the equipment was out-of-date or non-existent, the libraries were usually incomplete and often poorly maintained, the consumables budget which must be large for genetic engineering was usually much less than required and the number of senior staff with recent hands-on experience of modern laboratory techniques was low. Of course the visits were short. In some countries such as Cuba, most of the major research institutes were visited, whereas in others especially India, only a small proportion were visited. However, in every country the research centres visited were in the top rank in the country. With the exception of the CIB in Havana, not one of these laboratories was sufficiently equipped, funded, staffed or organised for molecular genetics. The usual arrangement was of one or perhaps two faculty or staff members of an institution carrying out or supervising molecular genetic research. One or two graduate students or technicians acted as assistants. In some laboratories where it was purported that molecular cloning was being carried out the Selected Committee found only one or two relatively junior people working without an experienced supervisor. Reagents were in short supply especially isotopically-labelled compounds, enzymes and fine chemicals; they were difficult to obtain not just because of finance but also because of problems in communication, transport and customs clearance.

The grim overall picture was relieved by the occasional scientist who understood molecular genetics thoroughly. Usually these scientists had studied and researched abroad, and faced virtually insurmountable problems in recreating the facilities for research programmes in their home countries. These are the people who must be given the responsibility for developing GEB and its underlying sciences in the developing countries. They have shown themselves as committed to their countries - the ones referred to would have easily found good positions abroad.

(d) The teaching capacity for GEB in developing countries.

Although the apparent quality of the universities in their capacity for teaching GEB varied greatly in the four main cities visited by the Selected Committee - Havana, Lahore, New Delhi and Bangkok - the impression was clear that the staff were always working under considerable difficulties. None of the universities visited has strong molecular genetics groups, courses tend to be traditional and it was apparent that the laboratory facilities are not adequate for providing good experimental training at the undergraduate or postgraduate levels. There are too few specialist staff and they are sometimes spread between several departments or institutions. Library facilities are sometimes good as in the new campus at Mahidol University, Bangkok, and the Biological Library of the Academy of Sciences in Havana. In other places

libraries were atrocious. Some had been forced to stop taking major journals as funds were no longer available; poignant evidence of the problems faced. Nowhere was there that close and free relationship between books and students which should be so much a part of learning and research in contemporary molecular genetics.

In every centre there were some members of Faculty who were well-read in molecular genetics, some had active research groups and some collaborated with laboratories abroad. But none of the university groups were close to realising their full potential, being always seriously impeded by the poor facilities for teaching and research. The experimental scientists, especially those who depend on high quality chemical and biochemical reagents and complex instruments are at a serious disadvantage in the universities of the developing countries. They are like carpenters without saws, skilled and knowledgeable but often utterly ineffective stymied by lack of facilities. This condition represents a waste of talent and appears to have had the more serious effect of biasing the main teaching and research programmes in biology towards the observational rather than experimental side of the subject. Such experimental programmes as do exist are of a rather more traditional kind. The overall impression is of biology as it was in the 1930s, with occasional almost idiosyncratic or capricious accretions, as for example an up-to-date electron microscope in an otherwise very poorly equipped laboratory, or a set of about 20 gamma counters laid out on benches behind double locked doors.

(e) The response by scientists to the Selected Committee.

Scientists in each developing country were extremely interested in the idea of the ICGEB. Some had had direct experience of GEB, sometimes abroad, and were trying to develop research and teaching programmes. Many of these scientists were coming up against the problems of lack of resources and lack of understanding. The UNIDO initiative on GEB provided a point on which to focus discussion. There was already much active discussion of GEB and the UNIDO documents seemed to have been helpful in adding weight to the arguments for increased investment in GEB. After the Belgrade meeting the scientists and administrators in all four developing countries quickly coordinated their efforts and produced offers to host the ICGEB and answers to the UNIDO questionnaire within 2-3 months. This required considerable commitment on the part of the governments of these countries, and the institutions which would be involved in the project in planning, management, construction and so forth. The Selected Committee was enormously impressed by the keen broadly-based support which had materialised for the project extending from the scientists to the political leaders. It was plain that the scientists were seizing the opportunity of the ICGEB project to press their case for more support for teaching and research in GEB and that the governments were sympathetic.

(f) The report of the Selected Committee.

The Selected Committee summarised its views on its enquiries about the role of GEB in developing countries and the need for

an institution like the ICGEB as follows:-

" The Selected Committee has greatly appreciated the unique opportunity offered to it to meet the working scientists in their own laboratories in so many countries. The Selected Committee has often been impressed by the quality of the science being conducted, sometimes under difficult circumstances and essentially in isolation from the international scientific community. The value of this science is increasingly recognized by the relevant authorities and wide support is being given to the fundamental areas of molecular biology, microbial genetics, biochemistry and fermentation processes, which have in some cases formerly been neglected. Recombinant DNA technology (genetic engineering) which has grown out of these fundamental sciences is now being used in some laboratories in developing countries though the efficiency of the projects is not usually high. It has been difficult to assemble the necessary numbers of experienced scientists to form a " critical mass" and it has often been difficult to arrange for sufficient support in terms of materials, technical support, information flow, buildings etc. However, the potential of genetic engineering and biotechnology is widely known at high political levels and there is a keen appreciation of the need to increase the efficiency of the research and development groups in this field. All developing countries visited have started programmes in genetic engineering and biotechnology. These activities in the developing countries show in the first place the need for the ICGEB and in the second place that the ICGEB will be able to construct and act as a resource centre for a network of affiliated regional and national centres.

The Selected Committee, considering the main tasks of UNIDO, has been at first hand the need to transfer the powerful science of genetic engineering and biotechnology to developing countries. In each developing country it has been made aware of research projects which are unique to that country which would benefit from association with the ICGEB. At the same time in the advanced countries it has noted the gathering speed of the genetic engineering and biotechnology research and development programmes. The need to establish the ICGEB is even greater now than it was two years ago when the idea was conceived. It is therefore important that the potential member countries of the ICGEB assess the urgency of this matter and note that the choice of location of the ICGEB will crucially affect the speed with which the Centre can begin to help the developing countries in a useful way."

It presented its unanimous report to UNIDO on 13th May 1983 dedicating it to Dr. Cesar Vasquez a member of the Committee until his tragic death from a heart attack on 19th April 1983. It was one of the documents considered by the Ministerial-Level Plenipotentiary Meeting in Madrid, September 1983.

THE MINISTERIAL-LEVEL PLENIPOTENTIARY MEETING ON THE ESTABLISHMENT OF THE ICGEB, MADRID SEPTEMBER 1983 AND VIENNA APRIL 1984.

Forty four countries participated in the Madrid Meeting and seven others sent observers. Fourteen organisations including the U.N. University, the European Molecular Biology Laboratory, WHO, FAO , EEC and the Rockefeller Foundation also sent representatives.

The meeting was in two parts, the first to resolve outstanding questions of the statutes, finance and location, and the second to adopt and sign the statutes establishing the ICGEB. The draft statutes were modified somewhat and then agreed. It was not possible to reach agreement on the location and financing. Indeed the discussions on these last two matters were difficult and the Report (UNIDO/ID/WG.397/9) indicates that opinion was so divided that it might be difficult to establish the ICGEB at one centre. In the event twenty five countries signed the statutes (Table IV) without deciding on the location or the financing. A Preparatory Committee, with one representative from each of the countries which had signed, came into being with the signing of the statutes and it was charged with the responsibility of resolving the outstanding matters of location and finance. The Plenipotentiary Meeting was adjourned and was to re-convene to hear the recommendations of the Preparatory Committee.

The Committee met twice in November 1983 and January 1984 and finally proposed that the ICGEB should be established initially with two components, one in Trieste, Italy and the other in New Delhi, India. The Plenipotentiary Meeting was re-convened in Vienna in April 1984 and accepted this proposal, with ten countries signing the amended statutes.

The decision to establish the ICGEB in two places, one in a developed country and one in a developing country, reconciled the two decisions of the Belgrade meeting that the centre should be of high excellence and preferably located in a developing country. Several scientific consultants to UNIDO, and the Selected Committee, had been concerned that if the ICGEB was located in a developing country it would be difficult to attract highly qualified and experienced scientists with international reputations sufficient to establish the standards of " high excellence". On the other hand the developing countries are to be the beneficiaries of the ICGEB and their governments' representatives were virtually unanimous at Belgrade and Madrid that the ICGEB would not function effectively unless it was part of the developing world, where staff would see at first hand some of the problems to be solved and would be more likely to focus their research towards relevant objectives and in a practical way . The Vienna decision that the ICGEB should have laboratories in Trieste and New Delhi, and that laboratories in other places should become linked to the ICGEB has resolved the matter in a realistic and constructive way. Trieste was highly recommended by the Selected Committee and the Italian government has offered $38 million towards the costs of the ICGEB. The Indian Government has offered $19 million and will facilitate

the foundation of the New Delhi laboratories in every way possible.

THE ICGEB AND THE BASIC INGREDIENTS OF BIOTECHNOLOGY.

The foundation of the ICGEB has been accomplished because it was accepted that there was little or no genetic engineering and related biotechnology in the developing world. The objectives and functions of the ICGEB as defined in the statutes are shown in Tables V and VI, which can be more easily understood if taken in conjunction with the reports upon which they are based. It would be redundant to rehearse all of the ideas contained in these reports but it may be valuable to look behind and beyond them.

The ICGEB will be a small institution with some 50-100 scientists working at any one time, it will undertake a small number of research projects, train a small number of people in the course of these projects, and its immediate impact on science could initially turn out to be small. It will never be able to match in scale the foreign students' programmes of the United States or other Western countries and will not match in scale the research programmes undertaken in these countries on some matters (e.g. malaria vaccine development) which are directly related to the needs of the developing countries. The question is how the ICGEB as a small institution can exercise a role which distinguishes it from the great national universities and research institutes of the developed world, many of which have close ties with developing countries. What will the ICGEB have to offer the developing countries ?

The reply to this question is this. The aid programmes of the developed countries (training of research students, collaborative research projects etc.) have not succeeded in the field of GEB, nor in the underlying science of molecular biology. This author is not in a position to comment on other fields, but GEB and molecular biology which have thrived in the US, Western Europe, Japan and Australia for twenty years or more, are very poorly established in developing countries in spite of the fact that many students from these countries have been trained abroad. There are many reasons for this failure - students not returning to their home countries; poor laboratory conditions; inadequate research and teaching budgets in the home countries etc. - but it is clear from the discussions at Belgrade and Madrid that the developing countries believe that international aid programmes are more likely to be successful than national ones, and in particular they will be more successful if they are under the supervision of the developing countries themselves. The ICGEB has been founded with these arguments in mind and its experience will be a test of them. The ICGEB is not just another research institution. It has been founded under the auspices of a UN organisation and so should be able to act and speak with an authority and objectivity that will enable it to have an influence which far exceeds what would be expected for an institution of its size. It will have the chance to influence people in universities, research organisations and governments about GEB and molecular biology in a way which no other body can at the present time. It is planned, desired and expected that it will have an authority for the developing countries which will compare with say, for example, the N.I.H. has for the U.S.

It is of course not enough to talk of this position of authority. The authority of the ICGEB will not be established

as a birth right, just because it is an international institution. The authority will be established as a result of the work of the ICGEB in its early years. How should it go about achieving authority ?

The scale of the task facing the ICGEB is enormous with the prospect of choosing between a great range of research projects on many species of plants, animals, bacteria and viruses, endemic in different climates in over a hundred different countries of the developing world. Plainly the ICGEB must be organised so that its influence extends far beyond its immediate day-to-day concerns. It must set out to be a prophet of its science, enlisting the faithful and training its disciples so that its effect permeates the universities and research institutes of the developing world. In the following paragraphs I want to draw attention to some ways in which the ICGEB might respond to this challenge - how can a small international institution significantly influence the development of a major field of science and technology in such a large number of developing countries ?

Of course this question was posed by the authors of the reports to UNIDO and some answers were suggested. There was clear emphasis on the necessity of establishing the highest possible standards of science in the ICGEB which in turn implied that great care had to be taken in the appointment of staff. This was accepted as the primary initial objective for the ICGEB - appoint outstanding staff. I will not labour this point further - sin qua non - except to say that the international scientific community will watch how these appointments are made and it is the collective opinion of this community which will signal whether the ICGEB is setting off on the right track.

The ICGEB will have as one of its most important elements a group of visiting researchers from developing countries who will spend a number of years at the laboratories and will then return to their home countries. They will be accepted by the ICGEB in the expectation that they will return to their home countries and play important roles in the development of GEB there. They will be vectors providing one of the most valuable ways of extending the effect of the ICGEB carrying with them knowledge of the latest discoveries and techniques, imbued with the intellectual standards of the ICGEB and in many cases having won for themselves reputations in their fields of research. It is therefore of paramount importance that when these scientists are chosen they meet the highest objective standards of intellect, scientific knowledge, experimental experience, commitment and personal qualities and that the process of selection does not take undue account of qualifications which are not germane to science. It would be wise to avoid rules reserving places for scientists from particular developing countries, but if such rules have to be introduced then they must include stipulations on two further matters. A scientist, to be accepted, must meet a set of objective criteria in respect of his ability as a scientist, and his country must show that when he has completed his study he will be able to pursue his science under reasonable conditions.

The reputation of the ICGEB as a research institute will be based initially on the reputations of the newly appointed staff. They in turn have to fulfill the trust placed in them and produce outstanding research results, comparable to those coming from the leading institutes of the world. This research as it is published will reach the international scientific community, carrying the influence of the ICGEB to all countries. Much depends on the way the research of the ICGEB is organised for example, on the balance between directed or contract research and independent research. How many major projects will be undertaken and in what areas ? How much of the research will be aimed at short term applications and how much at longer term results ? What will the balance be between pure and applied research ? It may at this stage be helpful to tease out some of these questions further.

UNIDO consultants did specify six major areas for research projects (UNIDO/IS.254, 1981) and Work Programmes for five of these and for the additional area of Bio-Informatics were drawn up (UNIDO/ID/WG.382/2/ Addenda 1-6 1982). The titles of these documents in the reference list describe the areas.

These Work Programmes cover an enormous range of projects from enhanced oil recovery by genetically engineered microorganisms to the development of novel vaccines. There is no question of the ICGEB being able to carry out significant programmes across this range and this was not the intention of the consultants. The projects were as described mainly to show the range of applications of genetic engineering, so that developing countries would be alerted to the potential value of GEB. The Work Programme of the ICGEB will very likely include some of the projects outlined in the original documents but the number of different ones must be rather small and carefully selected with respect to their chances of success, either in terms of scientific or applied value.

The balance between directed or contract research and independent research will be an important factor in attracting staff of high quality. It will also be important in helping to maintain a balance between pure and applied science. I argue below that the ICGEB must pursue strong programmes in pure molecular biology, and this may best be ensured through a policy of supporting independent work of the staff members, say to 60% of their time.

The questions of the number of major projects to be undertaken and the areas of research for these projects are difficult to answer. The scale of the ICGEB (50 permanent scientific staff plus 26 postdoctoral fellows and 40 technicians) and its facilities suggest that perhaps it might undertake about 5-10 major projects at the beginning, dropping some as others show promise of success. Some projects should be chosen in the expectation that within four years they will have a good chance of being perceived as successful in the developing countries, for example, programmes to develop novel vaccines against polio or typhoid, or to construct expression vectors for use in E.coli, Streptomyces, S.cerevisiae and Bacilli. Others for example the development of molecular cloning systems for monocotyledons (perhaps based on mobile genetic elements) and vaccines against malaria are of such importance that the ICGEB should probably have groups working on them even if success is not achieved in five years. The ICGEB personnel will at least be able

to advise about these topics which are of major concern to the developed countries as well.

One result of the process by which the ICGEB was founded was a serious revelation about science in the developing countries. One whole field of science, molecular biology, hardly exists in the developing countries. The scientists who participated in this project travelled to many developing countries; in my case to Egypt, Yugoslavia, Hungary, Kuwait, India, Pakistan, Thailand and Cuba. In extensive discussions amounting to several man-years of work, there was no dissent from this conclusion which was recorded in each of the reports. The question is what the ICGEB should do about this. I suggest that it will be extremely important that the ICGEB recognise that it has a role in fostering basic molecular biology as well as GEB in developing countries. Although the ICGEB has been established with a wide brief (Table V), it is at this stage too early to say how this will be interpreted. It will be extremely important that in its advisory capacity the ICGEB uses its influence to drive home the point that the basic ingredient of biotechnology is basic science in the relevant fields. It is worth repeating again the advice of Abdus Salam that " science transfer must go with technology transfer if technology transfer is to be meaningful and lasting."

There are two questions to be posed in pursuing this point. The first in respect of molecular biology is how can it be implanted in the developing countries to sustain the transfer of biotechnology? This question is the main matter that I shall deal with in the remainder of the paper, but I wish to pose the second question in thinking about how the developing countries might avoid another situation equivalent to the one in genetic engineering. The second question is: What other areas of mainstream science, which have yet to show obvious applications, are not represented in the developing world ? I am sure the answer to this is known, but has it been addressed in the proper international forums and are steps being taken to redress the deficiencies so that when novel technologies emerge from these other sciences, the developing countries will be able to benefit from them more quickly ? The example of genetic engineering must be used to support the case that developing countries cannot afford to neglect pure science.

The basic ingredients of genetic engineering and biotechnology are knowledge and skills in a wide range of fundamental sciences and technologies. The title of this symposium and the name of the ICGEB emphasise the role of genetic engineering, a field which is often subsumed within the general heading of biotechnology. This reflects the way in which the new biotechnology has been influenced by genetic engineering which more than any other field has been a source of inspiration, motivation and inventiveness for biotechnology. It is also an area of biotechnology in which the developing countries were found to be extremely weak by the scientific consultants who drew up the early reports. Moreover, because genetic engineering is composed of many different experimental procedures ranging from organic chemistry through biochemistry to microbial genetics, because these procedures are being

constantly changed and added to, and because they are bench skills demanding a high degree of experience, intuition and theoretical knowledge it was apparent that the transfer of genetic engineering to the developing countries vividly exemplified the problems of technology transfer, exacerbated by the neglect of the underlying basic science. Unlike say applied microbiology or applied botany which are parts of biotechnology for which the basic sciences exist in many developing countries, the basic science underlying genetic engineering is essentially absent. Not only is the technology of genetic engineering exceeding complex, there is virtually no base for it in the developing world, and the ICGEB must participate in building this base of molecular biology at least as much as it concentrates on the application of the technology.

There is of course a major task of influencing the policy makers within developing countries that the pure science of molecular biology must be fostered. The ICGEB will not be successful unless this argument is put forward and won. Let us assume that it is won, then how should the ICGEB advise the developing countries on the mechanism for implanting molecular biology, remembering that the ICGEB has been planned as a relatively small institution.

The ICGEB must be viewed as a catalyst, or perhaps as the provider of the seed corn. Its effects will be spread by its "graduates" who return to their home countries and impart knowledge and skill through their teaching and their research groups. These graduates of the ICGEB will be under great pressure to produce "meaningful" results, as will the ICGEB itself. The case for pure science is crucial to the international perception of whether the ICGEB and its scientists have succeeded; that being so it will be prudent as well as proper for the ICGEB to establish a programme for molecular biology in the developing countries, which reaches many more scientists within the developing countries than can be accomodated on long term research fellowships at the ICGEB.

The situation of molecular biology in the universities of the developing countries is extremely poor and this is described by Riazuddin in an accompanying paper, yet at the same time faculty members in these institutions could become powerful allies of the ICGEB. Molecular biology is virtually absent from the biology curriculum in developing countries. A curriculum approved by the ICGEB could be drawn up, textbooks, journals and laboratory manuals recommended, external examiners appointed, and courses ratified. Many faculty members in developing countries have had good experience abroad but have not been able to institute courses perhaps because of entrenched traditional interests, lack of resources, lack of colleagues in related areas, lack of suitable preliminary courses and so forth. The ICGEB might be asked to participate in reviews of national capacities for teaching molecular biology, perhaps to advise on how resources should be allocated. It would seem appropriate for the ICGEB to collaborate with UNESCO in these endeavours. The object must be to ensure that many more students graduate with degrees in molecular biology which meet international standards.

In advising about molecular biology in the universities it is important to advocate that resources are concentrated in a small number of universities so that critical mass of suitably qualified staff can be achieved. " An essential pre-requisite for the successful application of modern biological technologies to the needs of development is the creation in developing countries themselves of integrated scientific and technological communities large enough to be effective" (Wu et al. 1981). This is crucial for the universities which have the responsibility of undergraduate education in molecular biology. About 20 faculty members are required to form a core group in molecular biology, although even at that number, it is necessary to be cautious about spreading the interests too widely across molecular biology. It should be agreed that a core group of this size should concentrate its research (though not necessarily its teaching) on a relatively narrowly defined topic, thereby making it easier to achieve an international reputation.

In implanting molecular biology at the universities, it must be accepted that faculty members are required and permitted to conduct research. Without research the teaching will not prosper. More than the formal permission, which is usual in the conditions of appointment of university staff, the permission must mean that the university will provide full facilities for doing research. Permission at most universities in developing countries is meaningless since they do not usually have suitable laboratories, equipment or money for support staff, consumables etc. Further, university research in molecular biology must be carried out with graduate students who submit theses for higher degrees. In many developing countries, universities have extensive postgraduate research programmes but these need to be extended to include molecular biology, and monitored to ensure that they meet international standards. The ICGEB could serve a most useful function in establishing a system of external examining of B.Sc., M.Sc. and Ph.D. degrees in molecular biology awarded in developing countries.

The appointment of staff in universities always poses problems. No country has the perfect answer but in many cases it has been found useful, if not essential, to enlist the help of university colleagues from other universities, perhaps located in other countries. The developing countries with small peer groups in molecular biology might value the institution of an international system organised by the ICGEB to provide external assessors for critical appointments. No doubt external assessors are used by developing countries but I suspect it would be useful to have a formal mechanism supervised by an international body dedicated to the developing countries and controlled by them. The ICGEB could also have a role in devising an international system to review national research proposals in molecular biology once again fulfilling an essential function which cannot be properly exercised when peer groups are small.

The peer group problem in developing countries has many consequences and it is useful to draw this out. Peer groups

everywhere tend to coalesce, cooperation growing at the expense of competition and criticism. There is the real danger of peer groups becoming cartels, which carve up funds, competing only with other cartels which operate in quite different fields and cannot be easily compared on scientific merit. Consequently political manoevering determines how the cartels do, and this becomes a time consuming activity for the main group of scientists in the country. Political institutions are much impressed by the number of conferences held, especially if these are international, and they are impressed by the foundation of national societies, or journals. Political figures and officials seem to appreciate journals, conferences about policy, especially multidisciplinary discussions. Committees, commissions and subcommissions, reports and reports about reports add up to a frenetic merry-go-round of non-science. This pattern is represented to some degree in every country but in developing countries it seems to be much more pronounced. The scarcity of resources and the poor organisation of distribution divert scientists from science to politics. It is important for the future of molecular biology in developing countries that this problem is recognised and minimised. International agencies have a role and responsibility in advising on this, perhaps in the formulation of reports similar to those produced by the OECD on science in member countries.

Scientists in developing countries are frequently isol[illegible] from the mainstream of science. The isolation will be reduc[illegible] if the scientists are formed into groups of critical mass but the conduct of modern science in every country depends on frequent visits to other laboratories and countries. As a country is smaller and more distant from the main centres of the US, Western Europe and Japan, it is even more important that visits abroad should be frequent. These occur but not sufficiently often - sabbattical leaves should be one year in four, and should be mandatory in new centres of excellence in molecular biology. It is urgently required that UNESCO and other organisations establish and expand fellowship programmes in molecular biology to facilitate this.

Scientists in developing countries frequently found journals where most of the results of local research are published. This is a very large enterprise in some developing countries and at face value may suggest that science is in a healthy state. These publishing enterprises deserve great respect but of the kind shown to Sisyphus, " son of Aeolus, who was punished by the underworld by having to roll uphill a huge rock which as soon as it reached the top always rolled down again." At the risk of offending many other national sensitivities outside the developing world, it is evident that there are few major journals of molecular biology published outside the United States or Western Europe. In Western Europe the main countries which contribute to the list are the Netherlands, Germany and the United Kingdom. Of course the list of countries from which the Editorial Boards are drawn is much wider, and includes many developing countries, but the overall

picture is that the journals with international reputations in molecular biology are produced and edited by the developed countries of the West. Scientists from developing countries are at a great disadvantage in dealing with this system. On the one hand the facilities for their science are not usually sufficient to carry out experiments which are routine in developed countries, which means that papers as submitted are judged to be incomplete. On the other hand they often do not have the benefit of personal contacts which help to establish credibility. Although it is clear that science from developing countries is not so easily published in international journals, the response of publishing their science in national journals has been counter-productive. There it is in effect lost, not being read, or given credence and not being cited. The ICGEB should found two new journals. One in applications of GEB and the other in molecular biology, with special emphasis on publishing results from developing countries and results which are related to them in these fields. These journals will have a similar role for the developing countries as the EMBO Journal has for Europe. The international credibility of the EMBO Journal was assured by the reputations of the Editors and the link with EMBO and EMBL. The ICGEB should be able to do the same for journals founded under its auspices.

There are now more than 100 universities and research institutes in North America, Western Europe, Japan, Australia and elsewhere with prominent research reputations in molecular bibiology, and some have close connections with developing countries. The goodwill of international science towards developing countries is reflected in the readiness to accept visiting researchers and students but much more could be done. Funding of exchanges is frequently difficult. There is a lack of continuity and too often the relationships are based on personal connections which are easily lost. There is a need for a wider use of institutional connections, for example, where a department or faculty in a developed country is twinned with a corresponding one in a developing country. Close connections of this kind have certainly benefitted universities in Thailand facilitating exchanges of staff and students, establishing confidence in standards and leading to joint research programmes. The ICGEB will have a network of affiliated institutions but it could have a much larger effect if it initiates and coordinates a much wider set of linkages between " third parties."

Finally, I want to draw attention to the interplay between science and politics which has pervaded the process by which the ICGEB has been founded and which will be a powerful factor in its future activities, as the axis of molecular biology in the developing world. The statutes were amended in Madrid to the effect that the Director must be a citizen of one of the member states. This is a regrettable imposition equivalent to having a rule that a head of a University or a Research Institute within a country must be a citizen of that country. If such rules exist and I am sure they do, they should not be emulated. Coming from a country which was colonised for 750 years and which has its own special cultural strengths and weaknesses, I find it easy to discern sentimentality in the developing world. It serves not the interests

of the people but merely the vanity of the diplomats and politicians to exclude from consideration for the Directorship the great majority of eminent molecular biologists.

I make this point, not because I believe that it is going to matter in the end, in that I am confident a good appointment will be made, but a great principle, the internationality of science, which the ICGEB seeks to take advantage of and to strengthen, has been challenged and I am concerned that this sort of action must be strongly resisted as the ICGEB begins to operate. It is easy to foresee the pressures which will arise for example in the appointment of other staff, representative of regions, countries and so forth and the Board composed of representatives from member nations must endeavour to resist and protect the ICGEB and the Director from these pressures. The statutes provide for a Council of Scientific Advisors of up to ten scientists and technologists. It will not be representative, except that members are to be elected by the Board " on a balanced geographical basis" and it has a function to advise the Director on the appointment of senior staff and other matters. It will act to some extent as a buffer against unwanted and unproductive political interference.

Having made these cautionary remarks, I am optimistic that the ICGEB will succeed in avoiding most excesses of political meddling. The reason for my optimism is that in the process of its foundat it has already experienced substantial political pressures and great majority of these have been accomodated in one way or another without damaging the main scheme. The intrinsic idea of the ICGEB, the strength of the underlying science and the international scientific community, the skills of the UNIDO Division for Industrial Studies and ultimately the wishes of the developing countries have carried it through. The evidence is that the ICGEB is a recipe for success. The antipathy between science and politics emerged with science at the Renaissance and it will not go away, but in this project many scientists, officials and politicians have worked together usually in agreement but often with obvious tensions and difficulties. Usually principles have been adhered to, the scientists staying out of the politics and the politicians respecting the scientists' views. It is quite remarkable that the ICGEB has been founded if anything on a grander scale than was hoped for while retaining the essential ideas of its proposers.

The omens are right for success. Now there is nothing for nations to gain by staying aloof from the ICGEB and a great deal to lose. At this symposium of the American Association for the Advancement of Science it is opportune to ask what the United States has to gain by eschewing success in international science. Owen Sheehy Skeffington, an educator, sadly little known outside Ireland and France, resigned once from an educational institution and regretted it all his life because it opened the way for others who were not so well qualified as he.

TABLE I.

RECOMMENDATIONS ON THE ESTABLISHMENT OF THE I.C.G.E.B.
(Heden et al. 1981)

(i) An International Centre for Genetic Engineering and Biotechnology (ICGEB) should be established on the lines suggested in the report.

(ii) U.N.I.D.O. should follow up its initiative, pursue the question of establishment of the Centre vigorously and continue to fully and actively associate itself in this activity.

(iii) It should continue to associate the leading experts in the field in the setting up of the Centre.

(iv) It should initiate further consultations with interested United Nations agencies such as FAO, UNESCO, UNU and WHO and other international organisations such as AMBO, EMBO, ICRO and IFIAS.

(v) It should mobilise resources to create a small unit with a full-time project co-ordinator who would pursue the several activities leading to the establishment of the Centre.

(vi) It should carry out negotiations with interested governments and convene a meeting of participating governments where they could announce their participation and financial contributions and formally establish the Centre.

TABLE II.

THE BELGRADE MEETING: CONCLUSIONS AND RECOMMENDATIONS (Part A) ON THE ESTABLISHMENT OF THE I.C.G.E.B.

(U.N.I.D.O./ID/WG.382/7)

(i) There is an urgent need for broader and more effective international co-operation in the field of genetic engineering and biotechnology.

(ii) International co-operation should be promoted in the first place for the benefit of the developing countries and for strengthening their scientific and technological capabilities and industrial development.

(iii) An International Centre for Genetic Engineering and Biotechnology of high excellence should be established soonest possible with activities covering, inter alia, training, research, application and information, etc., taking into account the proposals in the UNIDO documents on these subjects.

(iv) It is most desirable to set up such a Centre in a developing country provided that such a country can meet the conditions envisaged in the UNIDO reports and can provide an attractive environment for the scientists.

(v) Within the framework of the International Centre it is necessary to support activities of affiliated regional and/or national centres to be sited in different regions on a broad, geographical distribution. Financial support for these affiliated centres should be pursued through national and international financing schemes based on the advice of the ICGEB. Preparatory activities should be started as soon as possible to achieve this goal.

(vi) There should be an emphasis on lower operational costs and a minimisation of operational problems of the International Centre.

TABLE III.

THE BELGRADE MEETING: TERMS OF REFERENCE OF THE SELECTED COMMITTEE. (U.N.I.D.O./ID/WG.372/7.)

(a) The mandate of the Selected Committee is within the framework of the consensus reached in the meeting.

(b) The Selected Committee is required to seek additional information and examine in detail information from the host governments, UNIDO and other sources about the suitability and advisability of accepting the offers submitted.

(c) For this purpose, it will examine the details of the offers received in regard to:

(i) physical facilities, including the site and location;
(ii) scientific infrastructure and supporting services;
(iii) availability of scientific and technological and administrative personnel including language services;
(iv) finances and ability to attract membership and other sources of finances; and
(v) legal and other privileges to retain an international character.

(d) The Selected Committee will visit the countries to ascertain all the details in (c) above and to acquire first-hand information about the submitted offers.

(e) In order to assist the Ministerial-Level Plenipotentiary Meeting to reach a decision, the Selected Committee will offer a critical and objective analysis on the merits and demerits of each case. Therefore, the Selected Committee will be advisory in character to the Ministerial-Level Plenipotentiary Meeting.

TABLE IV.

SIGNATORS OF THE STATUTES OF THE I.C.G.E.B. AT MADRID.

(U.N.I.D.O. ID/WG.397/9)

At the ceremony for signing the Statutes plenipotentiaries from the following countries signed the Statutes:

Afghanistan	Algeria,
Argentina,	Bolivia,
Bulgaria,	Chile,
China,	Congo,
Cuba,	Ecuador,
Egypt,	Greece,
India,	Indonesia,
Italy,	Kuwait,
Mauritania,	Mexico,
Nigeria,	Spain,
Sudan,	Thailand,
Trinidad,	Tobago,
Yugoslavia,	Zaire,

TABLE V.

OBJECTIVES OF THE I.C.G.E.B. STATUTES AS ACCEPTED AT MADRID.

(U.N.I.D.O. / CRP.14 1983).

a) To promote international co-operation in developing and applying peaceful uses of genetic engineering and biotechnology, in particular for developing countries;

b) To assist developing countries in strengthening their scientific and technological capabilities in the field of genetic engineering and biotechnology;

c) To stimulate and assist activities at regional and national levels in the field of genetic engineering and biotechnology;

d) To develop and promote application of genetic engineering and biotechnology for solving problems of development, particularly in developing countries;

e) To serve as a forum of exchange of information, experience and know-how among scientists and technologists of Member-States;

f) To utilize the scientific and technological capabilities of developing and developed countries in the field of genetic engineering and biotechnology; and

g) To act as a focal point of a network of affiliated (regional, sub-regional and national) research and development centres.

TABLE VI.

FUNCTIONS OF THE I.C.G.E.B.

STATUTES AS ACCEPTED AT MADRID (U.N.I.D.O./CRP.14 1983).

(a) Carry out research and development including pilot-plant activities in the field of genetic engineering and biotechnology;

(b) Train at the Centre and arrange the training elsewhere of scientific and technological personnel, particularly from developing countries;

(c) Provide, upon request, advisory services to Members to develop their national technological capacity;

(d) Promote interaction between the scientific and technological communities of the Member States through programmes to enable visits of scientists and technologists to the Centre, and through programmes of associateship and other activities;

(e) Convene expert meetings to strengthen the activities of the Centre;

(f) Promote networks of national and international institutions as appropriate to facilitate activities such as joint research programmes, training, testing and sharing of results, pilot-plant activities, information and material exchange;

(g) Identify and promote without delay the initial network of highly qualified research centres to serve as Affiliated Centres, promote existing national, regional, sub-regional and international networks of laboratories, including those associated with the organizations mentioned in

TABLE VI (continued).

Article 15, active in or related to the field of genetic engineering and biotechnology to serve as Affiliated Networks, as well as promote the establishment of new highly qualified research centres.

(h) Carry out a programme of bio-informatics to support in particular research and development and application for the benefit of developing countries;

(i) Collect and disseminate information on fields of activities of concern to the Centre and the affiliated centres;

(j) Maintain close contacts with industry.

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