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Biotechnology in India - Activities in Agriculture

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Biotechnology, despite the fact that its definition remains variable, is an extremely popular subject. The Indian scientific community, behaving as every other international scientific community, is actively incorporating biotechnology into their research strategies. In an effort to assess this activity and develop appropriate activities for A.I.D. in this area, I have been visiting research institutes in India. This report summarizes the facilities and activities I have seen and contains suggestions and recommendations for US/AID's activities in this area. Although the research institutions visited conducted research on a broad range of activities with a wide range of applications, this report focuses on agriculture.

Presented here is an overview of the range, interest, and quality of Indian research in biotechnology and the potential for A.I.D. activity in this area. A total of 11 research institutes were visited. Details of each particular institute are presented in Appendix 1. (At the conclusion of my fellowship in S&T/Agr I submitted a general report on Biotechnology and A.I.D. This is attached as Appendix 2.)

The research institutions visited during this survey are listed below:

ICRISAT
Center for Cellular and Molecular Biology
Indo/American Seed Co.
Andhra Pradesh Agriculture University
National Veterinary Research Institute
Indian Institute of Science
Bose Research Institute
Department of Biotechnology
National Institute of Immunology
Molecular Biology Unit - JNU
Indian Agricultural Research Institute

1. Organization and Location of Indian Activity in Biotechnology

The government supported research activity in India is spread throughout numerous agencies. A list of these agencies (not necessarily complete) includes:

Oceanic Development
Atomic Energy
Indian Council for Medical Research
Indian Council for Agricultural Research
Education
Environment
Space
Electronics
Science and Technology
Biotechnology

Although each of these agencies has a different mandate, activities in each can be classified as biotechnology. This is due to the close relationship between basic and applied research which is inherent to biotechnology. Since molecular advances have the potential for being universal in their application basic work done in any of these areas may have applications to agriculture as well as medicine.

Private sector activity in biotechnology is not as as apparent as that in the public sector. The one private company visited (Indo/American Seed Co.) is planning an expansion which includes a large activity in tissue culture. Other Indian businesses which were mentioned with activity in biotechnology were the Hindusthan-Lever Corp. and the Tata company. Activities of Western industrial interests in Indian biotechnology also appear to be developing. A Swedish company, Astra, and Pharmicia are initiating activities in Hyderabad.

The beginning of some interaction between the adacemic research community and the private sector are also evident. A couple of institutions (Indian Institute for Science and Bose Institute) are receiving grants from Hindusthan Lever for specific research projects. The Indian Institute for Science has a consultancy office specifically for the purpose of addressing institute/industry matters and patents. The Center for Cellular and Molecular Biology is already involved with patent agreements with the Max Planck Institute in Germany and Medical Research Center (MRC) in England, while the National Institute for Immunology claims that it is already receiving royalties from a patent in the United States.

In discussing the possibility of increasing this interaction between the public and private sector most institutions mentioned the distance that exists between these two groups within India. In general there is a willingness to experiment in this area. The question is who will make the first step. One of the most interesting comments made on this subject suggests an important role A.I.D. may want to play. Indian scientists would be interested in such interactions with the private sector but there are no models in India for such activity.

Department of Biotechnology

The government of India, in response to the potential and activity in biotechnology has established a separate department - previously biotechnology was the concern of an office within the Department of Science and Technology. In February 1986 this office was broken out from DST and Dr. Ramchandran was appointed secretary.

The Department of Biotechnology is the nodal agecny for all activity in biotechnology - private and public. The department is designing a number of programs and identifying thrust areas. (These are outlined in my previous report to the mission - March 86).

During this visit to the Department of Biotechnology I visited with Dr. S.C. Jain, Jt. Secretary and Dr. Aggarwal, Principal Officer. The department is continuing to develop programs and build its staff - which is to be composed primarily of scientists. The deparment is to provide technical expertise on a wide range of questions which are likely to arise including: the issue of the patentability of certain research products, the development of appropriate regulations (both in the laboratory and for field testing), and the involvement of private sector in public research activities. The Department is presently organizing (with the Science Office) a trip for Indian private sector representatives to the U.S. to visit American biotechnology companies.

Indian scientists throughout the country seem optimistic about the establishment of the Department of Biotechnology. It is generally viewed as progressive with the potential for overcoming some of the delays encountered with other departments. One criticism which was voiced about the new department is that it appears to be focusing on glamorous aspects of biotechnology, e.g. genetic engineering, to the detriment of the more basic and applied approaches.

The extremely broad mandate of the department, the large amount of activity in the area and the proposed small staff may make the Department of Biotechnology's tasks very difficult. Clearly the most critical function of this department will be the coordination of activities in this area. To be successful it will be necessary for the Department of Biotechnology to interact effectively with numerous other agencies (i.e. Agriculture, Health). The department is too new to have established such coordination yet.

1.Areas of Interest in India-in Biotechnology

Tissue culture - In agricultural biotechnology the area which is of greatest interest is plant tissue culture. Its popularity is due to the central role it plays in addressing numerous plant questions. Micropropagation can be used to speed production, screen for stress tolerance and disease resistance; embryo rescue and haploid culturing allows the crossing of distant otherwise incompatible lines. Looking to the future, tissue culture techniques are critical to any plans for genetic engineering of plants. An additional attraction of working in plant tissue culture is that getting started in this area is not extremely expensive.

Every institute visited, with the exception of the National Institute for Immunology and the Indian Veterinary Research Insitute, is carrying on active tissue culture work. The Indo-American Seed Company is also moving into the area with its new expansion plans.

The crops studied in these institutions include sandalwood, rosewood, eucalyptus, papaya, teak, sugar beet, rice, jute, chickpea, pigeonpea and groundnut. These crops and some of the research goals are discussed in Section 4 and Appendix 1.

Immunodiagnostics - The activity in this area is more limited than in tissue culture. The largest effort is being carried out at the National Institute for Immunology which has identified Immunodiagnostics as one of its priotity areas. The NII is working on diagnostics for both human and animal diseases. The animal diseases which are currently under study are rabies, tuberculosis, and brucellosis.

Research on plant viruses is being conducted at the Indian Institute of Science. This research is basic in nature - characterization of the virus. However the scientist involved hopes to eventually use the technology and expertise being developed to pursue diagnostic applications.

Additionally at the Indian Institute of Science work is being done on diagnostics for human health problems - specifically malaria and diarrehael diseases. The malaria work is being done with the Swedish company Astra.

Embryo transfer/Animal vaccines - The only institutes visited during this survey which are working in these areas are the National Institute for Immunology and the Indian Veterinary Research Institute. The NII has identified embryo biotechnology as another of their priority areas. The group is newly established and settling into their new facility. The laboratory is quite impressive with the latest equipment. The group claims to have already performed some embryo transfers. The visit to the Veterinary Research Institute was unfortunately limited in scope. The group is doing some recombinant DNA work on Foot and Mouth disease in collaboration with the Indian Insitute for Science.

Plant Genetic Engineering - The sophistication and difficulty of this work limits its present applicability. However due to the potential it offers most groups are attempting to establish some of the fundamentals in this area - to be prepared when the time is right. The institutes which are furthest along in this area are those whose mandate is basic research.

For example one group at the Bose Institute is working on the identifcation of important genes for disease resistance. Another group there is studying the Ri plasmid of agrobacteria to determine its usefulness as a vector for plant engineering. Likewise the Indian Institute of Science is also active in this area studying the relationship of increased proline levels to drought tolerance - with the hope of identifying the important genes.

Of special interest is the activity in Indian Agricutural Research Institute. A new biotechnology group has been established there, drawing on the personnel from numerous other departments. The group is small - 14 people, so far no new personnel have been employed. They have identified two areas of importance in the area of genetic engineering - improvement of the storage protein in chickpea and disease resistance in chickpea. These efforts are just beginning. However the efforts in chickpea are coordinated with the tissue culture activities in chickpea within the same group. (The focus and organization of this group has developed significantly or has become much more apparent since I last visted with them in March 1986.)

3.Quality of Indian Research in Biotechnology

The quality of the researh facilities visited covered the entire range - depending largely on the age and the mandate of the institution. The Center for Cellular and Molecular Biology (CCMB) is a brand new multi-million dollar research center whose mandate is pure basic research. Research topics are determined based on the identification and recruitment of reknown scientists. Groups are established around the interests and expertise of independent scientists, with some consideration given to coordination with established groups.

Another state of the art research facility is the National Institute for Immunology, located in New Delhi. This institute was inaugurated in Fall 1985. Its mandate is the investigation of basic and applied immunological questions of importance to India. The priority areas which the institute has identified are as follows human birth control, using contraceptive immunology; immunodiagnostics, for both human and animal diseases; and animal embryo biotehcnology. The staff is still being developed but it is of interest to note that I spoke with one scientist, an electron microscopist, who returned to India to work at this center after spending nine years doing research in the West (4 years - Paris, 5 years - UCLA).

On the other end of the spectra are the State Agricultural Universities whose mandate is much more applied in nature -- basic research in these institutions has been limited. Biotechnology, in certain areas, has closed the gap between basic and applied research and apparently (based on the one state university visited) the State Agricultural Universities are attempting to incorporate whatever techniques are useful into their programs.

Andhra Pradesh Agricultural University is making an effort to begin tissue culture work. They have a small, poorly equipped facility. (Most of the equipment was purchased 20 years ago with A.I.D. funding.) However, the work is slowly proceeding on micropropagation of roses and embryo culture of chickpea and pigeonpea. This group consists of a young associate professor and two graduate students. They have submitted grant proposals to the Department of Biotechnology and FERRO to expand their work in tissue culture.

In between these two extremes fall such institutes as the Indian Institute of Science and the Bose Institute. Both of these institutes are fairly academic and basic in nature. They have been the sites of solid basic research over the years so it is only natural that the newer methods used in biotechnology have been incorporated into their work. These laboratories are old but adequately equipped and expanding and staffed by very experienced scientists.

The enthusiasm and expertise of the scientists I met was quite impressive. Most are mid-level or senior scientists. Almost everyone of them had spent some time studying or working in the West. The discussions were typically energetic, but this did not always carry over to the lab activity. Usually the laboratories appeared quite empty - with minimal activity. This is not surprizing as many of the laboratories visited are basic research efforts consisting of very small groups (3 - 5 people). Another factor in the area of activity and therefore productivity is the postdoc situation in India. Repeatedly it was mentioned that the postdoc population is extremely low - the postdoc system is not working here. The lure of an experience in the West with both the scientific and economic benefits pulls postdoctoral scientists away from India during their most productive years.

There are some exceptions to this observation of limited activity. These exceptions are the result of the individual style, initiative of the principal investigator, and his ability to attract funds to maintain postdocs. Dr. S.K. Sen of the Bose Insitute has a tissue culture group of 33 people. He has approximately 9 postdocs - two are his own former students whom he has managed to keep with him. Dr. Sen is also the scientist at the Bose Institute who is receiving support from Hindusthan Lever.

Additionally Dr. H.K.Das, Molecular Biology Unit, JNU has an active research group, consisting of approximately 15 people. Dr. Das is a participant in the STI program. Through that program he has been able to send two postdocs over to the United States for limited research visits. He has also hosted two American postdocs in his laboratory here in Delhi and will be hosting another two this year.

The laboratories at the National Institute of Immunology which were occupied also were quite active.

4. Important Areas for Indian Agriculture

The Indian research/agricultural community have been and are in the process of identifying priority research areas in biotechnology. The most recent effort in this direction was a workshop held in March by IARI. The theme of the workshop was tissue culture and participants included Indian scientists with expertise in plant breeding, genetics, and tissue culture. This group discussed three broad priority areas - cereals, legumes, and oil seeds. Adding animal health/production to this list just about completes the important agricultural areas where biotechnology may have a significant impact.

Legumes - Legumes serve as the major source of protein in India. The majority of the Indian farmers are small farmers unwilling to utilize complicated and expensive innovations. The soil in many areas is becoming more saline due to mismangement. The quantity of marginal lands is increasing as farmers move on rather than experiment with new methods. Seeds for improved varieties is the best product for increased and improved production for the small farmer. Any improvement in the protein content, stress tolerance, or disease resistance of legumes would therefore have a major effect.

The legumes of importance in India include chickpea, pigeonpea, and mung bean. Tissue culture techniques are already underway or starting in a number of areas. Legumes are not easily tackled with tissue culture due to the production of phenols. Progress has been made in some systems e.g. soybeans so the future is hopeful.

Cereals - Rice and wheat are major food staples in the Indian diet. For the same reasons as stated above for legumes any improvement in the indigenous rice strains which would increase plant survival on marginal lands and increase production will have a major impact. There is large amount of activity on the Indian rice indicus. Most of the work in the past has been with japonicum which is not grown in India.

Oil Seed Production - The shortage of cooking oil in India and the resulting dependence on imported oil have made the research in oil producing crops extremely popular. Most institutions visited have ongoing projects or have submitted research proposals in this area.

At the Bhaba Atomic Research Center (BARC - visited in March) the GOI is supporting a project on the micropropagation of oil plam - the goal is to produce one million trees by 1990. The work is proceeding, but very slowly.

Other projects are in varying stages of development working with Brassica. The general aim is to improve the oil produced from indigenous crops through tissue culture. The techniques being used include microspore generation, generating alien chromosomne substitution, and somaclonal variation.

Animal health/production - India depends to a large extent on its animal population for work power, meat and milk. The techniques discussed at the two insitutions which were conducting research in animal science could play a major role in increasing the general health and production of an animal. These techniques are embryo transfer and immunodiagnostics. The development of new or improved animal vaccines was not discussed in detail at either institution. However this too is an area of opportunity in biotechnology. A more extensive survey of the animal side of the the Indian activities is necessary to determine exactly what the priority diseases would be.

Areas for Future Indo/US Collaboration in Biotech Research

In summary the Indian research community is actively incorporating biotechnology into all aspects of its research programs. As in all countries the activities in basic and applied research range from poor to excellent. Efforts are being made to identify research priorities important for individual institutions and national problems. Government agencies are beginning to talk about defining regulations and protocols for the potential new products. What is happening in India is really no different from what is happening in the rest of the scientific world. Everyone is rallying around biotechnology as a means of stimulating research, attracting funds, and generating new products.

However the Indian scientific community does differ from those in the West. India has developed an extensive infrastructure and foundation in basic scientific research but what is missing (although it is developing now) is the momentum and synergism which allows technology to flourish under its own power. There are a number of reasons for this problem: inconsistent short term funding; the failure of the postdoc system, resulting in the constant need to start from scratch training a graduate student and losing the most productive research years immediately following completion of the doctorate; reward systems which maintain a status quo rather than encouraging risks; extreme isolation between research sectors - between different types of academic insitutions as well as between the academic and the industrial world; the lack of mobility of scientists to move from one type of institution to the other. These are problem areas where A.I.D. and the experience of the American research community may be able to provide some substantial assistance.

The three most important types of activities for A.I.D. in biotechnology in India are the following:

The establishment and support of long term collaborative (India scientist/U.S scientist) research projects

The establishment and support of linkages between the various parts of the Indian research community through workshops where exchange of interests and information could be facilitated and specific areas of need identified.

The development of a useful model for India for a collaborative effort between the public sector and the private sector

Long Term Collaborative Research Projects

The establishment of long term collaborative research projects would be useful for a number of reasons. For many Indian laboratories equipment, although always needed, is as at an adequate level. What is needed is some continuity in personnel support and research direction. Through long term collaboration these could be provided.

Additionally long term research collaborations would serve as a vehicle for allowing Indian postdocs to have their experience in the West while still contributing to the advancement of science in India. Postdocs would not be free floating agents, but rather tied into ongoing research effort of mutual interest.

The succes of the project would depend largely on the interaction of the two groups involved, requiring similar interests and related or balanced levels of expertise. Certain technologies are more likely to be avaiable in the United States. This type of collaborative effort will facilitate the rapid exchange of such technology.

Awarding these grants should be a highly competitive process subject to peer review. The program should be run on a limited basis - perhaps 3 -5 grants in the first year as the selection process would be quite elaborate involving possibly preposals, visits of collaborating scientists and peer review. Such a process is required to ensure that the groups are well matched and that the project will be as collaborative in nature as possible.

Improved Linkages within the Indian Scientific Community

The various elements of a functioning scientific community are all present in India - of course some are more developed than others. However the interaction between these groups is very low. On more than one occasion during this survey one group's needs and interests would fit perfectly with some other group. Unfortunately they were not talking to each other.

A useful approach to overcoming this problem are workshops on specific subject areas which cut across institutional barriers. IARI in the report on their Tissue Culture meeting in March 1986 pointed out the need for the groups which attended that meeting (breeders, geneticists, tissue culture specialists) to contiune to interact. The report suggested that the groups meet again gathering together based on their crop of interest.

Such a mechanism would be useful to bring in representatives from the State Agricultural universities, the old research universities, the new state of the art centers and the private sector. At such a meeting common problems and needs could be discussed. Perhaps very particular needs could be discussed and solutions found either within the resources of the participants or through some limited A.I.D. funding. For example, the identification of a young assistant professor in the State university system who needs some limited aid to upgrade his program could be identified. Likewise the specific needs of a private company may become obvious and solutions found within the academic world. Such possibilities cannot be explored until these different groups sit down and talk to each other.

Development of a Useful Model for India for Collaborative Public/Private Efforts

There is a great deal of discussion of the need for involvement of the private sector in research and commercialization in Biotechnology. In India the public and private sector are very far apart. Discussions indicate that both sides are aware of the need for the other but it is the method of getting together that is elusive.

In supporting the development of a model or prototype A.I.D. would be helping in that first difficult step. A program could be set up requesting Indian companies and research institutions to submit preproposals or outlines on what they would consider the advantages and the disadvantages of such a collaboration. How would such a collaboration be structured? Once this information was obtained from the Indian community, the American scientific community (public and private) could participate with advice and suggestions based on their experience. Final proposals would then be a synthesis based on the unique aspects of the Indian scientific and business sectors and the U.S. experience.

A common quality shared by the programs suggested above is the well tailored aspect of the final product. The stage of development in India requires such fine tuning. Generation of such intangibles as momentum and syngerism requires a very precise fit and the cues should come from the Indian community.

A.I.D. can and should work closely with the Indian and American scientific community to develop such finely tuned programs. Additionally A.I.D. should work closely with other U.S. assitance efforts - Science Office and FERRO. Both of these offices have strong interests in Biotechnology and are developing specific activities. Likewise the interests and activities of American scientific institutions such as the National Science Foundation and the National Academy of Science should be coordinated. The activities of AID/Washington in this area should also be drawn upon.

APPENDIX 1

Institute	**ICRISAT - Hyderabad**
Contacts	**Dr. Phil Moss - groundnut group** **Dr. Jan DeWet - Leader Cereal Program**
Agency (core support)	CGIAR
Additional support	Numerous granting agencies, some limited industrial support
Degrees granted/ training provided	None
Research/organization	Number of programs at the center - e.g. Legume program, Cereal program. ICRISAT is using biotechnology in some of its ongoing research - specifically tissue culture and a diagnostic application for a peanut virus. The center is considering expanding its tissue culture facility and is currently looking for funds. Dr. DeWet is the chairman of ICRISAT's Biotechnology committee and has a cautious attitude about investing in Biotechnology.

Institute	**Andhra Pradesh Agriculture University, Rajendranagar, Hyderabad**
Contact	Dr. Appa Rao - Vice Chancellor Dr. C.S. Reddy - Dept. of Genetics & Plant Breeding
Agency (core support)	State
Additional support	Grant from ICAR. Grant submitted to the Department of S&T - coconut/oil palm. Grant submitted to FERRO.
Degrees granted/ training provided	B.Sc., M.Sc., Ph.D. (have a one semester course in tissue culture)
Research/organization	Numerous departments Tissue Culture : 1) Micropropagation of roses (used for developing the technology and commerical importance) 2) Production of haploids in rice (shorten the breeding cycle) 3) Embryo rescue in chicknea & pigeonpea (facilitate distant crosses) Rhizobium Work: Identification of useful indigenous strains for groundnut - some collaboration with ICRISAT - informal collaboration with IARI

Institute	**Center for Cellular and Molecular Biology (CCMB) Hyderabad**
Contact	Dr. P.M. Bhargava - Director
Agency (core support)	Council of Scientific & Industrial Research (CSIR)
Additional support	Dept. of Biotechnology is setting up one of the Bio inFormatics centers here. Institute of institute agreements with Max Planek Institute, MRC-, NIH
Degrees granted/ training provided	Grant Ph.D. through JNU. Other training provided is limited - real emphasis as a research institute.
Research/organization	New Facility eventually 20 research groups; to date 12 are established research topics include: - Protein phosphorylation at tyrosine residues in normal cells. - Cell lineage analysis in mammalian embryonic development - Chemical Synthesis of deoxyribo and ribo-oligonucleotides

Institute	**Indo-American Seed Co. Bangalore**
Contact	Mr. Manmohan Attavar - Director
Agency (core support)	Private company
Training provided	Do some contract work with farmers
Research/organization	Interested predominantly in hybrid seeds for exports. - Close ties with the U.S. - Expanding into tissue culture - (hope to start summer 87) micropropagation - foliage plants, ornamentals

Institute	**National Veterinary Research Institute, Bangalore**
Contact	Dr. B.U. Rao - Joint Director cum Officer-in-charge
Agency (core support)	Indian Council of Agricultural Research (ICAR)
Additional support	
Degrees granted/ training provided	
Research/organization	- Work on Foot and Mouth Disease (recombinant work in collaboration with indian Institute of Science) - Work on emerging health problems e.g. blue tongue, sinal tumors, brucellosis (received 1985 annual progress report)

*Note: This meeting was very limited. There was no tour of the facilities and Dr. Rao would not discuss specific topics.

Institute	Indian Institute of Science, Bangalore
Contact	Dr. Vaidyanathan - Division of Molecular Biology, Department of Biochemistry Dr. G. Padmanaban - Biotechnology Dr. N. Appaji Rao - Enzymology/Human Genetics Dr. Sankara Rao - Tissue Culture Dr. R. Venkateswara (graduate student finishing up) - Tissue Culture Dr. H.S. Savithri - Plant Virology Dr. G. Lakshmi Sita - Tissue Culture
Agency (core support)	Education - University Grants Commission
Additional support	ICAR, FERRO, Hindustan Lever, Dept. of S&T
Degrees granted/ training provided	Ph.D. - undergraduate training not provided; entering students required to have MSc.
Research/organization	Plant Tissue Culture - micropropagation - sandalwood, rosewood, eucalyptus, - also disease resistance to spike disease - sandalwood Role of proline in drought tolerance - mechanisms of enzymes involved starting molecular biology Cloning of histone genes from rice - to study genome structure Regulation of asparate transcarbamylase - role in water stress

Institute	**Bose Institute, Calcutta**
Contact	**Dr. B.B. Biswas - Director** **Dr. R.K. Mandal - Dept. of Biochemistry** Dr. S. Gosh - Dept. of Biochemistry Dr. A. Banerjee - Dept. of Biophysics Dr. S.K. Sen - Tissue Culture Dr. Anita Pal - Tissue Culture Dr. B. Majumdar - Botany Dr. S.N. Ganguly - Botany
Agency (core support)	Independent institution originally Presently Department of S&T
Additional support	CSIR, ICAR, Hindustan Lever, National Petroleum Industry
Degrees granted/ training provided	Ph.D. through JNU, Calcutta University petitioning to grant their own - workshops - practical - molecular biology 2-3 weeks long; 15 participants
Research/organization	Broad range of research topics Plant Chemistry/Botany - isolation of pharmaceutically active products. - production of oil by yeast - investigation of cellular senescience, seed viability (wheat) - isolation of plant growth regulators Tissue Culture - two isolated groups
1) Older group - Breeders/Tissue Culture	- Micropropagation papaya, teak - tobacco model to develop viral propagation system - sugar beet - crossing to obtain annual flowering and increased sugar content - rice - identify salt tolerance

2) New group

- Investigation of Ri plasmid as a vector and growth regulator
- use of bacillus thurengensis in control of stem borer
- oil seed - develop lines with desirable traits from indigenous strain - interspecific
- rice - production of haploid plants
- jute - interspecific work to develop desirable traits - protoplast fusion.

Biochemistry

- basic studies of azosperillum
- use of plant tubulin genes in targeting herbicibe specificity
- improvement of protein content in rice/mung bean storage protein (work proposed)

Institute	National Institute of Immunology, New Delhi
Contact	Dr. Talwar - Director
Agency (core support)	Department of Science and Technology (Biotechnology)
Additional support	UNDP, IDRC, AID, Rockefeller
Degrees granted/ training provided	Ph.D. through JNU UNESCO course - Gene Cloning Dept. of Biotech courses - enzyme immuno assays
Research/organization	New Facility Three target areas: - animal embryo biotechnology - immuno diagnostics - human birth control - contraceptive immunology Eventual size - 150 scientists

Institute	**Indian Agricultural Research Institute, New Delhi**
Contact	Dr. S. Kumar - Dept. Biotechnology Dr. N. Gupta - Dept. Biotech/Tissue Culture Dr. S.K. Raina - Dept. Biotech/Tissue Culture Dr. K.R. Kandel - Dept. Biotech/Plant Genome Organization
Agency (core support)	Indian Council of Agricultural Research (ICAR)
Additional support	
Degrees granted/ training provided	M.Sc. - Molecular Biology/Biotech started 10 students. Ph.D. - Molecular Biology/Biotech - to start 9/87.
Research/organization	New Department - (Work starting on chickpea) Three areas: 1) Cell and Tissue culture - rice - Dr. Raina - another culture, soma clonal variation - chickpea - Dr. Gupta - cold resistance resistance to fungal disease salt tolerance 2) Plant Genome Organization - concentre on chickpea - improve quality of storage seed protein - disease resistance 3) Plant microbe interaction - BNF work rectors - agrobacterium

APPENDIX 2

Kerri-Ann Jones
Final Report - AAAS Fellowship Year
October 31, 1986

As a AAAS Science, Engineering and Diplomacy Fellow I have spent the past year working in the Office of Agriculture, Bureau for Science and Technology. My work and activities focused on the area of biotechnology, which provided me with an extremely interesting and active year. I have divided this report into two sections - the first section contains a general description of my activities this year and the second section contains my observations and recommendations on A.I.D. and biotechnology

Before reporting on my observations and activities, I would like to thank all of the people at A.I.D. with whom I have worked. Under varying circumstances and pressures, I have consistently received friendship, support, information, and advice from my co-workers.

I Activities

In the office of Agriculture I worked most directly with Dr. Lloyd Frederick, Senior Soil Microbiologist. I participated in the management and backstopping of several ongoing projects. These included: Indo-U.S. Science and Technology Initiative (STI), Nitrogen Fixation in Tropical Agricutural Legumes (NiFTAL), Tissue Culture for Crop Production (TCCP), and Factors Limiting Biological Nitrogen Fixation. My activities also included backstopping a number of projects from the Science Advisor's Office. My responsibilities on these projects included responding to correspondence and day to day problems, reviewing grants and submitted proposals or agreements. I also participated in a workshop to design a molecular biology project supported under the Limiting Factors project and visited both NiFTAL and TCCP.

Additionally in the Office of Agriculture I participated in the development of the Animal Vaccines Project designed to develop an improved vaccine for rinderpest, through genetic engineering of vaccinia virus. The project paper was developed for this project based on a proposal submitted by the University of California at Davis. The project was approved and funding commenced on Sept. 1, 1986. I was involved with this project development from beginning to end, including discussions with the regional bureaus. Currently an extension of the Animal Vaccine project is being developed. I am participating in the review of this extension.

The Animal Vaccine project was an outgrowth of a larger proposed umbrella project in biotechnology. During the early months of my fellowship I worked on writing the project identification document for this umbrella project. This project consisted of the following components: animal vaccines, biocontrol of plant diseases and pests, and the three ongoing biotechnology projects in the Office of Agriculture (NiFTAL, TCCP, and Limiting Factors.)

As an agency resource person in the area of biotechnology, my activities and assignments extended to other A.I.D. offices. These offices and the assignments included: Dr. Brady's Office (working on an article and a speech), Technical Resources Office/Asian Near East Bureau (during my travel assessing missions' interest in Biotechnology; presenting a seminar for the India mission; participating in meetings at the regional bureau where biotechnology was discussed), Science Advisor's Office (participated in the preproposal reviews and panel reviews); General Counsel Office (development of environmental statement for the Animal Vaccine project); and discussions with the Bureau for Private Enterprise.

Given that biotechnology is presently such an active area I also maintained contact with other agencies involved in this area. These agencies include: National Science Foundation, the National Academy of Sciences, USDA/OICD and the Office of Technology Assessment. For the Office of Technology Assessment I prepared a summary sheet on A.I.D.'s activities in biotechnology and the level of funding involved.

In September my fellowship was extended to work with the Science Advisor's Office to develop guidelines for the incoming AAAS Science fellows. There are 10 fellows this year. On Sept. 17, 1986 we held a workshop and reviewed these guidelines with the new fellows. Also during this extension, I participated in a project review with Office of Health. The project is a research program to identify some of the important antigens on the malaria parasite which would be useful in vaccine development.

This broad range of activities provided me with a rewarding and enjoyable year. I have been able to learn a great deal about A.I.D., about science and development, and about government policy and science.

II Observations

Biotechnology is an area which is receiving worldwide attention. It is a very difficult area to define and this is a major problem and source of confusion. At A.I.D. a broad defintion of biotechnology is used. Biotechnology is defined basically as the use of the biological sciences to generate a product. This definition therefore includes research ranging from the collection of improved strains of rhizobium for biological nitrogen fixation to the use of genetic engineering to develop improved animal vaccines.

Biotechnolgy offers great potential for addressing problems which have previously been unapproachable - problems in both the developed and the developing world. Applications in the developed world are advancing - there are markets, interested investors and the infrastructure to support these new activities. However the actual number of products, in the market in the developed world which are a result of the new biotechnology, is surprizingly low. There are two factors responsible for this apparently slow progress.

First, biotechnology is an area which is composed to a large extent of basic research, in a number of fields, and this is a slow going process. Our capability to work at the molecular level has not overcome the necessity of addressing all of specifics unique to each problem. For example, when a microorganism has been engineered to produce the appropriate protein, there is still the next level of research to ensure that a successful scaling up and purification procedure exists. It is often assumed and discussed as if the desired products are right around the corner, ie. all that is needed is the scientist, the lab, and the financial support. This is not the case. The research must also be done and this takes time.

This is observation is stated in an efffort to remain realistic about biotechnology, neither negative nor pessimistic. Biotechnology is exciting because it allows us to approach these questions and get the work done. Before these new techniques developed it was impossible to attempt solving these problems -- we didn't know where or how to start.

The potential biotechnology holds is overwhelming. It has aroused the concern and interest of many diverse groups, which is critical for the successful use and understanding of the new technologies. However the necessary discussions that have arisen due to this interest and concern, have also lead to many delays. One of the results is that the current regulatory and legal situation is certainly the second issue responsible for slow progress.

The United States is considered the leader in biotechnology and yet we do not currently have in place a regulatory scheme for the use of these new products. Questions of what should be regulated, who will regulate and who owns these products are still the subject of intense discussion. An equally difficult question is what will be the source for the personnel and the funding needed to perform these regulatory duties ?

The situation in reference to biotechnology is complex and far fror clear in the developed world. When one moves to the developing world the same issues must be addressed in addition to an entirely new set of conditions unique to the developing world. What should A.I.D.'s role specifically the Bureau for Science and Technology, be in tne use of biotechnolgy in the development ?

Basic research has been identified by A.I.D. in "The Strategic Plan of the Agency for International Development" as an important component of development strategy. Biotechnology is simply a subset of any current biological research program and so it is just one of the tools important in a development strategy. The high technology and complexity of biotechnology are not adequate reasons to overlook its potential in solving some of the more difficult problems confronting the developing world. Biotechnology is really not new. It just happens to be the term used for the most recent collection of new technologies and capabilities in biological research.

Biotechnology is clearly one of the popular topics today. Three to five years from now another catch-all phrase may be vogue. However, what is not going to change is the critical role that research and technology play in development. The primary role of A.I.D. should be to ensure that the use of biotechnology is well thought out.

III. Recommendations

My recommendations for A.I.D.'s activity in the area of biotechnology are presented below. These are extremely general recommendations. However they are also very important ones if A.I.D. is going to maintain a consistent and credible effort in biotechnology. Due to the nature of biotechnology itself, these suggestions are not as obvious and straightforward as they sound.

1. A.I.D. must be well informed - what's going on in the universities, what's going on in industry, and what's going on in the regulatory arena?

The expanding and phenomenal amount of activity in this area makes it a genuine challenge to remain up to date. For example, it is likely that every state in the United States will soon have some kind of research center focusing on biotechnology - bringing together resources from the state government, the state industry, and universities. The activity in the LDCs is also expanding as these countries attempt to build their research capacity, protect their unique germplasm resources, and develop products which will be attractive to industry.

It is highly unlikely that there will be sufficient funds to support all of the proposed activity in biotechnology. State centers, small companies and others are already searching for alternative funding sources. It is at this juncture that A.I.D.'s knowledge of biotechnology activities becomes critical. For A.I.D. to use its own limited funds most effectively it must tie in to the most appropriate research community available. In the area of biotechnology this clearly extends beyond the traditional agricultural colleges.

2. A.I.D. must work with developing countries to define what is appropriate research and technology.

By staying well informed and connected with the scientific community in the developed world and building on its broad based knowledge and experience in the developing world A.I.D. is in a unique postion to carry out this task.

3. **A.I.D. must work on the coordination of efforts in the area of biotechnology.**

There is a good deal of activity and interest in biotechnology occuring in the LDCs. It is often difficult for the regional bureaus and the missions to be up to date on all of this activity. S&T could and should assume an essential role in this area. In my limited travel this year to Thailand and India it was obvious that collection and consolidation of this information would be valuable. Of course, India and Thailand are more the exceptions then the rule for activity in biotechnology. However, a number of other developing countries are establishing centers and even in countries where such activity is not yet possible, the proposed products will play an important role.

Some missions, for example Zimbabwe, are identifying and using consultants to fill this need. Obviously, S&T/Agr cannot serve each mission individually in this area but a central coordinated collection of the available information and activity in biotechnology would be worthwhile. Such an effort would be useful for three reasons: to avoid a duplication of efforts, to improve any research effort by providing additional information, and to accurately relay research conditions to U.S industry in order to develop well tuned and realistic programs.

4. A.I.D. must begin to creatively approach its biotechnology research programs.

Industry, both U.S. and LDC, must play a larger role in these programs. At the present time, A.I.D.'s structured programs and procedures discourage industrial participation. (I base this comment on a number of discussions I have had with industrial representatives.) A.I.D. should work with industry to design new approaches and projects which would combine the needs and capabilities of the LDCs, the research possibilities, and industrial interests. To do this A.I.D. must be fully cognizant of the research interests and capabilities in the LDCs in the area of biotechnology.

Creative approaches combining small research teams with industrial interests are needed. It is apparent at this point in the U.S. biotechnology arena that academia and business are joining together in creative collaborations to set priorities and move products out of the laboratory and into the market. The skills and the amount of work required for this process require such collaborations.

In conclusion, it is time for A.I.D. to take a leadership position in biotechnology and its role in development. A.I.D. can do this by becoming better informed, acting as a leader in coordinating the sundry activities that are going on, drawing on its experience in the developing world to aid in the identification of appropriate research, and creatively designing new project approaches which will attract private industry. It is not a matter of deciding whether or not biotechnology is a useful approach. Rather it is a question of getting some control over the activities that already well underway and behaving as a leader.

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