Government funding and support—the Department of Biotechnology

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Attention and resources have been focused on creating facilities, training scientists and technicians, and research and applications in birth-control vaccines, vaccines against diseases, immunodiagnostics, animal husbandry and plant breeding.

Work on different aspects of biotechnology has been done in various institutions in the country over the last couple of decades. The importance of biotechnology, however, greatly increased in the mid-seventies with the possibility of changing the activities of life forms through recombinant-DNA techniques and the use of biotechnology for human welfare becoming more and more possible and assuming far greater urgency. The Government of India took note of these developments and set up an interagency body, the National Biotechnology Board (NBTB), in early 1982. The Department of Science and Technology (DST) provided the secretarial services. Within the next few years it was felt that an independent department in the government was necessary, not only as a focal point for the various new programmes in biotechnology that could be taken up in the light of recent discoveries but also as a forum where the programmes and problems of institutions engaged in this field could be discussed and a direction given to the different programmes in biotechnology in the country.

Immediate objectives

The two areas on which the new Department of Biotechnology (DBT) initially concentrated, in continuation of the earlier emphasis by NBTB, were manpower development and creation and strengthening of infrastructural facilities. The objective was to build up trained manpower and general competence in the field of biotechnology. This made creation and strengthening of infrastructural facilities essential, so that scientists could pursue teaching and research careers. Core research groups were also set up, with grants for pursuing various areas of importance. Specialized major equipment and basic utilities like cold rooms were also set up to help the process. A beginning was made in the area of informatics by setting up Distributed Information Centres (DICs) and user centres in various institutions in the country, with links among the DICs themselves and with the central information network in DBT in New Delhi, which would also have access to international databases in biotechnology. DBT is also trying to remove some irritants standing in the way of research and training. One such problem, which has persistently defied attempts at a solution, is the import of highly perishable consumables for laboratory work. A pass-book system has now made it easier for teaching and research institutions to import consumables and equipment up to a certain value. This has, to some extent, eased the situation regarding timely availability of consumables. Steps were also initiated for production of consumables through the Centre for Biochemicals of the Council of Scientific and Industrial Research (CSIR) in Delhi. This centre has also been entrusted with the task of importing consumables in bulk on behalf of various indenting institutions in the country. [See also page 535 and advertisement, back cover, for information on a private venture]

There are now at least 30 institutions in the country, where, as a result of the initiatives taken by DBT in collaboration with the institutions, a strong infrastructure for training and research in biotechnology has been built up. There are institutions like the National Institute of Immunology in New Delhi [see article, page 528], which are not depending only on government grants but are also getting project funds from elsewhere, including funds generated as a result of transfer of technology in areas such as biomedical diagnostic kits. There is also intense interdisciplinary activity in the field of biotechnology. One outcome of this is the design and production of a working prototype particle gun for the facile introduction of foreign DNA into cells and tissues.

Brain-storming sessions to discuss problems in their totality are a common feature of the working of DBT. Programmes in, for example, silk, leather and crops have been discussed from all possible angles, and R&D programmes formulated through steering groups specially set up for the purpose (these groups discuss various projects and convey their approval). DBT is assisted not only by a Scientific Advisory Committee consisting of representatives of major organizations concerned with biotechnology and eminent Indian scientists and technologists in the country, but also by a Standing Advisory Committee (Overseas), whose members are eminent Indian scientists working abroad. The department also has the benefit of advice of members of international peer committees in review of its own major programmes. Thus, for example, in the field of fertility control the committee was headed by Nobel laureate Roger Grillman of the Salk Institute in the USA. With regard to academe–industry interaction, the concept of a science–industry consortium has been concretized and industries, research and teaching institutions, and financing institutions identified for this purpose. The objective of DBT is to bring about a qualitative difference in modern biology research in India. Indeed, our efforts go much beyond the money we are spending. DBT has been able to set the process in motion only with the cooperation of all the organiz-

ations concerned. A good beginning has been made.

Manpower development

Adequate trained/highly skilled manpower is essential for meeting expanding R&D and manufacturing needs in the multidisciplinary area of biotechnology. An important component of DBT's efforts are post-graduate and post-doctoral teaching programmes in biotechnology. DBT has provided funds and faculty positions for M Sc/M Tech/ post-doctoral training programmes in 25 selected universities and other institutions [see pages 537, 540, 542 for examples]. The selection was based on the strength of existing infrastructure and resource personnel, ongoing research programmes, proximity to other institutions working in related areas, and other criteria. A placement cell in DBT advises students who seek help in obtaining suitable positions. The department is also sponsoring short-term training programmes of 2–4 weeks duration in high-tech specialized areas in institutions where expertise and infrastructure required for the conduct of such courses exist. The objective of this programme is to reorient personnel within a short period of time to meet immediate requirements. About 1100 persons were trained during the Seventh Five-Year Plan period under this programme. In addition, technician training programmes and short-duration training courses for industrial R&D personnel for persons already employed have been started. A beginning has been made in producing freshly trained technicians by starting two one-year diploma courses for B Sc candidates.

A certain number of biotechnology associateships—both national and overseas—are awarded every year for advanced research or specialized training in identified priority areas of biotechnology within the country and abroad. The trained technologists are expected to meet the gaps in internal competence and the requirement of highly skilled manpower for the expanding biotechnology R&D activities in the country. So far over a hundred overseas and national associates have availed of the scheme A programme of 'visiting scientists from abroad has also been started. These scientists are associated in ongoing research programmes or in initiating collaborative research projects or conducting advanced training programmes in their fields in the host institutions.

DBT gives financial assistance to institutions for the conduct of national/ international seminars. The department has also initiated programmes for strengthening biology teaching in schools, popular lectures by eminent scientists, organization of open houses, training school teachers and bringing out publications in biology and biotechnology. It is also giving scholarships to 10 of the top students in biology in the plus-2-level CBSE examination who continue with biological sciences in the graduate course.

Creation of infrastructural facilities

One of the factors facilitating biotechnology research and applications in the country is its well-developed scientific and technological infrastructure. To build up a strong R&D base and manufacturing capabilities, DBT supports a network of service-oriented infrastructural facilities. Ones set up include germplasm banks for plants, animals, algae and microbes; animal houses; facilities for oligonucleotide synthesis; production, import and distribution of enzymes, reagents and radio-labelled compounds; bioprocess optimization and pilot plants; genetic engineering R&D units; centre for reproductive biology and molecular endocrinology; facility for carbohydrate cell surface and cellular transport; facilities for protein and peptide sequencing; national NMR facility; marine cyanobacterial germplasm collection; and antibiotic development consortium.

Research work is in progress for production of alcohol from molasses by an improved yeast strain developed at the Institute of Microbial Technology (IMTECH) in Chandigarh [see article, page 524]. The results are very encouraging In a 4000-kilolitre fermenter, after 36–48 hours of fermentation in the initial phase, 12–14% ethanol has been obtained. With the second phase already started, experiments were undertaken to generate data on the use of the strain with molasses (with different percentages of fermentable sugar) from various parts of the country, so that the technology can be transferred to different breweries.

Bioinformatics

There are nine DICs in universities and R&D institutions engaged in one or more areas of biotechnology: genetic engineering (Indian Institute of Science (IISc), Bangalore; Madurai Kamaraj University (MKU), Madurai; Bose Institute, Calcutta; Jawaharlal Nehru University (JNU), New Delhi); animal cell culture and virology (Poona University, Pune); plant tissue culture, photosynthesis and plant molecular biology (Indian Agricultural Research Institute (IARI), New Delhi); oncogenes, reproduction physiology, cell transformations, nucleic acid and protein sequences (Centre for Cellular and Molecular Biology (CCMB), Hyderabad); immunology (National Institute of Immunology (NII), New Delhi); and enzyme engineering (Institute of Microbial Technology (IMTECH), Chandigarh). In addition, 14 user centres have been established throughout the country, with an access mechanism that makes the information available at universities and R&D and manufacturing institutions. Access to the centres is provided through the Biotechnology Network (BTNET) linked at present to nine microVAX-II computers at the DICs.

R&D-cum-production programmes

While considering projects for support, priority is given to those proposals where there are possibilities of generation of products, processes and services for ultimate commercial exploitation. DBT has been supporting and is also associated with the following programmes.

- Development of larval insecticide against mosquitoes (Biocide-S)
- Extraction of copper through bacterial leaching
- Tissue-culture propagation of bamboo
- Tissue-culture propagation of cardamom
- Tissue-culture propagation of coconut
- Enhancement of alcohol production through use of improved yeast strain developed at IMTECH and better downstream processing
- Increase in production of antibiotics like penicillin and streptomycin

- Production of sex hormones—follicle stimulating hormone (FSH), human chorionic gonadotropin (hCG)
- Production of insulin
- Prawn aquaculture
- Hormone treatment for increased production of major carps and production of transgenic varieties
- Animal birth-control vaccine (Talsur) for reduction of scrub cattle and stray dogs
- Establishment of two pilot plants, at Delhi and Pune, for raising elite varieties of species of eucalyptus, teak, sandalwood, bamboo and poplar for forest regeneration, agroforestry and social forestry

Programmes in health

Effective control of communicable diseases makes a significant contribution to achieving a national goal—provision of health for all by the year 2000 AD. Vaccination is one of the most efficient cost-effective preventive practices against communicable diseases of children. DBT has initiated several programmes in the area of vaccines

Production of vaccines

Following the lead taken by WHO (World Health Organization), the Expanded Programme of Immunization (EPI) was launched in 1978 for the following diseases: diphtheria, pertussis (whooping cough), tuberculosis, tetanus, poliomyelitis and typhoid Measles was included in EPI in 1985 in India. The Government of India further intensified immunization efforts against vaccine-preventable diseases by launching the Universal Immunization Programme in 1985 and a National Technology Mission on Immunization in 1986 with the following objectives.

(i) To promote, set up, undertake and monitor highly objective R&D activities to develop new process technologies for new and improved vaccines
(ii) To achieve self-sufficiency in essential vaccines by 1990
(iii) To expand vaccination coverage to achieve 85% coverage of children and 100% coverage of pregnant women by the end of the Eighth Plan
(iv) To strengthen the storage and distribution system, disease surveillance, training of personnel, health education, as well as operational research and monitoring mechanisms

The mission is jointly implemented by the Ministry of Health and Family Welfare (nodal agency) and DBT. DBT has been entrusted with the responsibilities of (i) research and development for new and improved vaccines and (ii) indigenous production of vaccines

On the basis of recommendations of various technical/expert committees technologies like chick embryo fibroblast culture, microcarrier-grown Vero cell culture and primary monkey kidney cell culture have been chosen for production of vaccines like measles vaccine, rabies vaccine, inactivated polio vaccine and oral polio vaccine.

Two separate units have been set up under the administrative control of DBT. An R&D-cum-production unit for oral polio vaccine is being established by Bharat Immunologicals and Biologicals Corporation Limited (BIBCOL) at Bulandshahr with technology consultancy cooperation with the USSR Institute of Poliomyelitis and Virus Encephalitis, Moscow. The other unit is being established for production of rabies vaccine, measles vaccine, inactivated polio vaccine and DPTP formulations by Indian Vaccines Corporation Limited (IVCOL) at Gurgaon in technical collaboration with the Institut Merieux, Lyon, France. The first release of commercial lots of vaccines is expected to start soon.

Research in vaccinology

A major national R&D programme to develop new and improved vaccines and diagnostics against the major communicable diseases of India (e.g. tuberculosis, leprosy, diarrhoeal diseases, hepatitis, malaria, filariasis, typhoid) has been launched. DBT has initiated several R&D projects towards development of new and improved vaccines. A few cholera and typhoid vaccines are undergoing clinical trials and have been shown to be promising compared to the conventional whole-cell vaccines, which are less efficacious and reactogenic. An acellular (subunit) vaccine against pertussis is in an advanced stage of development. Current trends in vaccines have also indicated promising leads for development of new vaccines against leprosy, malaria, rotavirus diarrhoea, *E. coli* diarrhoea, oral-bait vaccine for canine rabies, etc.

Indo-US Vaccine Action Programme

The bilateral Indo-US Vaccine Action Programme (VAP) was initiated in 1987 through the signing of a memorandum of understanding and a grant agreement between the Governments of India and the USA. The Joint Working Group identified the following diseases as priorities for R&D under the Indo-US VAP and has been inviting collaborative research projects in these areas: viral hepatitis, rotavirus diarrhoea, cholera, *E. coli* diarrhoea, typhoid, pertussis, *Pneumococcus*, *Haemophilus* influenza, canine rabies, respiratory syncytial virus and poliomyelitis. Eight projects have already been sanctioned to Indian laboratories in the above areas.

Indo-Soviet collaboration

The Integrated Long-Term Programme of Cooperation (ILTPOC) in Science and Technology signed between India and the USSR in July 1987 has a component of 'basic research in selected areas of science'. Under this component, the two sides have agreed to take up advanced R&D in biotechnology and immunology. Fourteen projects are under implementation. Projects identified include studies on viral hepatitis; oral polio vaccine; development of vaccines against foot and mouth disease (FMD), sheep pox and rabies; development of immunodiagnostics for human and animal diseases; immobilized systems and novel bioreactor designs; isolation, purification and cloning of human plasminogen activator; development of drugs from indigenous medicinal plants against ectoparasites.

Future programmes

The Task Force in Medical Biotechnology set up by DBT has identified the following priority areas in respect of R&D in vaccines and related fields.

(i) Recombinant-DNA-based production of biomolecules, e.g. insulin, growth hormones, hCG, FSH, interleukins
(ii) Production of specified monoclonal and polyclonal antibodies against MHC-1, MHC-2, T-cell antigens, B-cell antigens, parasite antigens

(iii) Development of immunodiagnostics and DNA probes for communicable diseases
(iv) Production of synthetic peptides, oligonucleotides, and reagents such as peroxidase, alkaline phosphatase, galactosidases, avidin, biotin
(v) Development of drug delivery systems
(vi) Candidate vaccines for hepatitis, typhoid, rabies, tuberculosis, etc.
(vii) Chemotherapeutic intervention, mechanism of drug resistance, immune defects
(viii) Integrated neuroscience
(ix) Indigenous systems of medicine—biotechnological approaches
(x) Basic research related to the above areas

Immunodiagnostics

The S&T project 'in mission mode' on development and production of immunodiagnostic kits has the objective of developing simple, sensitive and reliable methods and kits for the diagnosis of physiological status or pathological and communicable-disease conditions. DBT has been identified as the nodal agency and the collaborating agencies are NII and the Indian Council of Medical Research (ICMR) in New Delhi. Investigations are being carried out at six institutions, viz. Central Drug Research Institute (CDRI), Lucknow; Post-Graduate Institute of Medical Education and Research (PGIMER), Chandigarh; All India Institute of Medical Sciences (AIIMS), New Delhi; National Institute of Health and Family Welfare, New Delhi; SN Medical College, Agra; and Institute of Post-Graduate Medical Education and Research, Calcutta.

A DBT task force surveyed the expertise developed in various laboratories and identified some conditions for which diagnostic tests could be developed. These include early detection of pregnancy, and diagnosis of filariasis, hepatitis B and amoebiasis. The filaria kit has already been released in the market. DBT is trying to explore possibilities of commercializing the kits for detection of hepatitis B surface antigen.

More agreements, for transferring technology for detection of falciparum malaria, amoebiasis and early pregnancy, are being negotiated Good progress was also made in the diagnosis of brucellosis, toxoplasmosis, tuberculosis, leprosy, typhoid fever and malaria. Work to develop immunodiagnostic systems for 12 communicable diseases is being intensified. The diseases include giardiasis, leishmaniasis, toxoplasmosis, rotavirus diarrhoea and shigellosis, in addition to the diseases mentioned earlier. DBT is funding several projects at various institutions for development of diagnostic kits for these diseases.

Immunological approaches to fertility control

The S&T project 'in mission mode' on immunological approaches to fertility control has the objective of developing safe, efficacious, cost-effective, long-lasting and reversible contraceptive vaccines using immunological approaches. The project was initiated as a part of the family-planning programme. It was financed by grant-in-aid to ICMR by the Ministry of Health and Family Welfare till 1986. The nodal responsibility was then transferred to DBT. The project is a multi-institutional one and is concerned with the development of three candidate vaccines, which are progressing well.

NII has developed a candidate vaccine based on the hormone hCG. Phase-I clinical trials conducted in 105 women showed that the vaccine was well tolerated. No harmful side-effects have been observed in any of the subjects who received the vaccine.

Scientists at IISc, Bangalore, have found that administration of anti-FSH antibodies to male monkeys renders them sterile without any effect on libido. Studies on safety, efficacy and standardization are being conducted to undertake phase-I trials. Another group of scientists at IISc is working on the idea of targeting vitamin carrier proteins for contraception. Lowering the concentration of vitamin carrier protein through the use of antibodies results in rejection of the embryo. After the results are established in nonhuman primates the work would be considered for trials in humans following normal procedures.

Programmes in agriculture

Achieving increase in agricultural production demands that greater attention be paid to evolving more integrated management of water, soil, soil moisture and soil fertility and to bringing more wasteland under cultivation. Greater fertilizer efficiency and decreased dependence on chemical pesticides should be attained. These requirements and problems have set our national priorities in biotechnology in the field of agriculture.

The new techniques of plant breeding, involving genetic engineering, protoplast fusion and tissue culture, make developing high-yielding varieties of food crops and fruit trees and fast-growing and stress-resistant agricultural and silvicultural plants far easier and quicker [see article, page 543]. New high-yielding varieties can increase agricultural productivity manifold. Genetic manipulation can produce varieties with greater tolerance to herbicides, soil toxicity, and stress situations such as salinity, pests and drought. In the area of agricultural and plant biotechnology, particularly in plant tissue-culture techniques, Indian institutions have achieved substantial progress in clonal propagation, micropropagation, somatic embryogenesis and production of somaclonal variation in respect of various agricultural, horticultural and plantation crops [see article, page 547].

Six centres for plant molecular biology have been established at MKU, Madurai; JNU, New Delhi; Tamil Nadu Agricultural University, Coimbatore; Osmania University, Hyderabad; Bose Institute, Calcutta; and National Botanical Research Institute (NBRI), Lucknow. The various elements built in these centres are (a) infrastructure strengthening for basic research, (b) three to four focused R&D programmes for problems in crops using genetic and molecular approaches, and (c) training in plant molecular biology.

Tissue-culture micropropagation of elite trees

Bamboo. A project on tissue culture of bamboo has been initiated by DBT at the University of Delhi. The objective is to develop and standardize methods for mass propagation of various species of bamboo available in India using tissue-culture techniques. About 7000 tissue-culture bamboo plantlets have been produced and planted in the states of Uttar Pradesh, Orissa and Karnataka and in Delhi for evaluation in

terms of fast growth and enhanced biomass production.

Pilot plants for teak, eucalyptus and sandalwood. Two pilot-plant facilities—one at the Tata Energy Research Institute (TERI) in New Delhi and the other at the National Chemical Laboratory (NCL) in Pune—are being set up for mass-scale micropropagation of certified planting material from elites of the important forest tree species teak, eucalyptus and sandalwood.

Biopesticides

Several projects aim at exploiting biological agents for efficient management of pests and diseases. Biotechnology will be a tool in developing effective biological-control agents. Mass-production techniques, first on a pilot scale and then on a large scale, will also be standardized. Under the programme, viral, bacterial and fungal agents are slated to be produced for use in the control of several insect pests of importance in agriculture and human health. Biocontrol agents have been produced and their efficacy tested for controlling pests and diseases of various crops. This was demonstrated in farmers' fields at several locations. Five workshops-cum-farmers'-fairs have been conducted for efficacy demonstration of biocontrol agents in the states of Tamil Nadu, Karnataka, Maharashtra, Gujarat and Uttar Pradesh. The crops include chickpea, lentil, cotton, tobacco, sugarcane, groundnut, cauliflower and tomato.

Biofertilizers

Rhizobium biofertilizer. A major programme for large-scale fermentor-based production of *Rhizobium* inoculants with high quality control and in-house R&D back-up is being taken up. The objective is to make available *Rhizobium* biofertilizer for use in some of our major oilseed and pulse crops. [See article, page 551]

Blue-green algal biofertilizer. DBT has established a National Facility for Blue-Green Algal Collection at IARI in New Delhi. This facility is collecting, screening and identifying nitrogen-fixing BGA strains suitable for use in rice fields in different agroclimatic regions of the country. It has also developed an economic rural-oriented algal biofertilizer technology for rice. The facility is also supplying soil-based BGA starter culture to farmers for use as biofertilizer in rice crops.

The blue-green algae will play a significant role as supplement to chemical fertilizers. Similarly, *Rhizobium* would be produced in fermentors and it would be possible to use rhizobial inoculants to cover 30 million hectares under pulses and oilseeds. The entire nitrogen demands can be met through these.

Tissue culture of cardamom

Cardamom is an export-oriented spice cultivated in over 100,000 hectares in the states of Kerala, Karnataka and Tamil Nadu. Our productivity, however, is very low, about 60 kg per hectare as against 250 kg per hectare in Guatemala. Tissue-culture propagation of cardamom has been standardized and techniques for large-scale multiplication are already available within the country. DBT has undertaken a project to demonstrate the performance of elite *in vitro* clones of cardamom in 100 units of one hectare each throughout the cardamom-growing areas of the country (Kerala 50 units, Tamil Nadu 15 units, Karnataka 35 units).

Oilpalm

Oilpalm has the highest productivity (4–6 tonnes per hectare) among edible oil-yielding crops. DBT has undertaken three oilpalm demonstration projects to demonstrate the feasibility of cultivation of oilpalm under irrigated conditions in the states of Maharashtra, Andhra Pradesh and Karnataka over an area of 1000 hectares each with both imported seeds (70% of the area) and indigenously produced seeds (30% of the area). Oil processing units will be an integral part of each Oilpalm Demonstration Project (ODP). Efforts are also on to standardize the tissue-culture technique for multiplication of oilpalm plants at the Bhabha Atomic Research Centre (BARC), Bombay, and the Central Plantation Crops Research Institute (CPCRI), Kasargod.

Veterinary biotechnology, aquaculture

The livestock and fish industry encompasses a wide range of products, including milk, meat, eggs, fish and marine products. The conventional methods of producing these are time-consuming, labour-intensive and less remunerative because of lower production and lack of proper quality control. With the advances in biotechnology, it is now possible to increase production and productivity of livestock and fish resources substantially, with improved quality.

Embryo-transfer technology. This technique offers scope for achieving faster multiplication of elite livestock and for devising methods for conservation of valuable germplasm. In conjunction with artificial insemination, it offers a powerful tool for increasing the population of a desired type of animal, say one with improved production potential. Success has been achieved in establishing facilities for studies of the application of this technique in India through DBT's 'mission-mode' project on cattle and buffalo-herd improvement. Surgical and non-surgical embryo transfers in cattle and buffaloes have been successfully done. NII has successfully produced calves with frozen-and-thawed embryos in cattle. NII has also been able to split embryos and produce pregnancies. The first bovine-split-embryo-technology calf was produced in November 1988. A buffalo calf of Murrah breed was born recently through transfer of *in vitro*-fertilized embryo at the National Dairy Research Institute in Karnal for the first time in the world.

Animal birth-control injection. An animal birth-control injection called 'Talsur' has been developed by scientists at NII for sterilization of male animals. It provides a cheap, fast and simple method with few side-effects. The technique will have an impact on efforts to reduce the population of low-grade genetic stock of little economic value.

Aquaculture. Under semi-intensive prawn farming, a harvest of 4 tonnes of prawn per hectare has been attained in a waterspread area of 8.8 hectares in Nellore, Andhra Pradesh. The technology will be demonstrated and R&D-cum-demonstration units will be set up in eight to ten places in states like Gujarat, West Bengal, Orissa, Goa, Tamil Nadu, Maharashtra, Karnataka, Kerala and Pondicherry. In intensive carp polyculture, a breakthrough has been achieved in demonstrating production of more than 12 tonnes of carp

per hectare in seven months time in the partial harvest conducted at CIFA, Bhubaneswar. The annual production would be more than 17 tonnes per hectare, as against the target of 15 tonnes for this year. Economically viable technology packages for farmers are being prepared.

Other important projects include the programmes for introduction of growth-hormone genes for increasing cattle productivity, fish production and prawn aquaculture through biotechnological innovations like chromosomal manipulation, gene cloning and transfer, cryopreservation of gametes and embryos, and *in vitro* fertilization; development of immunodiagnostics for veterinary use, based on monoclonal antibodies and DNA probes; and projects for production of vaccines for animal diseases.

Recombinant-DNA safety guidelines

Advances in manipulation of genetic material have generated a sense of concern among scientists about safety of work involving pathogenic microorganisms and genes encoding virulence factors. On the basis of recommendations of the Recombinant-DNA Advisory Committee and available scientific information, DBT has brought out a document on 'Recombinant-DNA Safety Guidelines'. The guidelines cover areas of research involving genetically engineered organisms, genetic transformation of green plants and animals, recombinant-DNA (r-DNA) technology in vaccine development, and large-scale production and handling of products obtained by r-DNA technology. Matters regarding notification, containment, recognition of facility, competent authority, large-scale experiment and manufacture, biologicals produced by r-DNA technology, release to the environment, and field experiments have been discussed in detail.

Biotechnology industry

In 1988 DBT assumed the administrative responsibility of examining applications under the Industries (Development and Regulation) Act 1951 in the area of biotechnology-related products. The department continued to receive applications from the Ministry of Industry for views regarding issue of industrial approval and clearance of foreign collaboration. The items of manufacture were antibiotics, vaccines, hybrid and high-yielding varieties of seeds, etc.

Realizing the potential of the scientific manpower and the R&D infrastructure in the country for production of economically beneficial products, processes and technologies in the area of biotechnology, the government had been considering the establishment of an interactive institution–industry group, along with financial institutions. The idea was to use the existing infrastructural facilities and available scientific manpower to work on problems relevant to industry. It is anticipated that, by this process, many industrial problems would also be referred back to the institutions and, in many cases, novel marketable products and processes would be developed that could benefit society. In the first of three phases, products and problems relevant to the country would be identified. In the second phase, pilot-scale development of prototypes, validation, market surveys and preparation of techno-economic feasibility reports are considered. In the third phase, manufacturing activities and marketing of products are expected to take place. In the first two phases, financial help to some extent would be provided by government/financial institutions, while, in the third phase, the project is expected to be a bankable one and therefore government help would be extended only in matters such as licensing and approvals. An institutional mechanism has been evolved in the form of Biotechnology Consortium India Ltd (BCIL), a venture company set up with the help of the Industrial Development Bank of India (IDBI) and other financial institutions. The main objective is to promote production and process development and improve technology development and technology transfer through entrepreneurs with the support of financial and industrial institutions.

Biotechnology district

DBT has a plan for developing Ernakulam district in Kerala as a 'biotechnology district' for its unique distinction of being the first district in the country with 100% literacy. The project is proposed to be implemented with the cooperation of central and other state governments and voluntary agencies with the aim of increasing productivity through improved genetic efficiency in agriculture, entrepreneurial development, and infrastructural facilities for development and diffusion of technology.

Action plan

Recently eight programmes of DBT were categorized under an 'action plan'.

New programmes
(i) Biofertilizer
(ii) Sericulture
Ongoing programmes
(i) Vaccines (oral polio vaccine and viral vaccines)
(ii) Oilpalm demonstration project
(iii) Increased production of biomass
(iv) Immunodiagnostics
(v) Aquaculture (increased production of prawns and major carps)
(vi) Embryo-transfer technology

The programmes were selected on the basis of their scientific status and their impact on the development process, particularly in the context of rural development and development of weaker sections of society.

The technology development and demonstration project in biofertilizers has two components, one concerned with blue-green algae for wetlands and the other with *Rhizobium* for leguminous crops. Depending on agroclimatic conditions, the yield increase due to application of biofertilizers in crops is 10 to 70%. The *Rhizobium* programme aims to make available biofertilizer for use in oilseed and pulse crops. The total requirement of *Rhizobium* biofertilizer is 9000 to 10,000 tonnes per year, but existing production is only 700 tonnes per year. New technological packages are being evolved for fermentor-based *Rhizobium* production. In the blue-green algae programme, extensive training, R&D, demonstration on a large scale and production will be taken up.

The sericulture programme envisages use of biotechnology in improving the productivity and quality of Indian silk. The programme mainly consists of three short-term demonstration projects, four medium-term R&D projects, and six

(See page 536)