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India's endeavors in biotechnology: A policy overview

A.S. Ninawe[1]

Introduction

Biotechnology may be defined as the application of science and engineering in the direct use of living organism or parts or products of living organisms in order to produce products, processes or services. Biotechnology may encompass recombinant DNA technology, used to modify the genetic material of living cells to produce new substances or perform new functions. Worldwide, biotechnology is revolutionizing the development of products, processes and services in healthcare, agriculture, industry and environment. Large investments are being made in biotechnology mediated enterprises, biotech products and services are becoming a multibillion dollar industry. Biotech products and processes enhance value in a range of industries from leather, detergents, textiles, food and feed, beverages, beer, wine, confectionery, cosmetics, therapeutics, vaccines, diagnostics and neutralceuticals are available in the market. In agriculture sector, transgenic crop are under cultivation increasingly. General awareness on biotech product and process development has brought public perception that has greater importance than any other technology in the global arena. The aim of this article is to present an overview of India's endeavors in the area of biotechnology.

Biotech Industry Backgrounds

The biotechnology sector is booming across the globe. Biotech companies are pioneering new technologies, platforms, industry segments and business models. According to an estimate, the global biotechnology industry has expanded to the tune of about US$ 250 billion. Global R&D expenditure in the private and public biotech sectors is around US$ 4.4 billion with over 95% of the total in the industrial countries.

1 The author is affiliated to the Department of Biotechnology. The views expressed are of author's and not necessarily that of the Department of Biotechnology

The developing countries find applications of biotechnology in diverse areas viz. hybrid seeds, tissue culture plants, fermentation derived products including antibiotics, bakers' and distillers' yeast and biological cultures. Biotech products are largely composed of therapeutics and diagnostics for human healthcare, industrial enzymes and contract research services. Considering the global trends on pharmaceuticals, 70% of the products under clinical testing are rDNA products or gene based products emanating from small and medium size companies. Approximately 25% of R&D is outsourced by drug majors. The baseline revenues of Contract Research Organizations (CROs) in 2000 were estimated at US$ 7 billion and are growing at 30% per annum. Outsourced R&D is estimated to account for 40% of R&D expenditure by the year 2008. The R&D expenditure of the top 20 pharma majors has more than doubled over the years, i.e. from US$ 20 billion in 1995 to US$ 40 billion in 2000 and it is expected to increase exponentially to more than US$ 100 billion by the year 2010. The genomics, proteomics and other informatics-based research is expected to expand further to meet the challenges for new drugs.

Asian biotechnology is focusing on strategies to become competitive at the global level. Singapore is currently considered the service hub in the South Asian region. The country is building up its biotech sector with a major focus on gene therapy, agri-sciences, bioinformatics, genomics and proteomics. Malaysia is focusing on the establishment of trade and investments to take advantage of the immense market potential of their close neighbors. China and India are attracting attention and deals to increase access to large and growing drug markets by lowering the costs of drug development. The number of deals in vaccines was energized by concerns around the avian flu, SARS, and biodefense products, while looming patent expirations in the generics segment. Asia-Pacific companies are forming partnerships to position themselves in an environment characterized by vigorous growth, increasing competition and sweeping regulatory changes.

China is the leading investor in R&D on crop biotechnology in developing countries, followed by India. China has an estimated 400 biotech companies, as against India's 200. China's biotech industry could be the fastest growing industry in the next 15 years and the China has already invested US$ 1.8 billion in it. There are 200 government-funded laboratories conducting biotech research in China. Their scientists have decoded the rice genome and they've commercialized bio-engineered crops and plans to increase funding of agri-bio research to US$ 500 million and more annually. In context of the size and

growth of the current Indian biotechnology market vis-à-vis the Asian and global market, India has great potential to become one of the most significant players on the global arena by 2010.

India's biotechnology industry is worth only US$ 1.1 billion which constitutes around 2% of the global revenues with a market share of US$ 705 million, investments to the tune of US$ 137 million and exports being 59% of the revenue with 37% growth over the previous year. Very few companies recorded revenue in excess of US$ 22 million in the sectors like health care, animal health, agri-biotechnology, drugs and biopharmaceuticals. The current market size of biotechnology products in India is expected to grow US$ 5 billion by 2010 and improve its share in the global marketplace to about 5%. India ranks third in Asia after Australia and China and in top ten in the world. US ranks number one followed by Germany, Scandinavia, UK and France in Europe. Successful initiatives in drug discovery, clinical development, bioprocessing and global marketing have raised to deliver products and solutions to partners and customers in over 50 countries.

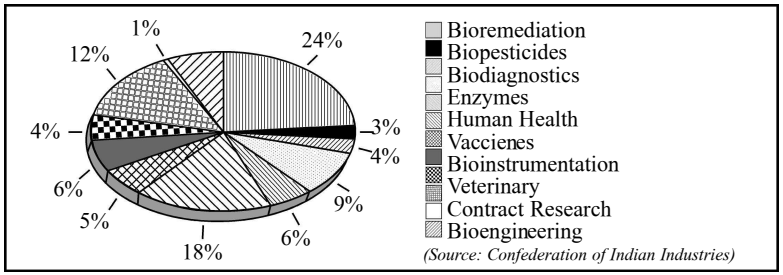
With an estimated growth rate of 55%, India is expected to reach over US$ 3 billion by the end of 2006 with the competition mounting between the Asian countries to establish their position as good environments for the industry. Biotechnology sector in the Asia-Pacific region exceeded rest of the world, with a 46% increase in revenues and significant progress toward profitability. An Australian pharmaceutical company, CSL Ltd., boosted the country's biotech revenues by over 60%, allowing the Australian biotech sector to reach profitability ahead of the U.S. and Europe, and propelling focus on biotech as a strategic priority segments as contract research and manufacturing, vaccines, information technology and bioinformatics, traditional medicines, and stem cells.

Emerging Segments for India

India is among the first few countries in the developing world to have declared the importance of biotechnology as a tool for advancing growth in the agriculture and health sectors. The Government of India established the National Biotechnology Board (NBTB) in 1982 as the apex body to identify priority areas and evolve a long-term plan for the development of biotechnology. Later, the potential and benefits of this industry were realized at an early stage and the Department of Biotechnology (DBT) was formed in 1986 that has now become the central agency, responsible for policy, promotion of R&D

and for international cooperation and manufacturing activities. India is already in a pivotal position to secure a significant share in important segments such as vaccines, diagnostics and clinical trials. It is considered that that India already has the largest vaccine production capacity in the world. By 2010, India could open new frontiers by developing the globally fast growing segments facilitated by the capabilities developed indigenously.

Table 1: Sectoral Break up of Biotech Market:



(Source: Confederation of Indian Industries)

It is estimated that vaccines, contract research, agriculture and human health sectors comprise as much as two thirds of the total market. It is further estimated that health care products would dominate the Indian biotech market, roughly 40% of the total market by the year 2010 followed by agriculture of about 30%. Contract research and bioinformatics would pick up and account for as much as 25% of the biotech market. An estimation by CII shows that the agri-biotech would see growth rates of as much as 60%, diagnostic and therapeutics of about 25% and Vaccines of about 15%. These figures clearly indicate good prospects for biotech industry in India.

Bio-Service Sector

On the threshold of the new biotech revolution, numerous companies have sprung up to take a piece of the exponentially growing market worldwide for products and services. India's population has a very interesting demography that creates almost a perfect environment for biotech companies to shift bases here. The biotech industry has also seen substantial growth over the past quarter century and poised to grow in the years to come. The Bio-services market is estimated to grow very fast. Two BT cotton companies, Mahyco-Monsanto and Rasi Seeds established in bio-agri sector shown the fastest growth, though it accounted for only 6.95% share of the total market. Bio-industrial sector

accounted for 6.74% of the total market. Bioinformatics sector registered 25% growth and accounted for 2.11% of the market. The total biotech exports from India stood close to US$ 455 million and contributed to 42.17% of the total biotech business. Table 2 summarizes the turn over of sales of major biotech products (current and forecast until 2010).

Table 2: World Biotech Product Sales Forecast

Secto	Year		
	200	200	201
Human Therapeutics	24	40	72
Human Diagnostics	5	7	11
Agriculture	2	4	8
Specialty Products	1	2	5
Total	32	53	96
Biotech Tools	3	5	8

Biotech tools have a wide range of products ranging from special enzymes (restriction enzymes, DNA modifying enzymes etc) used in recombinant DNA technology to ultra centrifuges which help purify DNA or fermentors to grow bacteria or automated sequences (and their reagents) which help sequence DNA so on. This industry supplies products and services as support for biotech industry. Increasing number of pharmaceutical companies finding it difficult to conduct entire drug discovery process-in-house and they are looking for the ways to minimize costs. India has become a very attractive base as the cost of infrastructure is relatively lower compared to other nations. Foreign companies also benefit from cheaper qualified workforce available in India. India produces enough qualified graduates each year thus companies looking to expand their operations can easily do so without facing a shortage in labor.

Healthcare and Pharmaceutical Sector

Biopharmaceutical industry is the single largest contributor to the total biotech business. The sector with total sales revenues of US$ 811.4 million accounted for more than 75% of the total business in India and registered about 30% growth, primarily driven by the vaccines business. Several large pharmaceutical and biopharmaceutical companies scattered around the country that

manufacture and export to global markets, such as Biocon, Intas and Zydus-Cadila to name a few.

The Indian pharmaceutical market is growing very rapidly. According to a study by Mckinsey, Indian Pharma industry is expected to grow to an innovation-led US $25 billion industry by 2010 with a market capitalization of almost US $150 billion from the current US$ 5 billion generic based drug industry. The vaccine market is expected to grow by roughly 20%.

India can achieve a global position in clinical trials hub of the world. Even if 15% of all clinical trials were to be outsourced in the next 3 years, US$ 4 billion worth of clinical trials will be conducted in developing countries and a large part of this opportunity can be secured by the Indian biotech industry. It is estimated that India can secure around US$ 250-300 million of the global clinical trials market by 2010. Clinical trial is a large opportunity given the number of patents but simply does not have the required number in terms of investigators and Clinical Research Associates (CRAs). A large number of focused training programmes are being conducted to address this gap. To reduce drug development cost through cost reduction in clinical trials, opportunities lies for the countries like India to provide low cost clinical trials. Opportunities for biotech business are vast through IPR and commercialization.

Indian R&D establishments like Central Drug Research Institute (CDRI) have produced a drug to treat cerebral malaria. Themis, and Indian pharma company sells it under the brand name E-Mal to 48 countries, many of them in Sub-Saharan Africa, at affordable prices. India's Shantha Biotech firm has come out with a recombinant DNA vaccine (Shanvac) on Hepatitis B. This vaccine was being sold for US$ 15 per dose. The prices of the vaccine kept on tumbling till they came to less than a dollar per dose. Shanvac today supplies this vaccine to UNICEF for 50 cents. This is a spectacular reduction in price by a factor of thirty. India's unique S&T capacity as well as low-cost manufacturing capacity can benefit India and the whole world. Opportunities are set on fermentation technology and innovative research skills in drug synthesis to focus on biopharmaceutical from small molecules to biologicals to develop, manufacture and market leading-edge drugs for human healthcare. Challenges may lead to good vaccine development for malaria and HIV/AIDS. New drug discovery research can take about 15 years and investment up to US$ 1.5 billion to move a molecule to the market. India has distinct comparative advantage to sustain biopharma sector and can be a major partner in the process of discovery, development and delivery of such healthcare products. For this,

specialized manpower like MDs and PhDs are in acute short supply to conduct trans-national research. DBT has initiated a number of links between medical colleges and research institutes.

Discovering New Medicines from Nature

Nearly 40% of the new drugs approved by the Food and Drugs Administration, USA were either directly or indirectly derived from natural products. In India, traditional system of medicine is an integral part of the health regime. Research and Development (R&D) is continuing to develop cures for diseases that have affected people for decades and even centuries. Medical tourism is high thriving activity in India with huge employment potential. Biodiversity treasure and rich traditional herbs provides an ideal combination for discovery and patenting of new drugs would be encouraged for screening, combinatorial synthesis, structure elucidation and profiling of bio-molecules for drug development. Neutraceuticals, functional foods that are used in preventive health care such as weight regulation, stress management, antioxidants, are another class of health care products having rich potential and will be the focus. Leading Ayurveda companies have large number of formulations, Ayur-clinics and health resorts. Out of the marketed classic formulations, a large number is of patented drugs. Herbal plantations are coming up in various states and coastal areas to meet the companies' requirements for potential Ayurvedic medicines and medical tourism. Creation of an advanced multi purpose analytical testing and standardization laboratory approved by the National Accreditation Board for Testing and Calibration of Laboratories will cater to the needs of the Ayurvedic and Pharmaceutical industry for meeting international standards.

With the advent of GATT in 2005, many multinational companies have set up their operations in India and investing in research and development of new products to compete in this market. Large career opportunities lie in biopharmaceutical sector due to increased awareness of healthcare and availability of newer medicines. It creates opportunities in entrepreneurship development, rural marketing, contract research outsourcing, medical insurance, quality control and logistics etc. This is a very vibrant and dynamic sector and offers immense scope for research and development activities.

Agriculture, Non-food Crops and Biodiversity

India has one of the largest agriculture sectors in the world and varied climatic zones, favorable for research and development products applicable worldwide. India has an excellent scientific infrastructure in agriculture, rich bio-diversity and skilled and low cost human-power. In a report by Ernst & Young, it is expected that the neutraceutical market is roughly US$ 532-638 million presently. The green revolution technologies with the productivity gains have brought about a major impact on increased crop production in the last five decades. However, the benefits of these technologies have leveled off. For example, the yield growth has slowed down from an average of 2.9% per year for cereals in 1967-82 to 1.8% in 1982-94. This may be due to depressed crop prices, increased input demands and resultant increase in fertilizer and pesticide prices and increasing water scarcities. In agriculture, the major emphasis is given on crop improvement through development of transgenics, genetic transformation, refinement of protocols for tissue culture and demonstration of horticulture, forest and woody species, bioprospecting and molecular taxonomy, biopesticides, biofertilizers etc. The focus is also on salinity, drought resistance, pest resistance and nutritional enhancement among others. Realizing the importance of bioresource conservation, the major emphasis is on inventorization of microbial, marine, animal and plant resources, silkworm, medicinal plants and studies on functional genomics. Unlike the west, which depends on relatively few plants and animals for food, India has an impressive variety of plants and animals in agricultural production, the majority of which are not the subject of research projects in Western nations. This in itself suggests scope for rapid improvement.

Attempts are being made on development of transgenic wheat with more protein content and higher lysine content. Transgenics of rice, brassica, mungbean, pigeon pea and some vegetables like potato, tomato, cabbage and cauliflower and cotton are under development. Marker assisted breeding programme is expected to be introduced in farmers' field for better quality yield. Laboratory research and field trials are being conducted on various genetically modified crops that include rice, tobacco, potato, tomato, brasssica, mustard/rapeseed and cotton. The major emphasis is either on pest resistance or abiotic stress. However, so far serious attention is yet to be given on enhancement of nutritive qualities in the GM crops. Recently, genetically modified seeds for the cotton industry launched by India based company, Mahyco, which attempts to increase the yield manifold and decrease the use of pesticides. The results for the new genetically modified cotton are encouraging.

Focus on fast-growing herbicides segment is currently on. Cultivation of transgenic crops has been spectacular over the last 5 years. The estimated global area of transgenic crops has increased from 1.7 million hectares in 1996 to US$ 44.2 million in 2000. Herbicide tolerant soybeans and cotton and insect resistant corn and cotton account for most of the transgenic crop acreage. Other commercial transgenic crops include herbicide tolerant canola and corn. Most of the transgenic crops are grown in the USA, Argentina, Canada, and China. In Europe, commercial cultivation of GM crops is very limited, primarily due to concerns expressed by environmental and consumer groups.

Marine Resources

Sea food export is one of the highest revenue earners, as it provides direct and indirect employment to hundreds of thousands of people. With its 8000 kilometer of coastline including Andaman & Nicobar and Lakshwadeep islands, India has a rich aqua culture and its Marine resource development holds great potential. Environmentally sustainable harvesting of fisheries wealth in the Indian EEZ as well as monitoring environmental health in the coastal ecosystems is the priorities. Upgrading of facilities and creation of new ones for testing and certification for microbial and viral loads and antibiotic, hormone and chemical pesticide residues are being attempted. Other commercial aspects on hatchery production protocols are also being attempted for variety of sea foods as well as marine ornamental fishes establishment of onshore and sea farms for shrimps, crabs, fin fish, shell fish, seaweeds, micro algae and other related marine products viz. agar-agar, aligns, anti-oxidants, neutraceuticals, seafood waste utilization towards development of byproducts. Apart from application of biotechnology especially in quality enhancement, establishment of gene banks and fish bio-reserves, R&D is required for genetic improvement of disease-resistant fish, productivity enhancement in fish, development of promoters for upgrading eco friendly, aqua-farming systems, biotech support for the large scale production of monosex species of endemic or exotic high yielding fish varieties, technology standardization for fixing systemic feeding and seeding schedules, and the application of standard units, legal regimes and control measures on the usage of probiotics and antibiotics. Marine bio-prospecting will be a major theme for novel anti tumour and immuno-modulatory agents from marine organisms such as sponges and blue green algae, e.g., *Lyngbya Majasculata;* marine microbes and saline fermentation for therapeutic and industrial applications; biologically active substances from amphibians and arthropods; combinatorial genomic which allows inte-

gration of DNA from non-culturable microbes into genomes of easily culturable host microbe organisms.

Biomining

The indiscriminate use of chemical pesticides and fertilizers are polluting the environment and sustainability of agriculture apart from destroying fauna and flora and aquatic species. Encroachment, siltation and eutrophication are destroying wetlands. Oil spills toxic effluents and sewage, blasting and dredging, collection of ornamental and undersized fish, trawler fishing, nylon nets, destruction of coral reefs and hot water from nuclear plants are destroying marine life. Chemical pesticides, sewage and other organic wastes and sand mining are destroying rivers. Forests are cut for timber and urban use. Underground mining of minerals and blasting of rocks goes on unchecked. There is no natural resource that is not under threat. Bio fouling of backwaters and rivers has assumed alarming levels in coastal areas. Similarly, pollution due to chemical and industrial effluents is a major environmental hazard. Although, prevention of this pollution is better than cure, biotechnological tools such as consortia of microbes and viruses as well as enzymes can be used for bioremediation. For instance, microbe and enzyme mediated solutions are feasible in the degradation of phonemics and tannins released in coir rotting as well as in biodegradation and by-product development from coffee pulp waste. Coir pith, a waste product in the coir industry, is already fast replacing peat moss as a multi million dollar industry. GMOs are now developed for bio-mining, or the inexpensive extraction of precious metals from low-grade ores using microbes. Plants are also developed to mine precious metals (e.g. Brassica, which is being developed to concentrate gold from the soil in their leaves).

Bioinformatics

Bioinformatics and information technology are much needed strategic initiatives for creation and access to the database on unique biodiversity and the related traditional knowledge in herbal medicines, the genetic traits, agronomic features and disease resistance sensitivity profiles of specialty spices and commercial crops, marine resources, the clinical/genetic information on diseases such as cancer, diabetes, cardiovascular-ailments and mental disorders. This will be extremely valuable for research and product/process development in these areas. Bio informatics as a service platform has great potential for several focus areas for catering to domestic and international clients for contract sequence services (synthesis and mapping (seeds, leaves, blood/organ tissue, purified DNA)) and molecular marker services (DNA fingerprinting, molecular markers and ESTs (Expressed Sequence Tags). Awareness courses on Bio informatics, genomic, DNA fingerprinting apart from specialized higher courses on physical mapping, YAC libraries, chip technologies and hardware and software support services (web hosting services for clients/institutions Data storage and documentation services). There is a network of 64 bioinformatics centers spread all over the country.

Interaction with Scientific Community and Researchers

DBT has been interacting with more than 5,000 scientists per year in order to utilize the existing expertise of the universities and other national laboratories. It has developed a very strong peer reviewing and monitoring mechanism. DBT has a close interaction with the State Governments particularly through State S&T Councils for developing biotechnology application projects, demonstration of proven technologies, and training of human resource in states and union territories. Since it inception, DBT has pursued programs to generate required specialized/trained human resource at postgraduate level in multi-disciplinary and application oriented field of biotechnology. As on date, about 61 post graduate teaching courses are being supported on a regular basis and DBT is giving a major push to provide an enabling policy framework for development of biotechnology industry in the country. This includes establishing a science based on professional regulatory system, promoting of industry-academia partnership in R&D, building competence in technology transfer and commercialization, building infrastructure-repositories, biotech parks, regulatory toxicology, safety assessment etc. On the international front, DBT has been instrumental in promoting biotech collaborations and enters into agreements with various countries through bilateral tie-ups. DBT has been deeply involvement with the scientific community through a number of technical task forces, advisory committees and individual experts in identification, formulation, implementation and monitoring of various programs and activities. Specialized manpower is certainly a scare resource and the DBT and other agencies alike are trying to address this through several initiatives to develop ability to build and leverage skills, investing in training and development activities for specialized skill building and integrated the network skills.

IPR and Patent Issues

India's commitment to the product patent regime is now aligned with the global IPR system. It can be possible that India should enable biotech innovation in areas such as diagnostics, recombinant bio-therapeutics, stem cell biology, bioinformatics, proteomics and genomics. Considering the growth rate to be constant at around 30%, the biopharmaceutical segment has the potential. Patents have attracted much of the attention for gap between rich and poor countries in access to medicine, especially for wide range of drugs to respond to most common diseases in developing countries. However, specialized drugs like that for HIV/AIDS drug resistant tuberculosis etc. are not accessible to the poor people. There is a major reinterpretation of patenting laws all over the world on patenting living organisms and their parts and processes, including the cells and genes of humans. The ethical and moral issues in the patent system play more important role where the patent system should be applied for more societal benefits. In India, patent filing in the area of biotechnology is based on the applications filed in the Indian Patent Office from 1995 to June, 2003. A total of 2378 patent applications have been filed in India till June 2003 and these applications are both conventional and PCT. The Council of Scientific and Industrial Research (CSIR) is the largest applicant in filing patents in the areas viz. hybrid, tissue culture, embryo, cell line, enhancer, marker, transformation and promoter etc. Many of these applications may be products, drugs/pharmaceuticals, genetically modified micro-organisms, naturally occurring RNA/nucleic acids and genes. The protein, the product of genes has opened a new branch in biotechnology proteomics and about 700 patent applications were filed for conventional and PCT applications including applications for enzymes. DBT emphasizes the development of all facets of IPR in biotechnology and helps in protection of inventions through patenting or through other suitable methods by giving importance for innovations and industrial development.

Till 2005, India only recognized process patents, however, in 2005 India committed to the product patents regime aligning its IPR system to global standards. It is a major step to achieve recognition its IPR system globally and to attract foreign investments, as there is larger scope at the cutting edge technology and product development, a strong product patent regime and its implementation. Indian Patents Bill recently passed by the Parliament allowing 20-year patent term, inline with provisions made by WTO and TRIPS.

Technology Transfer Issues

During two decades of the existence of DBT, the promotion and acceleration of development of biotechnology in the country was visible through several R&D projects, demonstrations and creation of infrastructural facilities and significant contributions to the growth and application of biotechnology in the broad areas of agriculture, healthcare, animal sciences, environment, and industry, which have been culminating into products and processes. Over the last ten years, some 50 technologies covering the areas of agriculture, aquaculture, human health, animal productivity, environmental biology etc. have been transferred to the industry or other user agencies. Some of these have already reached the market place. Numerous research publications, quality post-doctoral students, several technologies transferred to industries and patents filed including US patents, have been achieved through the efforts of the DBT. Research has been funded in genomics, proteomics, molecular basis of disease, pharmaco-genomics, stem cell biology, nano-biotechnology, and other frontier areas. The product development focus is on a new generation vaccines, diagnostic kits and therapeutics. In addition, a bioinformatics network established in major research institutions/universities of the country is being used to address major problems of biology and as an aid to drug design. DBT has been instrumental in bringing together academia, industry and research institutions to work coherently for a strong IPR system in the country.

The Ministry of Science and Technology, Government of India has brought out the guidelines for Technology transfer and intellectual property rights, which help in enhancing the motivation of scientists, research institutions and universities in various research and development projects funded by various departments of the Ministry of Science and Technology. The institution shall be encouraged to seek protection of IPR rights and granted ownership of intellectual property in respect of the results of R&D. The ownership of such IPRs can be retained and institutions, where the research is carried through funding by Central / State Governments, are permitted to take steps to commercially exploit patents on exclusive or non-exclusive basis. The owner institutions are permitted to retain the benefits and earnings generated out of the IPR generated. The inventors and other associated persons are allowed to share the royalty benefits.

Patent Facilitating Fund set with the owner institution(s) and the revenues generated from IPR are utilized to create a patent facilitating fund for updating the invention(s), filing new patents and protecting the IPR against infringement and for building competency in the area of IPR and related issues and the

institution. With the new patent regime in place, collaborations on the research front are likely to rise. India R&D of science and technology has been mostly government sponsored. India has a huge infrastructure and research network in place driven by nodal agencies like DBT, Indian Council for Agricultural Research (ICAR), The Council for Scientific and Industrial Research (CSIR) and Indian Council for Medical Research (ICMR). The emphasis now has been increased in the area of private public partnerships and most of the companies are catching up with discovery-led innovations.

Regulatory Issues in Biotechnology

In order to evaluate the risks related to biotechnology, a distinction has been suggested between technology-inherent risks and technology-transcending risk, as it is associated with threats to human health and the environment. It needs to be addressed by proper risk management covering issues relating to loss of biodiversity through biosafety policy and laws. Biosafety issues are not just related to GMOs alone. Traditionally, there have been regulations on manufacture, consumption, export and import of chemical pesticides, processed food and food additives, drugs, cosmetics etc. The procedures for assessment of toxicity, alergenecity, non-target affects have also adequately addressed all over the world while dealing with the drugs and pharmaceuticals. Therefore, both developed and developing countries have considerable experience in dealing with the food and environmental safety issues related to traditional technology derived from products and processes. The need for biosafety regulations to deal with food and environmental safety of rDNA products was realized in late 1970s. The products were, however, commercialized in late 1980s. Since the regulations of GMOs are of recent origin, they would also require adequate time for achieving stability in terms of procedures, framework and guidelines based on continuous feedback from knowledgeable stakeholders.

The Indian Acts, rules and regulations as well as procedures for handling of genetically modified organisms (GMOs) and rDNA products have been formulated under the Environment (Protection) Act (EPA) 1986 and Rules 1989. The rules in general cover manufacture, use/import/export and storage of hazardous micro-organisms, genetically engineered organisms or cells and came into force from 1993. India has a sound and widely acknowledged framework of bio-safety guidelines to deal with evaluation, monitoring and release of genetically engineered organisms and there are more than 106 institutional biosafety committees. A set of rDNA guidelines were brought and in 1990 covering genetically engineered organisms, genetic transformation of plants and animals, mechanism of implementation of biosafety guidelines, containment facilities under three risk groups. The guidelines have been revised matching with the needs of scientific know-how in 1994 as "Revised Guidelines for Safety in Biotechnology". During 1998, to provide special review for genetically engineered plants, "Revised guidelines for Research in Transgenic Plants and guidelines for Toxicity and Allergenecity for Evaluation of Transgenic Seeds, plants and plant parts" had come into force.

A regulatory framework has been set up for approval of GM crops and rDNA products. Recently, the Government of India decided to make changes to the Drugs & Cosmetics Act to make it more globally compatible. In order that biosafety guidelines are strictly followed to prevent damage to human health and environment, a three-tier mechanism has been instituted in the country. DBT provides recognition to Institutional Biosafety Committees (IBSC's) and also services a Review Committee on Genetic Manipulation (RCGM) for regulating research and limited field experiments. On the recommendations of the RCGM, the Genetic Engineering Approval Committee (GEAC) of Ministry of Environment and Forests provides clearance from safety angle for commercial purposes. Ministry of Health and Family Welfare provides final licenses for recombinant products of healthcare in accordance with Drugs and Cosmetics Act implemented by office of the Drug Controller of India. Separate guidelines for clinical trials of recombinant products and ethics are also published. State level committees have also been set up for proper coordination and follow-up. For the first time, guidelines for clinical trials of recombinant roducts / biiologicals, as approved by the Drugs Controller General of India have been publicized. Many contained field trials have been conducted under different agro-climatic conditions of the country using transgenic plants.

With the existing regulatory mechanism in force, so far 10 r-DNA drugs have been approved for marketing, 4 industrial units are manufacturing recombinant hepatitis vaccines locally and indigenously produced erythropoietin and G-csf are also in the market. There are several novel processes to produce r-DNA vaccines and drugs are in advance stages. In commercial plants viz. cotton with insect resistant BT gene has been given approval for commercial release in March, 2002. About 252 institutions (public and private) are working in r-DNA research by constituting Institutional Biosafety Committees (IBSC). Regulatory policies are in general compliance friendly.

National Biotechnology Regulatory Authority

To address the concern of both public and private sector, efforts are under way to establish a single window regulatory mechanism or structure to promote speedy commercialization of recombinant products and processes. A competent National Biotechnology Regulatory Authority (NBRA) is proposed to establish for agriculture products/transgenic crops, pharmaceuticals/drugs and industrial products and transgenic food/feed and transgenic animal/aquaculture. The authority is to be governed by an independent administrative structure to evolve suitable proposals for consideration by inter-ministerial group. A special regulatory cell is likely to be created to build capacity in the country for scientific risk assessment, monitoring and management, to foster international linkages, support biosafety research, to obtain and review feedback from different stakeholders and provide support to industry and R&D institutions to play promotional and catalytic role. NBRA would also evolve new guidelines on transgenic research and product/process development in animal, aquaculture, food, phyto-pharma and environmental application after its set up.

Biotechnology Parks and Incubators

Indian biotechnology sector has, over the last two decades, taken shape through a number of scattered and sporadic academic and industrial initiatives. DBT is supporting creation of incubators in biotech parks promoted by a private industry or through public-private partnership. Establishment of Biotechnology Parks plays a pivotal role in contract research, technology development, incubation, scale-up and commissioning of Biotech projects. It provides bioresource centre as a hub to provide infrastructure, equipment. facilities and services to assist the tenants and clients of the park and housing Technology Incubator with the capability to develop and license, in collaboration with R&D institutions, proprietary technologies to the tenants and clients in the State and elsewhere. It serves as a training facility where technology skill packages can be imparted in biotech streams, e.g., molecular biology, genetic transformation, immunology, tissue culture, fermentation and down stream processing and instrumentation. Proposals are also being examined to declare special economic zone status (SEZ) to Biotechnology Parks as an integral part of NBDS. These SEZ units would be benefited through pilot scale incubator facilities on the lines of software technology parks, already existing in India. The department encourages private players and private-public partnerships to create

such incubators in biotech parks and offers a grant up to 30% of the total cost or up to 49% in the form of equity for such incubators.

The industry is spread across the country. Several states have biotech policies and also biotech parks to promote the industry. It is the largest in revenue generation through bio-industrialization in the country. The industry comprises over 280 companies that are into biotech business and another 120 that supply technology products to these biotech companies. DBT is promoting establishment of national facilities and a number of programs regularly and extending financial/logistical support for establishment of biotechnology parks, biotechnology incubators, training and pilot projects. The DBT has been extending financial and logistic support for the establishment of biotechnology parks, biotechnology incubators, training and pilot projects in various states. Besides, it is offering the technical support for identification, implementation and review of the projects announced by various states. The DBT had a projected a budgetary allocation of US$ 5.5 million towards assistance for technology incubators, pilot projects, biotechnology parks and biotech development fund for the year 2005-06 and presently supporting activities on development of Biotechnology Park at various states. The department has also initiated a national wide consultation with stakeholders to create a strategic framework for development of biotechnology in the states.

Bioclusters

The government is considering launching special programs like biotech cluster innovative program, where R&D set up by the industry could be supported by providing competitive research grants with specific objectives to economic development of the country and alleviates human sufferings. It is not only the government, but also all individual stakeholders such as suppliers, venture capitalists, universities, research organizations, service providers and networking associations that are also contributing to the development of bioclusters in India. Clusters in knowledge based sectors like biotechnology, medical biosciences, life sciences, and information technology play a very important role in promotion of biotechnology research, use and development. Biocluster in terms of development of biotechnology industry have already grown unintentionally as clusters and such clusters are mainly located in the state territories.

However, the cluster concept in India is still at a nascent stage as an area can evolve as a meaningful cluster over a period of 10-15 years. It is prema-

ture to say when bioclusters like Research Triangle, Boston, Cambridge and the East England, San Francisco Bay will happen in India. The present biotechnology industry growth in major cities will emerge as a successful biocluster provided availability of capital and regular regional networking for free flow of information and fulfillment of gaps in next 5-10 years. The respective government policies and scientific ambiences have been responsible for the growth of such clusters.

The state and central governments have been taking many initiatives to support the biotech industry through policy initiatives and announcing incentive packages to the industry and entrepreneurs. In future specific clusters like proteomics, genomics and drug discovery are likely to come up. The regulatory and fiscal framework provides incentives that influence company formation and growth within clusters. The programs initiated by DBT like setting up of animal facility stem cell centre, incubation facilities and reengineering the existing institutions that would help in the development of bioclusters in metro cities.

Networking of Biotech Development

The success of many biotechnology products globally, rise of South Asian countries like China, Korea and Taiwan etc. is of national concern to Indian industry to compete. In India, organizations like Association of Biotechnology Led Enterprises (ABLE), Association of Diagnostic Manufacturers of India (ADMI), Association of Contract Research Organizations (ACRO), Indian Society for Clinical Research (ISCR), All India Crop Biotechnology Associations (AICBA), Confederation of India Industry (CII) and All India Biotech Association (AIBA) working for the growth of the biotechnology industry. AIBA closely associated with biotech industry suggesting fundamental restructuring of the regulatory system and emphasis to create resources for the private sector. Although about 50 GMOs have been approved for commercial production, India is yet to have its first large scale GMO field trial and only one home grown recombinant product hepatitis-B vaccine has been approved. Several lacunae are due to steps required to be followed in approval of biotechnology products, as they have to pass through monitoring committees at district and state level and then review committees at the government level, depending on the product's end use a process governed by 1986 Environmental Protection Act. Even if a product makes it through the committees, it needs to be pursued at the Drug Controller General on the basis of the Drug and Cosmetics Act. Thus, India's product approval process is more complex and time consuming than that of US and it lack transparency, which affects foreign agencies from collaborating with or investing in India's biotechnology sector.

It is also proposed to set up a central body, Biotechnology Parks Society of India (BPSI) for the promotion of biotechnology parks in the country on the lines of the Software Technology Parks of India (STPI). The BPSI should be run by professionals having experience in the areas of biotechnology, knowledge in Acts and Rules relevant to biotechnology and management skills. The existing parks can become members of these new biotech parks. The DBT is looking at a scheme to provide incentives to biotech units located in the parks. As part of this scheme, biotech companies located in biotech parks are to be allowed a five year time frame to meet the export obligation norms under the SEZ scheme. This measure helps to address the long and unpredictable gestational time lines that are inherent to biotech product development. With these initiatives, the biotechnology industry in India can reach new heights. The Government of India has been increasing its outlays to provide financial support to this industry. Government of India is also setting up a venture capital fund, to support small and medium enterprises. The initiatives taken by both Central government and State governments have given a big boost to the biotech industry in India. Foreign companies looking for new markets and to expand facilities to much more economical locations can find India ever more open and responsive to their needs.

Biotech for Women Empowerment: A Successful Entrepreneurship Park

The country's first biotechnology park for women has been set up near Chennai with the twin objective of harnessing Tamil Nadu's rich bio-wealth and addressing the gender bias that exists in society. The country's first biotechnology park for women, the Golden Jubilee Biotechnology park for Women, an autonomous registered society, is part of the Chennai based M.S. Swaminathan Research Foundation (MSSRF) and was established in 1996. The basic aim of the park is to utilize bioresources of the region and strength the women to develop their full potential. Apart from putting in place a sustainable system to make use of the rich bio-wealth of the State, the park addresses the problem of gender bias. Women make up half the world's population and perform two-thirds of all works, but receive a tenth of the income and own less than one-third of all works, but receive a tenth of the income and own less than one-hundredth of the world's assets. This discrimination needs

to be addressed and the role of women as innovators and agents of economic and social change should be emphasized. The park and the facilities there have been developed at a cost of US$ 0.28 million with raised up banking finance. The park offers decentralized services to promote services of biotechnology based enterprises in medicine, food and agriculture. The societal development programme of DBT has received special attention benefiting large number of target population viz. women, rural folk and deprived community through extending the income and employment generation activities through softer options of biotechnology by demonstrations and trainings to have access to new technologies of products promoting its mass use for health care, nutritional security and environment etc.

In addition to the state governments approach for creating conducive environment for early biotech players, the DBT in its Draft National Biotechnology Development Strategy report also noted its intention to promote and support at least 10 biotech parks by 2010. Each park will necessarily meet the qualifying criteria related to the characteristics of the location, a viable business plan, management strategy and a clear definition of the partners and their roles. The DBT is supporting research through public funding to promote innovations in small and medium enterprises by a new scheme 'Small Business Innovation Research Initiatives (SBIRI)' to help in developing products and processes that have high societal relevance.

Institutes of Excellence

Research organizations are gearing up to face the new challenges ahead - not only the new regulatory policies but also completion from the emerging private sector. Over the years, DBT has set up Centers of Excellence viz. National Institute of Immunology (Delhi), National Centre for Cell Science (Pune), National Brain Research Centre (Gurgaon) and National Centre for Plant Genome Research (Delhi) etc. to facilitate focused research in various fields like immunology, neurology and cell science among others.

The National Centre for Plant Genome Research (NCPGR) was established to carry intensive research on various facets of both fundamental as well as applied aspects of plant molecular biology. It aims at nutritional, structural and functional genomics of various plant systems with the ultimate goal to manipulate plant genes to breed improved varieties of crop plants.

The National Institute of Immunology (NII) has the mandate to undertake, aid, promote, guide and coordinate research in basic and applied immunology.

Over thirty independent research groups work in a broad range of modern biological disciplines. The research interests of the current groups join together in four major areas viz. gene regulation, immunity and infection and molecular design and reproduction and development.

The National Centre for Cell Science (NCCS) performs research and development in various areas including cell biology, cancer biology, immunology, diabetes, signal transduction and gene regulation. The NCCS also serves as a national cell repository and supplying cell lines to scientific institutions within the country.

The National Brain Research Centre (NBRC) provides infrastructure facilities and has a coordinated multidisciplinary team to work at the frontiers of neuroscience research and network the existing groups and whenever required, create satellite units to catalyze the overall growth of this discipline in the country. Besides research, the NBRC provides a national level nucleus for comprehensive training and teaching in diverse fields of neurosciences. Various other institutions and universities are part of its network activities. In addition to this, it is also working on three research areas namely molecular and cellular neuroscience, systems neuroscience and theoretical neuroscience.

Council for Scientific and Industrial Research (CSIR) has a network of laboratories and field stations/extension centers/regional centers all over India to undertake R&D in several disciplines including biotechnology. It currently employs more than 22,000 highly qualified multidisciplinary professionals. ICAR promotes science and technology programmes in agricultural research and education and carries out research directly through ICAR institutes and national research centers, project directorates and also in association with the State Agricultural Universities (SAUs) through the all India coordinated research project systems. This vast network of ICAR has manpower of about 30,000 personnel out of which nearly 7000 are engaged in active research and its management. The 30 SAUs employ about 26,000 scientists for teaching, research and extension education; of these over 6,000 scientists are employed in the ICAR supported coordinated projects. The ICMR formulates, coordinates and promotes biomedical research in India. Its network consists of 21 permanent research institutes/centers (national institutes) located in different parts of India and six regional medical centers. The ICMR national institutes offer opportunities for research in the area of medical biotechnology.

Specialized infrastructure and skilled human research is critical for promotion of innovation in research and product / process development. To achieve this, DBT has projected to support 50 centres of excellence in focused themat-

ic areas in existing institutes / universities across the country on improved crops, vaccines, diagnostics, nano-medicines and nano-agriculture, environment friendly technology, stem cell therapy, animal biotechnology, seri-biotechnology, plant based medicines and marine biotechnology etc.

Challenges through BT Strategy

India would evolve the growing partnership between the pharmaceutical and biotechnology industries to create complimentary capabilities in terms of research, products, marketing and manufacturing. S&T policies have focused attention from infrastructure development to defense needs and from socio-economic issues to innovation strategies. In the present juncture, the policies requires addressing the issues arising with the globalization, emerging technologies, challenges posed by agro-biotechnologies and intellectual property rights (IPR). India has already formulated its first Draft National Biotechnology Development Strategy, which outlines the importance of industry oriented research. The skilled human resources should be developed in accordance with the requirements of the industry and hence the educational curriculum needs to be amended accordingly. Further, entrepreneurs should be supported by establishing funds, incubators and biotech parks. The vision of the 'National Biotechnology Development Strategy' is to revolutionize agriculture, healthcare, industrial processing and environmental sustainability. The policy has proposed a customs and central excise holiday for start-up companies and duty-free imports of key biotech R&D items. In order to encourage R&D in the Institutions, Government of India continues to allow duty free import of research tools including tools for biotechnology.

Final Remarks

Although India holds a small share of the global biotech market, it has all the capabilities to become a dominant player. Consumption of biotech products is expected to quadruple in the next decade. India has rich human capital for this knowledge-based industry and has competency in selected areas of biotechnology. India is a significant player on the global arena projected to capture at least 10% of the biotech market by 2010, which ranks among the top 10 biotech hubs of the world. The draft biotech strategy of India covers small business incubation research funding, human resource development, establishment of regional technology centres and centres of excellence, technology transfer and crucial academic and industry linkages through public-private partnership.

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