BIOTECHNOLOGY: THE NEW EMERGING PARADIGM WITH PARTICULAR REFERENCE TO INDO-GERMAN RELATIONS

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Biotechnology has revolutionized the current status of knowledge of a number of biological pathways and processes applicable to the biological principles for human welfare and better quality of life as is evidenced from the all round increase in productivity and improved quality of products and services. Use of modern technologies have made substantial contributions to development in agricultural and plant biotechnology using transgenic technology, *in-vitro* propagation, plant tissue culture, molecular markers, crop resistance, molecular diagnostics, seed technology, biofertilizers, biopesticides, molecular taxonomy, animal biotechnology etc; Its greater impact in the area of human health has been through development of vaccines for communicable and non-communicable diseases, biomolecules and bioactive compounds, immunomodulators, new pharmaceuticals, delivery systems, diagnostics and other medical products, application of molecular genetics and genome analysis. Microbial biotechnologies improved the bioprocess technologies, efficient industrial development processes for transforming raw materials and the detoxification of hazardous material. Enhanced food productivity has been achieved through food safety analysis and food processing technology for the agro-industrial sector, diagnostics for pesticide residues and food borne pathogens. Environmental protection technology are being utilized for the biodegradation of industrial and agriculture wastes, molecular diagnosis for pathogen detection in water and food etc.

Indian Biotech Scenario

Although India has been practicing conventional biotechnology for several decades it is only in the past one to two decades that the products manufactured by the use of modern biotechnological techniques are increasingly being used and indigenous research in these areas has been intensified. The scientists in the country are actively engaged in fermentation based activities, production of valuable biologicals from microbial, plant or animal cell cultures, marker assisted selection and breeding, value addition, prospecting of biological resources, molecular taxonomy and micro-propagation methods for producing high quality, genetically superior planting materials.

India has a well established biotech industrial base, with more than 800 companies operating in various sub-sectors of biotechnology producing conventional and modern biotech products. The Indian strength lies in its having a large consumption market, liberalized economy and stable democracy and thus it is a better option for Foreign Direct Investment in all branches of scientific industries in general and biotechnology industry in particular.

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**The views expressed in the paper are those of the author and do not necessarily convey the views of the Department of Biotechnology, Ministry of Science & Technology, Government of India.*

The country today has excellent expertise in biotechnological processes, facilities and tools in many corporate R & D houses, industries and teaching institutions including the universities. Core competence in the country exist for handling of labile biomolecules and compounds, efficiently using downstream processing and unit process methods; production and handling of fermentation based products including foods, pharmaceuticals, geneticeuticles etc.; extracting value added products of high purity from plant and animal parts; use of plant/animal cell and tissue culture and microbial culture techniques; conventional plant/animal breeding techniques for variety improvement. The country has competence in the construction of bioreactors and processing equipment of diverse nature. The pharmaceutical formulation sector and handling of sophisticated biotech products under GMP has been developed to a high degree of proficiency.

The demand for existing and new biotech products in India has increased many folds with the increase in population as well as increase in awareness in the people about availability of such products. The Indian Biotech industry is estimated to grow exponentially in the coming years with many more indigenous technologies with more and more of expenditure on research and development. According to a conservative estimate, the turn over of biotech products which was $ 150 million in 2002 is predicted to reach about $ 750 million by the year 2005 and $ 4,500 million by the year 2010. These products would be mainly for the human and animal health, agriculture, industrial products and other value added products. The average estimates on demand of biotech products in India in 2005 would be for human & animal healthcare (39.5%), agriculture (32.8%), industrial (25.0%) and other biotech products (2.7%). There are over 15,000 thousand participants in the industry. The main contributors to the Indian Biotech industry are in the sectors of pharmaceuticals, immunobiologicals and industrial products.

The demand of biotech products is increasing. Looking at the volume of local consumption, the scope of trade as well as new investment is considered enormous. Industries are opening up and opportunities for collaboration between Indian institutes of excellence, Indian industries and multi-national companies / foreign investors for jointly developing biotech products that are research based, have increased tremendously. India is providing competitive advantages in attracting FDI for joint development of products/ processes in health care area as well as in agriculture and institutional teaming up for utilization by the private industries.

Vaccines: Sufficient capacities exist in the country for the production of vaccines against tetanus, diphtheria, pertussis (and combinations thereof like DPT and DT), BCG and measles etc. Polio vaccine bulk is being imported, blended and used. Genetically engineered as well as human plasma derived hepatitis B vaccines have already been marketed in the country partially through indigenous production and rest through imports. Recombinant vaccines for rabies, cholera, tuberculosis, malaria, HIV etc. are at different stages of research and development and opportunities are available for joint collaborative programmes. India being among the worlds largest markets for vaccines of all types has a growing demand for new generation and combination vaccines. Opportunities are there for collaborative linkages for production of combination vaccines or setting up of basic production facilities in the country.

Genomics and Proteomics: In the future scenario, biotech business platforms would use bioinformatics as tools to analyse huge data generated by the sequencing of human genome and study of genetic diversity and complex genetic diseases like schizophrenia, cystic fibrosis, Duchenne muscular dystrophy, retinoblastoma etc. Studies would also include proteomics, pharmacogenomics, biochips, combinatorial chemistry, xenotransplanation, tissue engineering, signal transduction for drug discovery etc. India is already supporting research and development for major programmes in these areas, which has large potential for collaborative efforts.

Animal & Poultry Vaccines: Currently vaccines against Foot and Mouth Disease, Anthrax, BQ, MCC, Enterotoxaemia, Rinderpest, Rabies, and Sheep pox are being produced in abundant quantities. Several other vaccines and diagnostics like IBR, PPR, Blue tongue virus etc. are in advanced stage of development. The poultry industry is also developing fast in the country. The area has grown steadily and considerable scope exists for fresh investments.

Diagnostics: India has one of the largest diagnostic market in the world. The demand of the country is increasing tremendously with the advent of new technologies. Major requirements are tests for early pregnancy, ovulation, T3/T4/TSH/sex hormones, tuberculosis, leprosy, typhoid fever, amoebiasis, diarrhoeal diseases (*E. coli*, rotavirus, cholera), filariasis, hepatitis-B, HIV(I+II), venereal diseases, rheumatic diseases and cancer (cervix, colon, prostate, lungs, mouth), liver and pancreatic functions. It is expected that this industry in the existing environment will grow much faster.

Bioactive Therapeutic Proteins: Currently several recombinant (r-DNA) products like human insulin, interferon, human growth hormone, streptokinase, erythropoietin, GM-CSF, G-CSF, bovine somatotropin, hepatitis B vaccine, tissue plasminogen activators etc. are being marketed globally. In India, insulin, alpha interferon, hepatitis B vaccine, GM-CSF, G-CSF, blood clotting factor VIII, streptokinase, human growth hormone and erythropoietin are already approved for marketing. Only a part of the requirement of vaccines in these areas is being met through indigenous production while the bulk requirement in the country is still being imported. Opportunities exists to speed up production facilities, based on licensing and other regulatory approvals for marketing in India.

Targeted Drug Delivery Systems: Vehicles being used to target specific sites include liposomes, virosomes, pharmacosomes, hydrophilic nano-particles, targeted polymeric chimera etc. These products are finding number of applications and have revolutionized pharma industry. Liposomal formulations are already available in Indian market through imports and have lot of investment opportunities. Simultaneous R&D efforts have already been launched in this area in India through public as well as private support.

Crop Biotechnology: The generation of transgenic plants has largely focused on important traits that benefit the farmers. Increasingly large number of transgenic maize, soybean, patato, tomato and cotton are being commercially grown worldwide for human use and consumption. In these crops genes for improving crop productivity and

manipulating starch/protein/oil quality and quantity, resistance to pests and diseases, environmental stresses such as temperature and drought, are being isolated and studied. In India efforts are being made to develop various transgenic crops for improvement in the nutrition as well as biotic and abiotic stresses. Programmes are funded mainly through public sector. This area has tremendous scope for further research and development and investment in the sector.

Hybrid Seeds: In India considerable attention has been given to the development of this sector for distribution of certified and quality seeds for crops including cereals, pulses, oilseeds, fibre, fodder and other species. Nearly 5 million kgs. of hybrid vegetables including tomato, cabbage, peas, cauliflower, ladies finger and cucumber are consumed so there is a good scope for setting up plants for organized production of hybrid seeds especially in vegetables.

Tissue Culture raised Planting Materials and Cut Flowers: In India, plant tissue culture techniques are being extensively used for the production of elite cultivars for flowers, ornamentals, tubers, bulbs and fruit plant species. Flowering plants include lily, carnation, chrysanthemum, orchids etc. Elite planting materials raised through tissue culture are being used for banana, pomegranates, peaches, berries, papaya, tamarind and pineapples among the horticultural plants and eucalyptus, sandalwood, teak, populous and bamboos among the forest plants. There is a huge local market in the country. The government has extended several incentives like automatic industrial approvals, refinancing facilities through certain banks etc to exploit full potential of this industry. Additional efforts are being made to attract more entrepreneurs and collaborating partners world around to enable India to contribute significantly in the global business in this area.

Biopesticides: Biopesticides based on *Bacillus thuringensis* (Bt) and *Bacillus sphericus* (Bs) are already being produced. Production techniques are being used for multiplication and formulation of Nuclear Polyhedrosis Virus (NPV) to control cotton bollworm (*Heliothesis armigera*) and tobacco caterpillar (*Spodoptera litura*); Granulosis Virus (GV) for sugarcane shoot borers (*Chilo infuscatellus*); Chrysopa for aphids, white flies and bollworms; *Trichogramma* for lepidopteran pests; and *Trichoderma* and Glioladium for root rot and wilt diseases. Controlled field level demonstrations in farmer's fields have been conducted and so far nearly 1,40,000 hectares have been covered in the fields of cotton, sugarcane, tobacco, tomato, chickpea, groundnut, pigeon pea, other pulses, sunflower and cauliflower at multi locations..

Biofertilisers: Nearly 13,000 tones per annum of rhizobium biofertilizers useful for leguminous crops is being produced in the country covering 50 to 60% of the 30 million hectare land being used for leguminous crops. The biofertilizer industry provides a high economic potential.

Animal Improvement: The milk production target of 85 million metric tonnes in 2000 AD was already achieved. Similarly production level of the meat, wool and grease has increased. The genetic stock of animals specially cows and buffaloes is being improved through embryo transfer and other technologies. Efforts are being concentrated on study

of some aspects of buffalo genomics. Cross breeding programmes have been intensified. Investment opportunities in various aspects of animal improvement such as production of bovine somatotropin and other hormones embryo banking, animal feed concentrates etc., seem enormous.

Industrial Products: A number of industrial products are being produced indigenously which meet only a part of the total requirement of the country. Major efforts are in the areas of alcohol and citric acid production from molasses, lactic acid production, glucose and dextrose from tapioca starch, penicillin acylase etc. The total consumption of all these enzymes in the country is anticipated to go up substantially within next few years.

Other Biotech Products: Restriction endonucleases, oligonucleotides, biochemicals, culture media etc. required for biotech research are being produced in increased quantities locally, in addition to imports. Solid state fermentation of agricultural wastes into vitamin rich products as well as conversion of such wastes into probiotics for enriching poultry and animal feeds are also picking up fast. Techniques have also been perfected for microbial leaching of copper pyrites, microbial benefaction of high silica containing bauxite and magnesite, using appropriate strains.

Bio Informatics: Indian bio-informatics companies can play a significant role in critical areas such as data mining, mapping and DNA sequencing besides functional genomics, proteomics and molecule design simulation in the $ 2 billion world market for bioinformatics services. Complex alorithm writing and the use of computational capacities to study the 3 D structures of proteins are the main skill brought into play in this segment.

Indian Industry and Government Initiatives for Biotechnology

The Indian government has paid enormous attention to the regulation of economy and the industrial wealth including the private sector with an aim of promote public sector industries, setting up of high capital intensive public sector undertakings, nationalization of major banks, central planning for the diversion of resources and introduction of industrial policy to boost public sector. These policies strengthened the private sector, regulated with the introduction of various Acts and other conservative policies like Foreign Exchange Regulation Act, Monopolies and Restrictive Trade Practices Act, The Indian Patent Act (1970), enactment of Control and Distribution of Essential Commodities Policy, Price Control Policy etc. Apart from these the small-scale sectors were given concessions at various levels. It was until late 1980's that the Government's initiative towards its industrial policy changed with new incentives.

The growth of biotechnology research and development in the country started through "National Biotechnology Development Board" set up in 1982 which was changed in to an independent Department for Biotechnology in 1986 by the Union Government. Since 1986, the Government has done a tremendous job in encouraging academia industry interface in biotech sector.

The Department of Biotechnology

Department of Biotechnology of the Ministry of Science and Technology established in February 1986 has the mandate to coordinate and promote biotechnology research and development in the country. As biotech research is multidisciplinary, biotech research has been linked with various other scientific ministries and departments and over 4000-5000 scientists interact with the Department in different capacities each year. Significant achievements have been made through its multi-pronged activities and a number of indigenous technologies have been developed and transferred to industry.

Major activities of the department include research and development in multi-disciplinary areas of agriculture, medical sciences and brain research, human genetics & genome analysis, vaccine and diagnostics, animal biotechnology including transgenic and embryo transfer technology, aquaculture & marine biotechnology, environment etc.; Biotechnology Product and Process Development & Technology Transfer; Biosafety aspects including GMOs; Intellectual Property Rights and Patenting; Human Resource Development; Setting up of infrastructure facilities, support services, advanced centres in biotech research and facilities; Biotechnology based programmes for the society; International Collaborations; Bioinformatics etc. The Department has already set up seven autonomous institutions looking into specialised areas of biotechnology. Biotechnology entrepreneurship development with industries and scientists teaming up for technology packaging and commercialisation is rapidly progressing.

There are more then 100 national laboratories, universities, private institutions engaged in biotech research. A number of service oriented national research facilities have been created. Major programmes in the area of manpower development have been launched to create highly trained and skilled manpower and reorient the existing strength. Efforts have been launched to evolve interaction amongst the academia, industry and the financial institutions. The promotion of R&D programmes leading to products or technologies, large scale demonstration of nationally important products, commercialization of biotechnology products and setting up of manufacturing ventures etc. have been launched.

The Department, with its intramural and extramural research efforts has been successful in generating a number of indigenous technologies and their transfer to industry with careful monitoring of their absorption. Resources have been provided to promote research within the country mostly in public funded institutions.

The Department in close collaboration with the Ministry of Environment & Forests, Department of Industrial Policy and Promotion, Ministry of Health, Drugs Controller General of India, Central board of Excise and Customs, Ministry of Commerce & Industry has been playing proactive role for the promotion of Biotech industry. The Department acts as the administrative ministry for framing various guidelines and policies for the biotech sector.

Government Policies and Biotech Industry

The Central Government, in order to promote economic growth, has brought significant changes and the previous developmental policies have been modified from July, 1991 onwards. The licensing policy were substantially liberalized. To attract foreign investors, the Ministry of Industry further liberalised the licensing policy through the establishment of Foreign Investment Promotion Board (FIPB) during 1997-98 and Foreign Investment Implementation Authority (FIIA) in 1999 to facilitate the flow of foreign investment in the country. These changes in the industrial policies helped to boost the biotech sector

Under the liberalised policies, the industrial licensing allows automatic registration process. 100% foreign equity investments is possible in almost all sectors. 100% foreign equity investment is automatic in biopharmaceuticals and biotech sectors. Fast track clearance route has been set up for Foreign Director investment (FDI). Depreciation allowance on plant and machinery set up is based on indigenous technology. Customs duty exemption has been provided on goods imported for use in Government funded R&D projects and under EPCG programmes.

These efforts have led to the establishment of various technology parks in various sectors especially in the knowledge-based industry like Drugs & Pharmaceuticals, Information Technology and Biotechnology. There are over 75 research and development laboratories in the public sector and more than 20 are engaged in conducting research in the frontier areas of biotechnology where the Government has invested over US $ 200 million for creating R&D infrastructure and skilled manpower. These facilities can be teamed up by the private sector to perfect their technologies that cannot invest large amounts to create their own sophisticated infrastructure.

Department of Biotechnology has been working in close interaction with the Ministry of Industry on the promotion of Biotech industry in the country. The Department is the Administrative Ministry for Biotech Industry and heads the Fast Track Committee (FTC) of Foreign Investment Implementation Authority for the single window clearances of all mega projects costing more than US $ 20 million as Foreign Direct Investment (FDI) in the country.

Indo-German Collaboration in Biotechnology

Framework of Cooperation: Cooperation in biotechnology has been undertaken within the framework of Indo-FRG agreement in S&T, signed in 1974. A workshop at the University of Tubingen in identified the scope of initiating bilateral R&D programme and specific institutes and research scientists were identified. After scientific review five projects were identified and implemented in crop biotechnology on both sides during 1988-89.

During the visit of Indian Prime Minister to FRG in 1989, a Joint High Level committee was constituted between the two countries for exploring further areas of mutual interest.

Biotechnology was identified as the key area under major programmes on Joint Commercial Interest and Joint Interest in R&D.

Broad areas identified for cooperation for commercial interest included Pharmaceuticals and other Biologicals; Agricultural Biotechnology (including food crops, trees, aquaculture and animal biotechnology); and Biotechnology Information System. The mechanism of co-operation included straight transfer of technologies between partners of the two countries; Joint Venture Commercial units in India or FRG for producing items of mutual benefits and projects for Joint development of products and processes with a view to setting up joint commercial ventures eventually. Efforts on Joint Interest in R&D were stressed on development of biological products; agricultural biotechnology including food crops, trees and animal husbandry; microbial genetic engineering; molecular immunology; and bioprocess engineering; and bio-informatics.

Indo-German Agreement in Biotechnology: A Special Arrangement between Department of Biotechnology and Forschungzentrum Julich GmbH (FZJ) was signed at Julich on February 15, 2001 which has now been recognized by BMBF as a mechanism to receive proposals from other institutions and universities. Specific areas identified for collaboration included isolation, characterization of micro-organisms for production of metabolites, NMR-Spectoscopy-techniques for investigation of metabloc pathways, development of bio-reactors for laboratory and for industrial purposes, new cell culture techniques, overexpression of proteins and protein design by genetic engineering etc. The cooperation also include the exchange and training of scientists, joint execution of scientific projects as well as reciprocal support in procurement of scientific equipment. The Agreement also provides a scope to enhance cooperation in additional areas.

Areas identified for collaboration with Gesellschaft fur Biotechnologische Forschung (GBF) include genomics of pathogens and infections, genomics in environment including infections, nutritional aspects, drug development, bioinformatics, expression profiling etc.

High level delegations on both sides including that of the State Secretary at the Federal Ministry of Education and Research to India in October 2001, discussed joint cooperation programme in science & technology particularly in the area of biotechnology. Emphasis was given on establishment of a technology incubator centre in India. The establishment of genome centre was also discussed. Joint collaborative programmes in the areas of genomics, fermentation technology, bioinformatics, development of bio-safety protocols and marine biotechnology were suggested

Review Mechanism: The Indo-German High Level Committee discuss the mechanism and implementation of the projects already identified by the Indo-FRG evaluation committee. Progress in scientific programmes is reviewed at Joint Indo-German Committee on Science and Technology, which meets alternatively in India and Germany. The projects received on both sides are peer reviewed independently and considered for implementation at joint meetings. On Indian side the projects proposals are reviewed by

an International Projects Approval Committee of the Department of Biotechnology while on German side the projects proposals are considered by the BMBF.

Joint R&D Projects: List of projects in biotechnology undertaken so far under the Indo-German collaboration are given below:

Nitrogen Fixation and Ammonia Transport and Excretion in Appropriate Microorganisms isolated from the Rhizosphere of Cereal Crop Plants between Jawaharlal Nehru University, New Delhi and Universitat Bayreuth, FRG

Studies of Nitrogen Fixation Genes of Non - Symbiotic Microorganisms and Their Expression between Jawaharlal Nehru University, New Delhi and Biologie Genetik Universitat Beilerfed, FRG

Ammonia Transport and Excretion by Cyanobacteria and their Practical use in Agriculture between Jawaharlal Nehru University, New Delhi and Universitat Bayreuth, FRG

Insertion Mutagenesis in Higher Plants between Jawaharlal Nehru University, New Delhi and Institut fur Angewandte Genetik, Berlin

Regeneration studies of Somatophytic and Gametophytic Plant between Jawaharlal Nehru University, New Delhi and Institut for Genetik, University of Bonn.

Human genome research and medical genetics between Guru Nanak Dev University, Amritsar and Institute of Human Genetics, Berlin.

Enzymatic modification of *Cicer arietinum* as a nutritious food between J.S.S. College of Pharmacy, Ooty and Institute of Physiological Chemistry, University of Bonn, Germany.

Rapid detection of seafood associated pathogens using molecular techniques between College of Fisheries, Mangalore and University of Wurzburg, Germany.

Growth, control, cell shape and tumorigenesis between Devi Ahilya Vishwa Vidhyalaya, Indore and German Cancer Research Centre, Heidelberg

Significant achievements: Important leads in some of the projects are:

Studies on nitrogen fixation with strains of Azospirillum brasilense showed that a DNA fragment of 2114 bases was involved in association of the bacteria with plant roots;

The Azobacter vinelandii nifL like gene was cloned and sequenced to be 1.9 kb segment with 1557 base long open reading frame coding for a 519 amino acid polypeptide. The size of Azobacter vinelandii chromosome was determined to be 4.5 megabases and circular in shape;

Studies demonstrated that fixed nitrogen sources like nitrate or ammonia cause repression of genetic evidences indicating participation of an ntr like gene in positive control of heterocyst formation, nitrogenase activity and ammonium transport activity. This finding provided a genetic tool to construct biofertiliser strains of heterocystous cyanobacteria producing heterocyst and nitrogenase activity in the presence of exogenous ammonia. Gene transfer methods were developed for identification of useful genes including tagging gene with t-DNA on transposon;

Studies on Brassica culture revealed that hormones caused cell proliferation, which was further enhanced by addition of polyamines such as spermidine and spermine. However, Methylglyoxal-bis-(guanylhydrazone) (NGBG) an inhibitor spermidine biosynthesis had a retarding effect on proliferation and was able to induce differentiation. Auxin binding proteins have been identified from etiolated hypocotyl segments of B. napus;

Under the programme on human genome research and medical genetics genes have been mapped for central pouch like cataract with sutural opacities at 15q 21-22 in a 7 generation family locus for sutural cataract with punctate and cerulean opacities at 22q 21-22. Mutation has been identified in exon of 6th CRYBB2 gene and for retinitis pigmentosa on chromosome 1 at 1 p 13-q23. In Reis-Buckler corneal dystroply, possible linkage in chromosome 5 has been identified in two autosomal dominant hereditary multiple exostosis families, loci have been identified on chromosome 8 and 11;

Nucleic acid probes have been developed for white spot syndrome virus (wssv) which were found to be useful in confirmation of disease in shrimp tissue and screening the shrimp larvae. Technology has been transferred to industry. RAPD pattern studies on detection of shiga – toxigenic *Escherichia coli,* in fresh fish, shellfish and meat sold in open markets, indicated diverse sources of contamination of fish and shellfish.

Workshops: (i) An Indo-German Workshop on Infections Disease Research in Post – Genomic Era: Protein – Protein Interactions to Understand Disease Mechanisms held at the Center for DNA Fingerprinting and Diagnostics, Hyderabad from December 11 – 13, 2002, considered specific programmes in the areas of genomics, host pathogen interactions, cell functions, structural biology and immune responses. New contacts were developed and two projects have already been developed and agreed on both sides for implementation.

(ii) An Indo-German Joint Workshop on Proteomics and Bioinformatics held from October 17-18, 2003, considered specific areas for study of protein – protein interactions, proteomics including bioinformatics, structural genomics and structural proteomics and post genome biology for important infectious diseases using technologies of micro arrays, gene expression and regulation, protein expression analysis, structural analysis, etc., Joint Collaborative projects are being developed.

Training: The Joint R&D projects include training of scientists as the integral part of cooperation and accordingly scientists were trained and exchange visits by the

investigations were undertaken. In addition, under the new agreement, two scientists were trained in various areas of genomics in the laboratories of GBF.

To Conclude

Biotech industries are at the forefront of other technological revolution. It is estimated that in India in the first decade of the new millennium, approximately US $ 4000 million would be invested mainly in the areas of health-care, agriculture, environment and the food processing industries. The demand for human and animal health care products would increase which would have potential opportunities for the biotech industry for further development.

Indian laws and the government policies are changing fast with the opening up of the economy. The scope of free trade and industrial approvals have been significantly broadened and liberalized and unnecessary procedural controls have been eliminated. New policies are in the offing especially pertaining to Intellectual Property Rights, right to information, foreign direct investment, customs and excise duties etc.

The country, is pursuing an active programme of research and development cooperation in biotechnology with number of developed and developing countries including that with Germany. A major successful programme of cooperation has been pursued with Germany. A number of research and development programmes have been implemented and there has been a continuous transfer of knowledge on both sides based on mutual cooperation and mutual trust. A number of missions in biotechnology including potential private partners have been exchanged. There exists an institutional mechanism for cooperation in biotechnology between the two countries under which new programmes of collaboration can be considered.

Under a positive IPR regime, the synergies in pharma-biotech relationships can be successfully turned into an opportunity for undertaking international contract research in segments of new drug discovery, clinical trials, and bioinformatics related services.

Opportunities are available for strong Indo-German relation in research and development and developing biotechnology related industrial products and processes through direct participation or through industrial and institutional framework.

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