Draft

NATIONAL BIOTECHNOLOGY DEVELOPMENT STRATEGY

Department Of Biotechnology
Ministry Of Science & Technology
Government Of India

CONTENTS

SECTION I

INTRODUCTION

Biotechnology, globally recognized as a rapidly emerging and far-reaching technology, is aptly described as the "technology of hope" for its promising of food, health and environmental sustainability. The recent and continuing advances in life sciences clearly unfold a scenario energized and driven by the new tools of biotechnology. There are a large number of therapeutic biotech drugs and vaccines that are currently being marketed, accounting for a US$40 billion market and benefiting over a hundred million people worldwide. Hundreds more are in clinical development. In addition to these there are a large number of agri-biotech and industrial biotech products that have enormously helped mankind.

The Indian Biotechnology sector is gaining global visibility and is being tracked for emerging investment opportunities. Human capital is perceived to be the key driver for global competitiveness. Added to this is a decreasing appetite for risk capital in developed countries, which has led to a decline in the biotechnology sector in these regions where survival lifelines are being provided by the lower cost research environs of the developing world such as India.

For a country like India, biotechnology is a powerful enabling technology that can revolutionize agriculture, healthcare, industrial processing and environmental sustainability.

The Indian biotechnology sector has, over the last two decades, taken shape through a number of scattered and sporadic academic and industrial initiatives. The time is now ripe to integrate these efforts through a pragmatic National Biotechnology Development Strategy. It is imperative that the principal architects of this sector along with other key stakeholders play a concerted role in formulating such a strategy to ensure that we not only build on the existing platform but expand the base to create global leadership in biotechnology by unleashing the full potential of all that India has to offer.

Why Biotechnology is Important to India

Biotechnology can deliver the next wave of technological change that can be as radical and even more pervasive than that brought about by IT. Employment generation, intellectual wealth creation, expanding entrepreneurial opportunities, augmenting industrial growth are a few of the compelling factors that warrant a focused approach for this sector.

Vision & Mission:

Biotechnology as a business segment for India has the potential of generating revenues to the tune of US$ 5 Billion and creating one million jobs by 2010 through products and services. This can propel India into a significant position in the global biotech sweepstakes. Biopharmaceuticals alone have the potential to be a US$ 2 billion market opportunity largely driven by vaccines and bio-generics. Clinical development services can generate in excess of US$1.5 billion whilst bioservices or outsourced research services can garner a market of US$1 billion over this time scale. The balance US$500 million is attributable to agricultural and industrial biotechnology.

India has many assets in its strong pool of scientist and engineers, vast institutional network and cost effective manufacturing. There are over a hundred National Research Laboratories employing thousands of scientists. There are more than 300 college level educational and training institutes across the country offering degrees and diplomas in biotechnology, bio-informatics and the biological sciences, producing nearly 500,000 students on an annual basis. More than 100 medical colleges add ~17,000 medical practitioners per year. About 300,000 postgraduates and 1500 PhDs qualify in biosciences and engineering each year. These resources need to be effectively marshaled, championed and synergized to create a productive enterprise.

India is reorganized as a mega bio-diversity country and biotechnology offers opportunities to convert our biological resources into economic wealth and employment opportunities. Innovative products and services that draw on renewable resources bring greater efficiency into industrial processes, check environmental degradation and deliver a more bio-based economy.

Indian agriculture faces the formidable challenge of having to produce more farm commodities for our growing human and livestock population from diminishing per capita arable land and water resources. Biotechnology has the potential to overcome this challenge to ensure the livelihood security of 110 million farming families in our country.

The advancement of biotech as a successful industry confronts many challenges related to research and development, creation of investment capital, technology transfer and technology absorption, patentability and intellectual property, affordability in pricing, regulatory issues and public confidence. Central to this are two key factors: affordability and accessibility to the products of biotechnology. Policies that foster a balance between sustaining innovation and facilitating technology diffusion need to be put in place.

There are several social concerns that need to be addressed in order to propel the emergence of biotechnology innovation in our country such as conserving bioresources and ensuring safety of products and processes. Government and

industry have to play a dual role to advance the benefits of modern biotechnology while at the same time educate and protect the interests of the public. Wide utilization of new technologies would require clear demonstration of the new added value to all stakeholders.

The National Science and Technology Policy of the Government and the Vision Statement on Biotechnology issued by the Department of Biotechnology have directed notable interventions in the public and private sectors to foster life sciences and biotechnology. There has been substantial progress in terms of support for R&D, human resource generation and infrastructure development over the past decade. With the introduction of the product patent regime it is imperative to achieve higher levels of innovation in order to be globally competitive. The challenge now is to join the global biotech league.

This will require larger investments and an effective functioning of the innovation pathway. Capturing new opportunities and the potential economic, environmental, health and social benefits will challenge government policy, public awareness, educational, scientific, technological, legal and institutional framework.

The issue of access to the products arising from biotechnology research in both medicine and agriculture is of paramount importance. Therefore, there should be adequate support for public good research designed to reach the unreached in terms of technology empowerment. Both “public good” and “for profit” research should become mutually reinforcing. Public institutions and industry both have an important role in the process.

The National Biotechnology Development Strategy takes stock of what has been accomplished and provides a framework for the future within which strategies and specific actions to promote biotechnology can be taken. The policy framework is a result of wide consultation with stakeholders – scientists, educationists, regulators, representatives of society and others and reflects their consensus. It focuses on cross-cutting issues such as human resource development academic and industry interface, infrastructure development, lab and manufacturing, promotion of industry and trade, biotechnology parks and incubators, regulatory mechanisms, public education and awareness building. This policy also aims to chalk out the path of progress in sectors such as agriculture and food biotechnology, industrial biotechnology, therapeutic and medical biotechnology, regenerative and genomic medicine, diagnostic biotechnology, bio-engineering, nano-biotechnology, bio-informatics and IT enabled biotechnology, clinical biotechnology, manufacturing & bio-processing, research services, bio-resources, environment and intellectual property & patent law.

Several state governments have enunciated biotech policies spelling out a comprehensive blueprint for the sector. It is, therefore, prudent to have a

National Biotech Development Strategy that charts an integrated 10-year road map with clear directions and destinations.

This is the time for investment in frontier technologies such as biotechnology. It is envisaged that clearly thought-out strategies will provide direction and enable action by various stakeholders to achieve the full potential of this exciting field for the social and economic well being of the nation.

SECTION II

KEY POLICY RECOMMENDATIONS AND INTERVENTIONS

2.1 Human Resource Development: Academic and Industry Needs

Biotechnology is a knowledge-driven technology, which needs to be driven by a flow of new ideas and concepts in the development of new tools for research, new processes for manufacturing and innovative business models. Rapid responses are needed to meet the challenges as they unfold and there is a requirement for specialized personnel and centres of excellence for R&D.

The policy goal for the next decade is to facilitate the availability of scientific and technical human resource in all disciplines relevant to the life science and biotechnology sector. In order to build a successful biotechnology sector, large talent pools are required in multiple scientific disciplines such as molecular and cell biology, chemistry, physics, engineering, bioinformatics, medicine, agriculture, microbiology, technology transfer & commercialization, bioentreprise & biofinancing and intellectual property rights management. Product and process development are inter-disciplinary in nature and deficiencies in specific areas may weaken the whole sector. The key issue is the manner in which to create an effective interface across disciplines.

Reliable estimates of human resource availability for the next 10 years are required. Expert consensus indicates that there is adequate enrollment currently at the post-graduate and under-graduate levels, however the quality is inconsistent. Areas such as intellectual property rights, regulatory issues and industrial training have received inadequate attention. There is a consensus that there is an urgent need to augment the number of Ph.D. programs in the Life Sciences and biotechnology. A strong pool of academic leaders is key to sustained innovation.

Strategic Actions:

(i) National Task Force on education & training

- A National Task Force will be created to formulate model undergraduate and postgraduate curricula in Life Sciences keeping in view, future needs. The said curricula must address the underlying need for multi-disciplinary and inter-disciplinary learning and the appropriate stage for biotechnology training.

(ii) Need assessment

- There would be need assessment in 2005 for the next five years and close monitoring during the period for interim changes.

- A 10-year perspective plan for human resource will be prepared every five years.

(iii) Curriculum development

- Course curricula will be reviewed and improved in consultation with industry and research establishments and standard e-learning modules will be developed for specific skill areas such as IPR, regulations, and bioentreprise.
- Hands on exposure to M.Sc. biotechnology students will be enhanced through an extended industry internship as well as through short-term placements at CSIR and other appropriate National Institutes.
- Dual degree programs in biotechnology that include regulatory matters, IPR and bio-enterprise management will be encouraged and supported by the Department of Biotechnology.
- Emphasis will be given on training of high quality technicians and technologists in skills required by the industry by establishing Regional training centres at diploma, graduate and postgraduate levels.

(iv) Quality improvement

- An accreditation mechanism will be put in place for ensuring minimum standard of education and training at the post graduate and undergraduate levels. Base requirements for teaching and laboratory infrastructure will be specified and enforced.
- Teachers training programs will be taken up by creating regional teachers training centres

(v) Strengthening of teaching and R&D in life sciences and biotechnology in the university system

- Strengthening R&D in Life sciences and biotechnology in the university system will be accorded high priority. This is considered important for improving the quality of education and providing exposure to new technologies for students at various levels. Specific mechanisms to achieve the goal will include
- Creation of inter-disciplinary centres of excellence with world class infrastructure in key areas
- Program support to encourage inter-departmental networking
- Visiting professorship and creation of industry sponsored chairs in partnership with the Department of Biotechnology.

(vi) Attracting talent to life science and biotechnology

- Bright students will be attracted to take up careers in biology and biotechnology through special scholarships. Summer assignments at Academic and Industry research laboratories will be introduced at the school level to create interest in the fields of biotechnology and biology
- Women scientists will be encouraged to take up careers in biotechnology. Service conditions will be liberalized for women to be able to return to research/academics after maternity breaks.

(vii) Creating science & technology leaders for the industry

- The number of Ph.D fellowships offered by the Department of Biotechnology will be increased to 200 per annum
- Public-private partnerships will be encouraged in Ph.D programs through creation of the *'Bio-edu-Grid'*- a network of universities and industries facilitating pooling of resources.
- Masters degree level professionals in industry will be encouraged to undertake Ph.D. programs while retaining their jobs through industry-university tie-ups.

(viii) Arresting and reversing brain drain

- As mentioned earlier, the number of postdoctoral fellowships offered by the Department of Biotechnology will be increased to 200 per annum in order to attract talent.
- Outstanding young investigator grants in biotechnology will be introduced. This will provide a package including salary support, research grant, equipment and opportunities to attend national and international conferences. The salary support under the scheme will be at par with that of entry-level faculty positions.
- Information on availability of positions in education/research establishments and industries will be provided on a website to facilitate employment of scientists with specific skills at appropriate positions.
- A database of scientists working in different areas of biotechnology within and outside the country will be created to utilize the expertise appropriately.

(ix) Enabling working conditions for scientists to undertake industry oriented research

- *Lateral mobility of scientific personnel:* Scientists working at universities and research institutions may be allowed to work in industries for commercialization of their research efforts. This could be in the form of secondment or consultancy with industry or by a sabbatical for three years during the working life of scientists

- *Dual/adjunct faculty positions:* Researchers working in university/research institutions may be allowed to hold positions in the industry and vice-versa
- *Joint salary support:* Faculty employed in academic institutions may be allowed to hold positions for a period of time in which their salary is contributed both by the industry and the academic institution on a mutually agreed basis. (Such an arrangement will work well only if the teaching requirements of the academic institutions are made obligatory).
- *Rapid travel grants:* Rapid travel grants scheme for approval within two weeks for young scientists to interact with mentors and industry collaborators would be initiated.
- *Institute Innovation grants* through the Department of Biotechnology to fund academic researchers to develop their concepts into patentable and more importantly licensable technologies. Such grants may be utilized for the purpose of providing additional infrastructure and manpower, patenting costs as well as costs related to proof of concept studies.

These steps will ensure that the large available resources of human talent in biotechnology are supported and this will guarantee the progress of the biotech sector.

2.2 Infrastructure Development and Manufacturing

The strength of a biotechnology company lies in up scaling a number of proven technologies - diagnostics, vaccines, products, and processes - for fine-tuning and large-scale production. While Indian industry is strong in product development and marketing for commercial benefits, biotechnology in India still lacks the infrastructure required to take up R&D in areas like molecular modeling, protein engineering, drug designing, immunological studies, pre-clinical studies, clinical trials, etc.

In order to get the best from public and privately funded biological/biotechnological research, it is imperative to utilize the infrastructure generated optimally for societal benefits. The concept of contract research organizations (CROs), contract manufacturing organizations (CMOs), contract packagers, lab services providers etc., is steadily taking shape in India.

In the area of biomanufacturing, industry estimates that the market for biogenerics in India is expected to see a 43 percent jump from Rs 308.50 crore in 2001 to Rs 1,305.7 crore in 2005 and projected to reach Rs 1,864.3 crore by 2007 registering a growth of 19 percent.

India's strengths lie in the availability of educated and skilled manpower, proficiency in English, low capital and operational costs and the proven track record in meeting international standards of quality. There is ample proof that

the Indian companies are committed to global standards. According to reports, outside of the US, India ranks the highest with 61 USFDA-approved plants and in excess of 200 GMP certified pharmaceutical manufacturing facilities.

Strategic Actions:

(i) Department of Biotechnology will act to facilitate a Single Window Clearance mechanism for establishing Biotechnology plants.

(ii) Encourage private participation in infrastructure development like roads, water supply and effluent treatment.

(iii) Depositories of biological materials will be created in partnership with industry on IDA model for agriculturally important organisms, medically important organisms, plasmids, cosmids and constructs of special nature generated with adequate human interventions

(iv) State of the art large animal house facilities with GLP will be created for testing candidate vaccines and biotherapeutics. Testing facilities will be created for GMO/LMO

2.3 Promotion of Industry and Trade

The emergence of India as a global player in the biotech sector requires government to play the role of a champion and foster an international competitive environment for investment and enterprise development. India's strategy must be to get more value from its R&D investment and from IPR generation.

The Biotechnology sector has in recent years witnessed accelerated growth. With approximately 200 industries the growth of the biotech sector in India has been rapid. Current estimates indicate that the industry grew by 39% annually to reach a value of US$ 705 million in 2003-2004. Total investment also increased in 2003-2004 by 26% to reach US$ 137 million. Exports presently account for 56% of revenue. Currently the biopharma sector occupies the largest market share of 76% followed by bio-agri 8.42%, bioservices 7.70%, industrial products 5.50% and bioinformatics 2.45%. The bioservice sector registered the highest growth (100%) in 2003-2004 with bioagri 63.64% and biopharma 38.55%.

The current policy review envisages an annual turnover of US$ 5 billion by 2010. India has to develop its own biotechnological and pharmaceutical products to ensure quality and affordability for global trade. In addition to opportunities in drug discovery and development there are significant openings to provide services to the worldwide biotech and pharmaceutical industries and to leverage low cost high quality manufacturing with a global discovery

potential. Capitalizing on these opportunities would create many new valuable jobs in India as we have seen in the outsourcing and service industry.

However, to achieve the targeted business volume, several new challenges have to be met. These are predictable and enabling policies, increased public and private support for early or proof-of-concept stage of product development; improved communication among stakeholders in the sector, public-private partnerships, integration of the Indian biotech sector globally; and improved infrastructure. The vision is to maximize opportunities in the area of contract research, manufacturing and to promote discovery and innovation.

The Biotech industry being capital intensive in nature has historically relied on venture capital from public and private sources. India needs to provide active support through incubator funds, seed funds and provision of various incentives in order to develop the biotech sector.

In a highly competitive and fast moving business environment, innovative capacity is an important determinant of the ability to create a continuing pipeline of new products and processes. Innovation covers knowledge creation (R&D), knowledge diffusion (education and training) and knowledge application (commercialization). Innovation is not a one-time event; instead, it has to continuously respond to changing circumstances for creating sustainable growth.

Innovation is measured in terms of external / domestic patent applications; human capital devoted to R&D, government expenditure on R&D proportionate to country's GDP, business funded expenditure on R&D, indigenous technologies standardized, demonstrated and transferred to industry for commercialization; and the number of spin off companies created.

Clear government policies for promotion of innovation and commercialization of knowledge will propel the growth of the biotechnology sector.

Strategic Actions:

(i) Innovation:

- Basic and translational research in key biological processes and new materials will be supported as innovation for tomorrow. Access to the knowledge generated will be improved by supporting knowledge and social networks among stakeholders so that those with appropriate skills can convert the research output into useful products and processes.
- Research to promote innovation must be supported increasingly on a cooperative rather than a competitive basis. This requires effective communication among science agencies, research institutions, academia and industry.

- To promote India as a hub of innovation, a network of relevant stakeholders should be developed. Public investment should be used as a catalyst to promote such clustering and networking as this can lead to enhanced creativity by sharing of expertise, resources and infrastructure.
- Availability of human resource would be ensured at each phase of the product cycle.
- Strengthening technology transfer capacity

It is proposed to create several national/regional technology transfer cells (TTC's) over the next 5 years to provide high caliber, specialized and comprehensive technology transfer services. The services would include: evaluating technology and identifying potential commercial uses, developing and executing and intellectual property protection strategies identifying potential licensees and negotiating licenses. Each TTC would service a cluster of institutions in a region or a large city. Optimal delivery of services by the TTCs requires professionals with background in industry and science, wide networks, an external focus and high level licensing skills. The best practices for effective technology transfer will be benchmarked.

The skills of existing technology transfer professionals will be upgraded by a combination of specialized training courses, including linking to important programs redesigning the incentives and career paths for posting.

Scientists and other innovators shall be equipped with a better understanding of markets and commercialization pathways, the process of technology transfer, the strategy of protecting intellectual property rights and industrial licensing.

(ii) Fiscal and trade policy initiatives

Biotechnology firms are by far the most research intensive among major industries. On an average the biotechnology sector invests 20-30 % of its operating costs in R&D or technology outsourcing. Government support, fiscal incentives and tax benefits are therefore critical to this sector. These measures will also help to capitalize on the inherent cost effectiveness of the Indian biotech enterprise. The suggested interventions include:

- Exemption of import duties on key R&D, contract manufacturing / clinical trial equipment and duty credit for R&D consumer goods to enable small and medium entrepreneurs to reduce the high capital cost of conducting research.
- Extending the 150 % weighted average tax deduction on R&D expenditure under section 35 (2AB) until 2010 and to permit international patenting costs under this provision and enable eligibility of expenditure

incurred with regard to filing patents outside India for weighted deductions u/s 35 (2 ab)

- Enable lending by banks to biotech companies as priority sector lending. Currently banks are almost averse to lending to young biotech companies. In order to encourage banks to lend and provide banking services to the biotech sector, a significant push through appropriate policy guidelines from the Reserve Bank of India is necessary. Currently lending to agri-businesses as well as investment in Venture Funds by banks is categorized as Priority Sector Lending. Biotech as a business has similar characteristics in terms of risk as well as gestation time lines and it is therefore recommended that lending to Biotech be also categorized as Priority Sector lending.
- Remove customs duty on raw materials imported into India, where the finished product is imported duty free. Life Saving Drugs imported and sold in India are exempted from paying customs duty; whereas raw materials for diagnostics and other pharmaceutical biotech products manufactured in India are levied customs duty. To promote the indigenous manufacturing industry and make it competitive globally, raw materials imported by Indian manufacturers should be eligible for Duty Drawback.
- Rationalization of import and export of biological material is considered critical for clinical research and business process outsourcing.
- Simplification and streamlining of procedures for import, clearance and storage of biologicals, land acquisition, obtaining environmental and pollution control approvals would be simplified and streamlined within shorter time frame lines through consultations with various central and state government departments.
- As an effective regulatory mechanism has been put in place though recent interventions, Foreign Investment Promotion Board (FIPB) approval for equity investment may no longer be necessary.
- Joint R&D collaboration and generation of joint IP though global partnerships would be fostered.
- International trade opportunities would be promoted to guide R&D investment Indian biotech strengths would be aggressive by promoted globally.
- Efforts would be made to remove hurdles for contract research especially for input output norms and tax on revenue generated through contract research / R&D.
- Easy access to information, regarding legislation and rules and regulations for transboundary movements of biologicals would be promoted.
- Current standards and safety of products would be enhanced.
- Efforts would be strengthened to promote acceptance of Indian regulatory data internationally.
- Research, trade and industrial partnership would be fostered at regional and sub-regional levels.

- A "cluster" approach would be encouraged to operations. One significant features of the industry is the fluidity and variety of its inter-company relationships, traditionally much greater than in other industries. It has relied to a considerable degree on contracting and outsourcing, especially "upstream" in R&D through various licensing arrangements and "downstream" through co-marketing agreements.
- Collaborative knowledge networks would be promoted. Expanded sharing of information, including creation/use of collaborative knowledge networks (CKN), can greatly enhance a company's performance under a cluster approach. Managing the many external relationships is complex. Flexible and pervasive communications systems that allow information to flow effortlessly within and between contracting organizations will provide the key to success. Increasingly, IT advances, including web-based approaches, will provide the foundation for these systems.

(iii) Public investment for promotion of innovation and knowledge commercialization

Availability of financial support for early phase of product development to establish proof-of-principle is the key to sustaining innovation. In this context, it is proposed to institute **'Small Business Innovation Research Initiative'** (SBIRI) scheme through the Department of Biotechnology in 2005-06 for supporting small and medium size enterprises as a grant/loan. Companies with up to 1000 employees will be eligible. The scheme will support pre-proof of concept, early stage innovative research and provide mentorship and problem solving support in addition to the grant / soft loan. The SBIRI scheme will operate in two phases of innovation and product development.

- ***SBIRI Phase – I :***

  The funding in this stage will be provided for highly innovative, early stage, pre-proof-of-concept research. Preference will be given to proposals that address important national needs. The maximum amount of funding to an enterprise will be limited to Rs. 50 lakh with not more than 50% of it going as grant and the remaining as an interest free loan. For projects to be considered at this stage, though a partner from a public R&D institution would be considered important, it will not be a mandatory requirement for those companies that have good quality scientists. This should encourage high quality scientists to agree to work in small and medium biotech companies, a change from our traditions. The R & D requirement of the public institution will be met through a grant.

- ***SBIRI Phase – II :***

  It is expected that some of the proposals funded with SBIRI Phase-I will establish the proof-of-concept. At this stage, the ability of the project to get venture capital funding improves. Such projects will be eligible for Phase-II funding. Some projects could be eligible for direct phase-II support. It is

proposed to provide soft loan at this stage for product development and commercialization at an interest rate of 2%. The role of public R&D institution at this stage too is critical. The partner in the public institution at this stage will get the R&D support as grant.

- Small and medium knowledge-based industries in biotech sector will be encouraged to avail of equity support from the **SME Growth Fund of Small Industries Development Bank of India (SIDBI).**

(iv) Code of best practice for disclosure guidelines

Setting up a 'Code for Best Practice for Disclosure Guidelines for the Indian Biotech Industry'. This Code will be a part of the General Listing Requirements and Disclosure Guidelines and will be in conjunction with SEBI's General Listing Rules and Disclosure Guidelines.

2.4 Biotechnology Parks & Incubators

Establishing biotechnology parks for the growth of the biotechnology industry is essential either through public-private alliance or public/private sponsorships. With its large human resource in molecular biology, microbiology, biochemical engineering, synthetic organic chemistry, chemical engineering and allied branches of engineering and strong institutional base at the universities, CSIR, ICMR and ICAR, India is well placed to support a number of biotech parks.

Biotechnology Parks can provide a viable mechanism for licensing new technologies to upcoming biotech companies to start new ventures and to achieve early stage value enhancement of the technology with minimum financial inputs. These biotech parks facilitate the lab to land transfer of the technologies by serving as an impetus for entrepreneurship through partnership among innovators from universities, R&D institutions and industry.

Basic minimum components for parks should include research laboratories for product development, multi-purpose pilot facility for manufacturing and process development, quality control and validation of technologies, common effluent treatment plant, a GLP Animal House, a recognized human resource training centre, administrative support centre etc.
The biotech parks should be located so as to be easily accessible for all the stakeholders, tenants, academia with connecting roads, water and power supply and should also attract less administrative clearances from the government.

Strategic Actions:

(i) The Department of Biotechnology will 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.

(ii) The Department of Biotechnology will support creation of incubators in biotech parks promoted by a private industry or through public-private partnership in the form of grant upto 30% of the total cost or upto 49% in the form of equity.

(iii) It is proposed that a central body *Biotechnology Parks Society of India (BPSI)* be set up for the promotion of biotechnology parks in the country on the same 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 BPSI would be responsible for evaluating the project proposals and advising the Department of Biotechnology on the funding pattern; facilitating industries in obtaining industrial, environmental and other relevant approvals from the central government; making recommendation regarding fiscal incentives to be granted to the biotechnology parks; providing guidance to the venture capital institutions on investment in biotech parks; providing accreditation to the parks etc.

(iv) Concessions to biotech companies located in biotech parks

Biotech companies located at biotech parks are eligible for benefits as per the recent changes in the Foreign Trade Policy:

- Duty free import of equipment, instruments and consumables.
- Tax holiday under Section 10A/ 10B of the Income Tax Act
- A scheme will be put in place for operationalising of the incentives to biotech units located in biotech parks. As a part of this scheme biotech company located in biotech parks 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.

2.5 Regulatory Mechanisms

It is important that biotechnology is used for the social benefit of India and for economic development. To fulfill this vision, it has to be ensured that research and application in biotechnology is guided by a process of decision-making that safeguards both human health and the environment with adherence to the highest ethical standards. There is consensus that existing legislation, backed by science based assessment procedures clearly articulates rules and regulations that can efficiently fulfill this vision.

Choices are required to be made that reflect an adequate balance between benefit, safety, access and the interest of consumers and farmers. It is also important that biotechnology products that are required for social and economic

good are produced speedily and at the lowest cost. A scientific, rigorous, transparent, efficient, predictable, and consistent regulatory mechanism for biosafety evaluation and release system/protocol is an essential for achieving these multiple goals.

Strategic Actions:

(i) The recommendation of the Swaminathan Committee on regulation of agri-biotech products and of the Mashelkar committee on recombinant pharma products will be implemented in 2005

(ii) It is recommended that an event that has already undergone extensive biosafety tests should not be treated as a new event if it is in a changed background containing the tested and biosafety evaluated "event". Where adequate evidence is available that the recurrent parent genetic background of a notified/registered genotype is nearly restored (through field data/molecular data), only the agronomic performance and the level and stability of the transgene expression may be analyzed by two-year trial data by the ICAR. Even in case of a structurally altered transgene with no significant modifications in protein conformation, the toxicity and allergenicity tests need not be carried out provided the predicted antigenic epitope remains the same and the level of expression of the transgene is within the defined limits. For the released event, Department is of the view that there is no need of large-scale trials under the Genetic Engineering Approval Committee, as the biosafety aspects have been already addressed adequately before releasing the "event". Only ICAR trials may address the agronomic evaluation of the crop.

(iii) An inter-ministerial group chaired by a reputed scientist will be established in 2005 to address anomalies and issues that arise in regulation from time to time. It is proposed that the administrative support to this committee be through the Department of Biotechnology. The mandate of the committee should be to vet any changes in policies, procedures, protocols by departments dealing with regulation in biotech products and processes; resolve issues emanating from the overlapping/conflicting rules in various acts related to regulation of biotechnology activities in R&D, import, export, releases etc. and to review guidelines, protocols, standard operating procedures and ensure their dissemination to all stakeholders from time to time

(iv) A competent single National Biotechnology Regulatory Authority be established with separate divisions for agriculture products/transgenic crops, pharmaceuticals/drugs and industrial products; and transgenic food/feed and transgenic animal/aqua culture. The authority is to be governed by an independent administrative structure with common chairman. The inter-ministerial group will evolve suitable proposals for consideration of the government.

(v) A centre for in-service training of all professionals, irrespective of their location, engaged in the regulatory process to be established by the

Department of Biotechnology in close collaboration with other concerned departments and institutions.

(vi) All existing guidelines to be updated and made consistent with the recommendations of the Swaminathan and Mashelkar committees in 2005. New guidelines on transgenic research and product/process development in animal, aqua culture, food, phyto-pharma and environmental application to be put in place in 2005 by the concerned ministries/departments

(vii) As an interim measure, a special regulatory cell will be created by the DBT 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. This cell will only have a promotional and catalytic role

(viii) Measures will be taken to build professionalism and competence in all agencies involved with regulation of biotechnology products

(ix) Research is support of regulation, to safeguard health and environment shall be supported by the concerned funding agencies to generate knowledge that will guide regulations and bioethics policy.

(x) Concerned ministries will make a vigorous effort to promote acceptance of the Indian regulatory decisions by other trading countries.

2.6 Public Communication and Participation

Biotechnology today has become as important as traditional plant and animal breeding have been in the past. At the same time, it raises a number of difficult economic, social, ethical, environmental and political issues that constitute major challenges for the human society. The reception of biotech products by the public has been rather mixed. In general biopharmaceutical products seem to be better accepted than transgenic crops. Clearly it is no longer possible to assume automatic public acceptance of new products and processes that promise public and commercial benefits. Public perception and opinion have a significant influence on the direction and funding of biotechnology research. Hence there is a need to work actively and transparently to inform and engage the civic society in decision-making, and to maintain a relationship of trust and confidence. The government and the industry must actively promote access to information on the benefits and risks in a balanced manner.

To achieve this goal, several enabling factors already exist: a sound biosafety regulatory system; well respected appellate and judicial system for redressal of grievances; cadre of willing and able scientists for effective and accurate communication of information; a large body of extension personnel in agriculture, fisheries, veterinary and human health sectors; large NGO network spread across the country; and an effective and independent mass media.

However, several challenges to success need to be recognized while framing the strategies: diverse levels of education and literacy across the country; low understanding of biotechnology among the public; lack of simple communication material; varying quality of science reporting; inadequate inter agency coordination; insufficient dialogue between scientists, industry, policy makers, regulators, consumer for a civil society organizations and the mass media; and lack of sufficiently proactive administrative machinery.

There is a need to build public awareness about opportunities and challenges presented by biotechnology development and to inspire public trust and confidence on the safety, efficacy as well as social and ethical acceptability of products among consumers and civil society through the dissemination of accurate information in a coherent, balanced well articulated, user-friendly and transparent manner. Several focused and well-directed measures are needed to achieve public trust and confidence in biotechnology.

Strategic Actions:

(i) Create a cadre of resource persons to reach the stakeholders

- Creation of a cadre of resource persons to provide credible information based on scientific data
- Training media personnel through Institutes of Mass Communication, colleges of journalism and others
- Capacity building among extension personnel in agricultural, fisheries, veterinary and medical sectors
- Involvement of *Panchayati Raj* institutions in the process of analysis and understanding the risks and benefits associated with GMOs as they will be playing an important role in the local level management of bio-diversity, access to benefit sharing etc.
- Awareness generation among undergraduate and post-graduate students in universities, colleges etc on issues related to biosafety.
- Promoting a genetic literacy movement within government and public schools through 50 genome clubs nature clubs each year.

(ii) Creating a media resource network

- To facilitate access to information

(iii) Empowering policy makers

- Regular training programs for policy makers

(iv) Empowering the judiciary

- Setting up a training school for the judiciary under the aegis of Centre for DNA Fingerprinting and Diagnostics, Hyderabad
- Training through the National Law Schools and other similar institutions

(v) Institutional mechanisms for strengthening public trust

- Establishment of a dedicated training centre for biosafety, food and nutrition safety and standards as per codex alimentarius committee.
- Creation of a 'National Biotechnology Awareness Fund' for providing support for the education and preparation of educational resource material for various sections of stakeholders in different regional languages of the country

SECTION III

SECTORAL ROAD MAPS

3.1. Agriculture & Food Biotechnology

Biotechnology is necessary to maintain our agriculture competitive and remunerative and to achieve nutrition security in the face of major challenges such as declining per capita availability of arable land; lower productivity of crops, livestock and fisheries, heavy production losses due to biotic (insects pests, weeds) and abiotic (salinity, drought, alkalinity) stresses; heavy post-harvest crop damage and declining availability of water as an agricultural input. Investment in agricultural related biotechnology has resulted in significantly enhanced R&D capability and institutional building over the years. However, progress has been rather slow in converting the research leads into usable products.

Uncertainties regarding IPR management and regulatory requirements, poor understanding of risk assessment and lack of effective management and commercialization strategies have been significant impediments. India owns very few genes of applied value. The majority of the genes under use – about 40 – are currently held by MNCs and have been received under material transfer agreements for R&D purpose without clarity on the potential for commercialization.

The spectrum of biotechnology application in agriculture is very wide and includes generation of improved crops, animals, plants of agro forestry importance; microbes; use of molecular markers to tag genes of interest; accelerating of breeding through marker – assisted selection; fingerprinting of cultivars, land raises, germplasm stocks; DNA based diagnostics for pests / pathogens of crops, farm animals and fish; assessment and monitoring of bio diversity; in vitro mass multiplication of elite planting material; embryo transfer technology for animal breeding; food and feed biotechnology. Plants and animals are being used for the production of therapeutically or industrially useful products, the emphasis being on improving efficiency and lowering the cost of production. However, emphasis should not be on edible vaccines for which use in real life condition is difficult. Nutrition and balanced diet are emerging to be important health promotional strategies. Biotechnology has a critical role in developing and processing value added products of enhanced nutritive quality and providing tools for ensuring and monitoring food quality and safety.

It has been estimated that if Biofertilizers were used to substitute only 25% of chemical fertilizers on just 50% of India's crops the potential would be 2,35,000 MT. Today about 13,000 MT of Biofertilizers are used – only 0.36% of the total fertilizer use. The projected production target by 2011 is roughly around 50,000

MT. Biopesticides have fared slightly better with 2.5% share of the total pesticide market of 2700 crores and an annual growth rate of 10-15 %. In spite of the obvious advantages, several constraints have limited their wider usage such as products of inconsistent quality, short shelf life, sensitivity to drought, temperature, and agronomic conditions.

From a research perspective the spectrum of organisms studied has been rather narrow and testing has been on limited scale and restricted mainly to agronomic parameters. Environmental factors such as survival in the Rhizosphere / phyllosphere and competition of native microbes have not received sufficient attention. Moreover, results on crops are slow to show. Unless there is a policy initiative at the centre and the state to actively promote Biofertilizers and biopesticides at a faster pace, there is unlikely to be a quantum jump in their consumption.

A taskforce headed by Dr MS Swaminthan (2004) under the Ministry of Agriculture has prepared a detailed framework on the application of biotechnology in agriculture. The report rightly lays emphasis on the judicious use of biotechnologies for the economic well being of farm families, food security of the nation, health security of the consumer, protection of the environment, and security of national and international trade in farm commodities.

Guiding Principles

Consistent with the overall vision outlined by MS Swaminathan taskforce, the priorities in agri-biotech would be based on social, economic, ecological, ethical, and gender equity issues. The following guiding principles would apply across the sector:

- A comprehensive and integrated view should be developed of r-DNA and non r-DNA based applications of biotechnology with other technological components required for agriculture as a whole
- Use of conventional biotechnologies (e.g. biofertilizers, biopesticides, bioremediation technologies, molecular assisted grading, plant tissue culture etc.) should continue to be encouraged and supported. A precautionary, yet promotional approach should be adopted in employing transgenic R&D activities based on technological feasibility, socio-economic considerations and promotion of trade.
- Public funding should be avoided to research areas of low priority or those that could reduce employment and impinge the livelihood of rural families.
- Regulatory requirement in compliance with Cartagena Protocol, another international treaty and protocol for biosafety, germplasm exchange and access and the guiding principles of codex alimentarius will be implemented through inter ministerial consultative process

- Transgenic plants should not be commercialized in crops/commodities where our international trade may be affected. However, their use may be allowed for generation of proof of principle, strictly for R&D, their alternate systems are not available or not suitable.
- In a long term perspective basic research for development of low volume, high value secondary and tertiary products through enabling technologies of genomics, proteomics, engineering of metabolic pathways, RNAi, host pathogen interaction and others. Research and support of biosafety regulation would need support.

It is proposed to do away with the large-scale field-testing of the released transgenic events and make it compliant to agronomic test requirements.

Strategic Actions:

(i) Accelerating the pace of product development

- In our quest for better products, strong and sustained support should be given to encourage indigenous discovery of new genes and promoters in both public and privately owned institutions. Nevertheless, wherever there be an urgent need for a product to achieve food or nutritional security, creative commercial and academic international partnerships should be explored in national interest for sourcing important genes and promoters through licensing arrangements on exclusive/non-exclusive basis. The cost effectiveness should be carefully assessed on a case-to-case basis.
- A gene bank should be created and be accessible to private and public sector organizations after payment of an appropriate fee.

(ii) Public-Private Partnership

- There is an urgent need to promote and improve the levels of horizontal integration between public-public and public-private laboratories.
- Institutions that generate knowledge and those that specialize in late stage field trials are currently compartmentalized. While support to public-funded innovation must continue to be strengthened, it is proposed that at least 30% of government-funded programmes must have a commercial partner who will be responsible for directing R&D towards commercialization. Public investment should also be encouraged in small and medium companies, especially for late stage trials of transgenic crops. Partnership between public-funded organizations and industry is crucial in the science-to-product chain.

(iii) Inter-ministerial Agriculture Biotechnology Board

- An inter-ministerial Agriculture Biotechnology Board involving Ministry of Agriculture, ICAR, DBT, MoEF, regulatory authority, expert scientists, industry, and the farming community should be established to continuously assess cross cutting issues such as: duplication of R&D investments;

capacity building; promotion of horizontal partnerships between various components in the knowledge-product chain; the most cost-effective manner of overcoming nutrition deficiencies (viz. iron, zinc, iodine, vitamin A); availability, access, release and efficient system for biosafety assessment of GMOs and products thereof; safe use of approved technologies and prevention of unauthorized ones; building public trust and understanding biotechnological application relating to global warming, climate change and sea level rise; global trends in consumer/industry preferences of farm commodities. This will also monitor trade and collect market intelligence with respect to GM crops and products and follow the trend of organic markets and watch international developments to identify niche markets, monitor countries that are rejecting GM foods and feed this intelligence to concerned agencies.

Priorities

Priorities for crops and traits should be set after conducting a need assessment exercise in various farming zones. However, an indicative list has been suggested by MS Swaminathan Task Force (2004).

(a) Crop

Priority target traits in crop plants would be yield increase, pest and disease resistance, abiotic stress tolerance, enhanced quality, and shelf life, engineering male sterility and development of apomixis. Crops of priority should be rice, wheat, maize, sorghum, pigeon pea, chickpea, moong bean, groundnut, mustard, soybean, cotton, sugarcane, potato, tomato, cole crops, banana, papayas and citrus. In priority crops equal emphasis should be given to GM hybrids and new varieties. The varieties in contrast to hybrids, are preferred by small farmers as they can use their own farm saved seeds for at least three or four years. In case of hybrids, research on the introduction of genetic factors for apomixis would be supported so that resource-poor farmers can derive benefits from hybrid vigour without having to buy expensive seeds every cropping season.

(b) Livestock

Priority target traits in livestock would be enhanced fertility and reproductive performance, improved quality, resistance to diseases for reduced drug use, production of therapeutically useful products and quality feed. Livestock of priority would be buffalo, cattle, sheep and goat. Emphasis would be given to animal healthcare, nutrition, development of transgenics and genomics. It is proposed to set up an autonomous institution for animal biotechnology.

(c) Aquaculture and marine biotechnology

Application of biotechnology would be crucial in disease resistance, enhanced productivity, fertility and reproductive growth, use of aquatic species as bioreactors for production of industrial products, value added products from sea weeds and other marine taxa and biosensors for pollution monitoring. Species of priority in fisheries would be carps, tiger shrimps and fresh water prawns. It is proposed to set up under the auspices of DBT and autonomous centre for marine biotechnology

(d) Food and nutrition

R&D would be focused on: development of biotechnology tools for evaluating food safety, development of rapid diagnostic kits for detection of various food borne pathogens; development of analogical methods for detection of genetically modified foods and products derived there from; development of nutraceuticals / health food supplements/ functional foods for holistic health; development of pre-cooked, ready-to-eat, nutritionally fortified food for school going children; development of suitable pro-biotics for therapeutic purposes and development of bio food additives. It is proposed to set up (under the auspices of Department of Biotechnology) an autonomous institute for nutritional biology and food biotechnology (2006).

(e) Biofertilizers and biopesticides

Priorities would include screening of elite strains of micros-organisms and / or productions of super-strains, better understanding of the dynamics of symbiotic nitrogen fixation, process optimization for fermentor – based technologies, improved shelf life, better quality standards, setting up accredited quality control laboratories and standardization of GMP guidelines. Integrated nutrient management system would be further strengthened.

3.2. Bioresources

The combined annual global market for the products derived from bioresources is roughly between US$ 500 billion and US$ 800 billion. India is one of the 12 global mega biodiversity centres harbouring approximately 8% of the global biodiversity existing in only 2.4% of the land area. The country is also home to two of the world's 25 hotspots. The varied cultural diversity across the country as well as a very ancient traditional knowledge system associated with the biodiversity represents added assets. Nonetheless, much of this biodiversity is in peril owing, in the main, to anthropogenic causes. Thus, if the goal of converting our bioresources - animal, plant, microbial and marine - into commercially useful products and processes is to be realized, we need to not only conserve the biodiversity and but also utilize it in a sustainable manner. In

this context, absence of a good quantitative information network on bioresources combining remote-sensing data and ground surveys is a major constraint. The situation is even worse for microorganisms. Field- and marine biologists rarely work with molecular scientists and chemists, pharmacologists or other experts, and there is practically no bioprospecting industry. While our traditional knowledge base would be the starting for bioprospecting, ethics and equity should be our guiding principles in benefit sharing.

Animal resources

India is home to an estimated 86,874 species of animals accounting for 7.25% of global animal diversity. The degree of endemism is high and populations of several animal groups are diminishing due to habitat destruction and poaching. Several species, their products and the services rendered by them are crucial to our economic well-being: pollination services by insects (e.g., honey bees, bumble bees, moths, butterflies, beetles, flies) to our agricultural and forestry crops, honey, silk, lac, musk, skins are just a few examples. Other species (e.g., molluscs, frogs, toads, spiders, termites, and snakes) represent potential reservoirs of useful products such as toxins, venoms, enzymes, therapeutic molecules and other bioactive substances. Prospecting for these and other products should be a priority. Biotechnology should be effectively employed for molecular characterization along with bioscreens in search of useful products. Utilization of selected species as bioreactors for production of complex proteins is another important opportunity.

Plant resources

India has a huge treasure of plant resources with over 45,000 known species representing 11% of earth's flora. In terms of flowering plant diversity alone, India ranks tenth in the world. About 33% of flowering plants and 29% of total plants are endemic to the country. Genetic erosion is rampant and conservation is a priority. Prospecting of wild plant resources using molecular approaches and mechanism-based screening should be used to identify novel genes (temperature, drought, salinity tolerant) and gene products (therapeutic compounds, dyes, essential oils, biocontrol agents, gums resins and taxmins). There are potential ornamentals, including foliage – and flower – bearing plants that could be bulked up to be subsequently cultivated on large scale for domestic and international trade. Bioconversion - both cellular and microbial – should be employed to convert intermediates of secondary metabolism into valued added products. Application of genomics, proteomics and metabolomics in carefully selected plants will be very useful.

Biotechnology can contribute substantially in providing cost-effective therapeutically active biomolecules through target/mechanism – based screens, biotransformation, metabolic engineering and transgenic approaches. Biotechnology should also be utilized to add value to our traditional knowledge especially Ayurveda, Sidha and Unani systems as well as tribal and folk medicine. Medicinal plants are also the prime targets of bioprospecting. Besides, the tools of biotechnology can be used for conservation and characterization of plants.

Fossil fuels are chief contributors to urban air pollution and a major source of greenhouse gases (GHGs) - considered to be the main causes behind the climate change phenomena. In contrast, biofuels are renewable; hence, they can supplement hydrocarbon fuels, assist in their conservation, as well as mitigate their adverse effects on the climate.

Two major biofuels for the transport sector, bioethanol and biodiesel, are fast becoming popular in many countries around the world. While bio-ethanol (called ethanol) is produced from raw materials such as molasses, beet, sugarcane juice, grains and tubers, biodiesel is produced from oil (derived from oil-bearing seeds such as *Jatropha curcas*, *Pongamia pinnata* i.e.karanja).

India imports nearly 70% of its annual crude petroleum requirement. The net oil import bill (import minus exports) was Rs 77,058 crore (Rs 770.58 billion) in 2003-04 as against Rs 74,174 crore (Rs 741.74 billion) the previous year. This expenditure on crude purchase impacts the country's foreign exchange reserves in a big way. The petroleum industry now looks very committed to the use of ethanol as fuel.

It is estimated that 75% of the increase in world demand for oil will come from transport. India's transport sector will consume ever-higher amounts of fuel over the coming years. Being one of the largest producers of agro products, including sugarcane, India should take a lead in this worldwide effort at promoting sustainable development.

Microbial resources

Currently only five percent microbes are culturable but there are others of considerable potential value that need to be characterized by new and novel techniques. The five percent culturable microbes have been a source of valuable products.

India should play a leading role in the study and utilization of microbial resources. Our priorities include: preparation of inventories based on primary

and secondary data; exploration of micro flora in the north-eastern region of the country, and extreme habitats (hydrothermal vents, deep sea sediments, highly acidic, alkaline and anaerobic regions, degraded ecosystems etc.) for discovery of novel bioactive molecules; and study, characterization and screening of uncultivable microbes through appropriate molecular approaches.

Marine resources

The economic zone of the sea as a source of novel genes and gene products - biopolymers, novel enzymes, new therapeutic leads, and other value-added products such as osmo-tolerant crops – has hardly been explored. Marine organisms also present immense potential as biosensors for pollution monitoring as well as bioreactors for production of novel products. Besides, the study of deep-sea organisms including marine microbes has tremendous implications for human health. Expertise in these diverse areas is scattered across a number of agencies/institutions. Strategic Actions would be in the following areas.

Strategic Actions:

- There is an acute shortage of expertise in India particularly in taxonomy (the science of the classification of the living and extinct organisms) and microbial ecology. We need to take urgent steps to rectify this.
- Support to capacity building in microbial taxonomy through intensive training programmes at graduate and post-graduate levels
- Promotion of horizontal networking between remote sensing experts, field biologists and computer specialists for inventorisation of bioresources based both on primary and secondary sources of information
- Promotion of closer and effective interaction between biotechnologists, foresters, oceanographers and field biologists.
- Ensure that the use of bioresources be sustainable by regulating the harvesting of medicinal plants
- Formulate a policy to regulate the procurement and sale of medicinal plants in India. Introduce regulatory norms prescribed by DCGI that evaluate the efficacy, safety, and quality of herbal products, which currently are exempt from the scope of any regulation of the DCGI.
- Establish a close working relationship between field scientists, pharmacologists and clinicians so that an all round integration is achieved.
- Public-private partnerships need be promoted for product generation
- Creation of a gene bank for maintaining ‘mined’ genes

- There is, as on date, only one international depository authority (IDA) in the country at the Microbial Type Culture Collection (MTCC) at IMTECH, Chandigarh; however, for securing our IPR interests, we need to initiate steps to establish a few more centres as IDAs.
- Currently, MTCC does not accept biological materials such as cell lines, cyanobacteria, viruses etc. as it has no expertise or facilities for this purpose. Yet, these are essential for filing patents. IDAs in other countries may refuse to accept such material as they may be potentially hazardous or the shipments may have restrictions. In view of this, the scope of MTCC needs to be expanded by upgrading the existing expertise and infrastructure. Alternately, IDAs should be set up where such expertise and infrastructure are available.
- End products from bioprospecting need to be tested for a variety of parameters before commercial production can begin. There is a need to set up appropriate facilities for such late stage testing of products.
- An autonomous Centre for Marine Biotechnology is proposed to be set up under the auspices of DBT
- An autonomous Institute for Biotechnology for Herbal Medicine under the auspices of DBT is proposed to be established.

3.3. Environment

Environmental issues concern everyone. Biotechnology has tremendous potential for application to a wide variety of environmental issues including conservation and characterization of rare or endangered taxa, afforestation and reforestation. It can help in rapid monitoring of environmental pollution, eco-restoration of degraded sites such as mining spoil dumps, treatment of effluents discharged by industries (oil refineries, dyeing and textile units, paper and pulp mills, tanneries, pesticide units etc.), treatment of solid waste, and so on. A number of technologies have already been generated and demonstrated in the country. The real challenge is their adoption by the industry, which has been somewhat uneven. In general, corporate groups have not been overly enthusiastic in adopting biotechnologies even where they have proven efficacy. The reasons may be several: industry is usually not involved at the planning stage of experiment; enforcement of environmental laws is not always strict or uniform at the ground level and offenders can often escape with impunity; manufacturers frequently change their production schedules based on demand profiles resulting in varied streams of effluents, but microbial consortia specifically designed to one set of effluents may be ineffective in breaking down the changed pollutants.

The goal of environmental biotechnology would be to provide cost-effective and clean alternatives for risk assessment and quality monitoring, eco-restoration of degraded habitats, conversion of toxic recalcitrant chemicals into harmless by-products, bioremediation of wastes, value-added products from biomass, control of biological invasion through biotechnological interventions, greener process technologies, and effective *ex situ* conservation strategies. These can be fulfilled through a deeper understanding - and engineering - of the metabolic pathways for degradation of toxicants, environmental genomics and proteomics, and other molecular techniques.

Strategic Actions:

For the diffusion of biotechnologies to be successful the following measures should be put in place:

- Ensuring effective and closer horizontal linkages between research workers and the user corporate groups
- Public-private partnership in research and application of clean technologies
- Strict enforcement of the 'polluter pays' principle. This would require interaction with law enforcement agencies
- Capacity building and training, through workshops, of law enforcement officials, municipal workers, state government functionaries and corporate groups on role and relevance of biotechnology in waste treatment
- Steps to encourage small and medium business companies in producing eco-friendly products, microbial consortia etc. for wider usage
- Building greater awareness for protection of proprietary rights of microbial consortia through appropriate methods (e.g., process patent, trade mark etc.)

Greater inter-agency coordination between DBT, MoEF, ICAR, CSIR, CPCB, user agencies and industry through an inter-ministerial Task Force.

3.4. Industrial Biotechnology

At present, a third wave of biotechnology – industrial biotechnology – is strongly developing. Industrial biotechnology (also referred to as white biotechnology) uses biological systems for the production of useful chemical entities. This technology is mainly based on biocatalysis and fermentation technology in combination with recent breakthroughs in the forefront of molecular genetics and metabolic engineering. This new technology has

developed into a main contributor to the so-called green chemistry, in which renewable resources such as sugars or vegetable oils are converted into a wide variety of chemical substances such as fine and bulk chemicals, pharmaceuticals, bio-colorants, solvents, bio-plastics, vitamins, food additives, bio-pesticides and bio-fuels such as bio-ethanol and bio-diesel.

The application of industrial biotechnology offers significant ecological advantages. Agricultural crops are used starting raw materials, instead of using fossil resources such as crude oil and gas. This technology consequently has a beneficial effect on greenhouse gas emissions and at the same time supports the agricultural sector producing these raw materials. Industrial biotechnology frequently shows significant performance benefits compared to conventional chemical technology.

Strategic Actions:

- Focus in industrial biotechnology will be on reducing chemical and toxic load in our effluent streams, developing non-fossil fuels that are eco-friendly and developing green technologies in Industrial processing.

- Encourage public-private partnership to promote investment in this sector.

- Promotion of industrial biotechnology in strategic areas of manufacturing and developing green technologies.

3.5. Preventive & Therapeutic Medical Biotechnology

A healthy population is essential for economic development. Important contributors to the total disease burden are infections like HIV-AIDS, tuberculosis, malaria, respiratory infections and chronic diseases affecting the heart and blood vessels, neuro-psychiatric disorders, diabetes and cancer. It is important to synchronize the technology and products with the local needs of the health system and to facilitate technology diffusion into health practice.

Increasing knowledge about pathogen genomes and subtypes, host responses to infectious challenges, molecular determinants of virulence and protective immunity and novel understanding mechanisms underlying escaped immunity and ways to develop novel immunogens will guide development of vaccines against infectious diseases. Translational research and ability to rapidly evaluate multiple candidates in clinical trials can help accelerate the pace of vaccine development.

New directions in manufacturing and delivery are emerging. Major opportunities to control costs are the more efficient processes for manufacturing of new pharmaceuticals, more efficient systems for production of therapeutic proteins

and biomaterials and development of drug delivery systems that release drugs at a target site. A shift from parenteral to oral or transcutaneous administration of drugs and vaccine holds the promise of simplifying delivery in health systems.

Medical biotechnology offers a significant possibility for Indian industry to establish a strong pharmacy sector, a growing number of small and medium biotechnology companies, a large network of universities, research institutes, and medical schools and low cost of product evaluation. The medical biotechnology sector annually contributes over 2/3rd of the biotechnology industry turnover. The Indian vaccine industry has highlighted India's potential by emerging as an important source of low cost vaccine for the entire developing world. Further, economic opportunities through contract research and manufacturing through global partnerships are large if supported by enabling government policies and incentives.

The policy goal is to accord high priority to basic and applied research, to strengthen capacity in pre-clinical and clinical product evaluation technologies relevant to all aspects of health and medical care-predictive, preventive, therapeutic and restorative will be supported. Innovation will be supported through new granting mechanisms to support interdisciplinary networks and public private partnerships.

Strategic Actions:

(i) Research emphasis

- Basic and applied research would be supported in molecular and cellular biology, genomics, proteomics, system biology, stem cell biology, RNA interference, host response and new platform technologies.
- Pathogenesis of major diseases and molecular mechanics of disease transmission would be investigated
- Product development will be focused on vaccines, diagnostics, new therapies based on cell and tissue replacement, therapeutic antibodies, herbal medicine, plant based medicine, nucleic acids, therapeutics, drug and vaccine delivery systems, new anti microbial agents
- Research to improve production and manufacturing process and local production of biological reagents for development of diagnostics will be supported.

(ii) Improvements in infrastructure and networks

- A centre for translational research will be established. This new institute will be interdisciplinary and will deal with technology policy for public health, molecular pathogenesis of disease, technology development, scale up, product evaluation and technology diffusion into programmes.

Centre will be unique in having a pool of scientists, physicians, engineers, and public health persons working on public health grand challenges. This institute will work through public-private partnerships and be a training centre for product development, IPR and regulation.

- A mission mode programme will be initiated in biomaterial and medical device area as an integrated effort by the Department of Science & Technology and Department of Biotechnology. The goal is to promote R&D and industrial activity.
- Two centres of molecular medicine will be supported within medical school system closely interacting with basic science institutes.
- A virtual network of stem cell centres will be established, using a city cluster approach to network scientists and clinicians. Two core stem cell research centres will be established together with several network sub-clusters. An umbilical cord stem cell bank will be established.
- Mechanism based screening of herbal drugs known in traditional Indian systems would be carried out so as to get value added therapeutics products quickly
- An inter agency task force of ICMR, Department of Biotechnology, and DST will be established to suggest strategies for strengthening medical school based research. Capacity related to translational biology, clinical trials, molecular epidemiology and product development would be strengthened. Integrated MD-PhD programs will be supported.

(iii) Streamline guidelines and procedures for the approval of recombinant pharmaceutical products.

Currently there are multiple regulators, multiple ministries, lack of coordination between these regulators, Over-lapping and duplication of responsibilities of these regulators, lack of a linear progression in the approval process and committees working outside their area of expertise**.** **The Mashelkar Committee (2004)** has drawn up a new procedural framework for Biopharmaceuticals, which has streamlined the regulatory process:

- **IBSC** will monitor all development work (upto 20 Litres) and recommend to RCGM for Animal Toxicity Tests (ATT) & Scale up.
- **RCGM** will evaluate the recombinant technology & grant permission for scale up – R & D, review and approve for preclinical animal toxicity tests and evaluate ATT data & recommend to DCGI for Human Clinical Trial (HCT).
- **DCGI** will permit Human Clinical Trials, review Human Clinical Trial Data, grant permission for Manufacture and Marketing the product and inspect the facility where product is manufactured.
- **GEAC** will review the manufacturing process to ensure that the LMO (living modified organism) is "inactivated" during the process and send its recommendations to the Drugs Controller General of India within the

specified time. The GEAC would confine its approval role to LMOs and Category 3 and 4 microorganisms.

3.6. Regenerative & Genomic Medicine

The first wave of real healthy life extension therapies seems likely to result from research stem cells and regenerative medicine which helps natural healing processes to work faster, or uses special materials to regrow missing or damaged tissue. Doctors use regenerative medicine to speed up healing, and to help heal injuries that cannot heal on their own. Regenerative therapies have been demonstrated (in trials or the laboratory) to heal broken bones, bad burns, blindness, deafness, heart damage, nerve damage, Parkinson's and other conditions. Regenerative medicine will result in extended healthy lifespan; we will be able to repair some of the damage caused by aging, organ by organ. The first crop of simple stem cell therapies for regenerative medicine might be only a few years away from widespread availability.

There are major scientific and ethical challenges and safety concerns that must be overcome in taking stem cell based technology for bench to bedside. As it is rapidly evolving field, the existing national (ICMR) guidelines need to be updated and supported by clear articulated procedures. India must consider the potential medical applications of stem cell research. We must reassure end users on the safety and quality by ensuring regulation on stem lines having stable characterizations so that safety risks are predictable. We must reassure suppliers by regulation from lab to market.

Strategic Actions:

- Formulate a comprehensive Human Tissue Act (end 2005) with codes and guidance for regenerative medicine. In the intension, ICMR and DBT will support existing guidelines for stem cell research with clear procedures to be followed by scientists and physician.
- DNA and stem cell banking facilities will be created.
- Lay down clearer laws on animal testing in the country for progress to be made in this sector.
- Emphasize on Intellectual Property Rights, confidentiality and feedback
- Regulation for human tissue engineered products.
- Public awareness to be created in order to allay fears through education programmes, industry conferences and seminars.

3.7. Diagnostics for Emerging Medical Paradigm

There is potential to generate a new repertoire of tools for screening people for risk of disease, for early detection of infections and chronic diseases and for predicting outcome. In certain circumstances, single tests are requires to detect multiple pathogens or biochemical abnormalities. To be widely useful,

diagnostics need to be real time and low cost. Advances in biosensors and gene amplification are in the offing to enable real time medicine. Immuno proteomics has the potential to reveal multiple targets for development of diagnostics for diseases for which existing tools are unsatisfactory. For chronic diseases, a shift from treating disease on an individual basis is visualized by genetic assessment of likelihood of benefit from a therapeutic intervention, the so-called personalized medicine. It is seen that most drugs work in only a proportion of patients, targeting therapy to the right sub-group will not only make therapy more efficacious but also make evaluation of newer products cheaper.

Pharmacogenomics is a rapidly growing segment that provides a wealth of information pertaining to defective or missing genes, which call for differentiated medicine – a new avenue for drug research. This emerging discipline combines both infotech and biotech skills in augmenting high-speed data mining of both genotypic and phenotypic information with a view to evolving new forms of medical diagnostics and therapies. Gene regulation and other bio-algorithms will form the core of a new wave of diagnostics that are now being referred to as 'theranostics'.

India can be positioned as the hub for differentiated medicine as the country offers one of the most affordable development bases for personalized medicines. Personalized therapies will demand extensive clinical data generated from well-differentiated patient populations. India has one of the most desired disease and patient profiles that can enable such studies. Coupled with this is the need for a large number of novel diagnostics based on gene and non-gene based platforms. These are clearly large opportunities for Indian Biotech companies to pursue. Personalized drugs also address the affordability factor for expensive therapies such as those that are involved with cancer.

Some important barriers to improving the clinical utility of such knowledge exist. These include the highly complex nature of the problem, little incentive for industry to move to genomic-based approach, and lack of provider education.

Strategic Actions:

- Establish a cell for Diagnostic Biotechnology to encourage and support studies into the clinical application of pharmacogenomics. This cell should be well positioned to overcome barriers in its work to bring pharmacogenomics to the clinical setting.
- Encourage research-involving investigators with both clinical practice and pharmacology/ pharmacokinetics expertise while at the same time keeping the overall goal of clinical application/utility in focus.
- Provide incentives for this group of clinician-researchers to bring these scientific advances to the patient bedside

- Support education programs to providers of the importance of this field and its utility.
- Encourage biopharmaceutical companies to include pharmacogenomic data in their drug submissions

3.8. Bio-engineering & Nano Biotechnology

Bioengineering covers a wide range of areas such as tissue engineering, biomaterials for therapeutics, biomedical devices and instrumentation, biomedical sensors etc. Tissue engineering, especially of tissues derived from the patient's own cells, offers total acceptance and integration, unlike non-living materials or tissues from other species. Research is focused on developing non-immunogenic materials to serve as scaffolds for regeneration of damaged tissue. Bone and cartilage can be grown today and there is potential for other tissue. Developments in novel biomaterials for micro-particle and nano-particle encapsulated drugs, proteins and other molecules have offered improvement in quality of many therapies with minimal side effects.

Bioengineering offers opportunities for indigenous development of critical implants and extra corporeal devices. Nanoscale structured materials and devices hold a great promise for advanced diagnostics, biosensors, targeted delivery and smart drugs. The application of nanotechnology in bioengineering together with biotechnology offers a great new range of advanced biomaterials with enhanced functionality; and intertwined with tissue engineering, it has the potential to provide true organ replacement technology of the coming decade. While recognizing this potential, it is important to assess not only the efficacy, but also safety of these new interventions regard to human health.

The current market for medicinal devices such as implantables, disposables wound care, dental and orthopaedic materials etc is estimated at around Rs 7000 crores another Rs 5000 crores for the medical instrumentation sector in the country, with a growth rate of 15% per year. Nearly 80% of this demand is met by imports. Major factors limiting the growth of indigenous medical devices industry are the high cost and non- availability of imported technology, higher risks involved in producing and marketing medical devices, inadequate indigenous technology development and production of biomaterials and device and lack of a regulatory authority for medical devices in the country.

Strategic Actions:

(i) In bioengineering research emphasis will be on:

- Development of tissue engineered skin, cartilage, cornea, acute liver support, large segment bone repair and small diameter artery
- Biomaterials for drug delivery and controlled release

- Regenerative therapy for the failing myocardium through LVAD support, drug therapy and stem cell technology
- Advanced blood compatible surface fir cardiovascular devices
- Advanced burn and wound dressings
- Bioinstrumentation and physiologic monitoring
- Biosensors for detecting and monitoring metabolites and identifying specific genetic materials and for home monitoring of critical parameters like creatinine, cholesterol and triglycerides
- Dental and orthopaedic materials based on polymer-ceramic composites
- Test methods for safety evaluation of tissue engineered and combinational products.

Pre-eminent applications derived from Nano-biotechnology include drug delivery systems and diagnostics. R&D support will be focused on:

- Micro-electro-mechanical systems (MEMS), medical electronics and fibre optics
- Bio-molecular chips for analysis
- Carbon nanotube based biosensors
- DNA nanowire and electrical characterization of DNA

(ii) Establishing effective institutional mechanisms

- An inter agency working group will be formed to develop a common vision and working strategy in this area
- Appropriate regulatory process will be established to hasten introduction of new medical devices through inter-ministerial consultation
- Focused multi-disciplinary research groups shall be formed with clear mandates, targets and adequate funding; these will be monitored regularly for accountability on research output.
- Suitable institution-industry linkage will be built for technology proving and scaling up of products / medical devices developed at laboratory level

3.9. Bio-informatics and IT - enabled Biotechnology

Bioinformatics has proved to be a powerful tool for advanced research and development in the field of biotechnology. Bioinformatics holds out strong expectations of reducing the cost and time of development of new products such as new drugs and vaccines, plants with specific properties and resistance to pests and diseases, new protein molecules and biological materials and properties. As the full genome sequences, data from micros arrays, proteomics as well as species data at the taxonomic level became available, integration of these databases require sophisticated bioinformatics tools. Organizing these data into suitable databases and developing appropriate software tools for

analyzing the same are going to be major challenges. India has the potential to develop such resources at an affordable cost.

Bioinformatics in India can be used effectively for promoting research in biology; prospecting; conservation and management of bioresources; evaluation of products, processes and raw materials, managing complex data required to plan and monitor major national programs; and meeting the growing need of contract services and business outsourcing in pharma and biotechnology sectors. One of the major challenges in optimum exploitation of bioinformatics for solving life science issues is the formulation of appropriate computational biology problems that can be addressed through IT tools. This requires adequate appreciation of the scope and strength of bioinformatics by the biologists and basic understanding of the biological sciences by the information scientists. The solution lies in having adequate leaders with expertise in both life sciences and information technology and strong institutional / program tie-up between specialists from both the fields.

In India, Informatics for life Sciences is an emerging sector – the market size is still quite limited (many verticals each of size USD 20 million – USD 100 million). India has strengths in Chemistry and Computer Science, Software, Health Care and biology.

An extensive bioinformatics network has been established covering more than 60 centres spread all over the country. The network has generated human resources through education and training programs at different levels. Some of them have the potential of emerging as advanced R&D facilities. To promote R&D and to utilize the business opportunities would require creation of broadband connectivity, high performance computing facilities, virtual reality centres, availability of high quality trained manpower, interactions with bioinformatics centres in different countries and industry academia interactions for joint database and software creation.

Strategic actions:

(i) Human resource development

- A continuous talent pipeline will be ensured by producing 50-100 quality PhDs, 500 M.Sc and 500 advanced diploma holders in bioinformatics every year
- A national testing program will be put in place for accreditation of students at different levels
- The fellowships of PhD students shall be increased
- Industrial training will be introduced for students pursuing advanced diploma course in bioinformatics

- Virtual classrooms will be established in identified institutions. Teaching material in electronic form will be developed and made available at a reasonable cost.
- Industry participation in developing course content and materials will be ensured.

(ii) Infrastructure development

- Super computing facilities with 10 teraflops computing capacity will be created on biogrid to promote protein folding and drug design activities
- Broadband internet connectivity shall be provided for bioinformatics research and manpower development at subsidized rates

(iii) Testing of public domain resources

- Institutional mechanism will be put in place for testing public domain databases and software and making them available to the users from the academia and the industry. After such testing, these databases and algorithms will be graded so that scientists can use them with higher confidence.
- Commercial databases and software will be tested before the industry invests in the products. Such service will help the industry to reduce their costs and use only certified products

(iv) Inter agency coordination

- There are many government departments and agencies, which are supporting bioinformatics activities. These include CSIR, ICMR, ICAR, DST and MIT. An independent inter departmental agency will be established to coordinate these activities among these departments and agencies.
- The agency will be empowered by legislation to provide the direction and oversee the implementation of the coordinated action plan.

(v) Strengthening of DICs and sub DICs

- The CoEs DICs and sub DICs of BTISnet will be strengthened for hardcore research in bioinformatics as well as high-end human resource development.
- Department of Biotechnology will increase the investment in this sector three times over a period of five years

(vi) Bio IT parks and promotion of bioinformatics industries

- Department of Biotechnology in association with the Ministry of IT will set up bio IT parks for the promotion of the bioinformatics industry.

- High-risk projects in bioinformatics will be promoted through special support mechanism including public-private partnerships.

3.10. Clinical Biotechnology and Research Services

(a) Clinical biotechnology

The cost of launching a new drug into the marked is estimated to cost between $300-500 million of which the cost split between Research and Development is 25% : 75% which would translate to an approximate cost of US$200-400 million for patient clinical studies and trials which form the main components of drug development. The potential of being a key player in this segment is high and remunerative. India has made tremendous progress in clinical biotechnology over the past few years. However, the infrastructure required to identify, document and monitor patients under clinical trials need to be first put in place before India can partake in this activity. There is also an exciting opportunity of conducting longitudinal studies in disease segments for prospecting new biomarkers and novel pharmacogenomic information both yielding high value Intellectual Property.

(b) Research services

With the global pharmaceuticals companies looking outward to reduce their ballooning research costs, a country like India is in a good position to tap the new business opportunities. Due to the emphasis on outsourcing in the nearly stagnant economies to cut costs and retain competitiveness, India is being considered as a destination for contract research in the pharma sector.

Custom research is a services model that most Indian biotech companies have opted for at their start-up stage in order to earn early revenues with which to fund infrastructure and scientist salaries. These companies harbour ambitions of original R&D once they reach a certain profit level.

Since research service is about delivery of results, the Government has an important role to play in facilitating the industry. India needs to be promoted as a research service destination. The IP environment is confusing since there is no mechanism or standard for contract sharing. The industry needs to collaborate with the academia and a code of conduct for biotech members has to be designed.

Number of clinical trials that Indian companies would be conducting will increase tremendously for products developed indigenously and imported. Measures are needed that ensure patent safety and

compliance with ethical and regulatory requirements. The quality of trials should be such that data generated are accepted globally. Clarity in rules is required related to biotech drugs developed by Indian companies abroad, drugs discovered abroad and licensed to an Indian company, and drugs discovered by an Indian subsidiary of foreign company. The policy goal would be to promote consultations among all stakeholders within the Government and private sector to evolve clear guidelines and procedures.

Strategic Actions:

- Frame appropriate rules and procedures to support contract research services through stakeholder consultation.
- Harmonise and streamline the regulatory issues for important and export of biological materials.
- Review eligibility of virtual export of R&D services through contract research for fiscal incentives.
- Address the operational deficiencies through stakeholder consultations for conducting clinical trials.
- Develop a Good Clinical Trial Practice Manual taking into account international guidelines and disseminate these widely.
- Promote, train and support clinical trial investigators as a collaborative ICMR, DBT initiative.
- Strengthen clinical trial capacity in medical schools and hospitals and create centres of excellence.
- Address issues and frame guidelines for patent protection including issue of liability.
- Strengthen institutional ethics committees to bring them at par with global benchmark.

3.11. Intellectual Property & Patent Law

The development of capabilities for the effective management of Intellectual Property (IP) is an important element in securing the benefits of public and private sector research in biotechnology. In this context, filings of patents both in India and aboard are critical to the growth of the Indian biotech Sector.

The expenses for filing patents especially outside India are prohibitive and a major barrier to effective Intellectual Property Management within the country.

Whilst expenses incurred with respect to filing of patents in India is eligible for weighted deduction, similar benefit is not provided for expenses incurred with regard to filing patents outside India. As Intellectual Property Right (IPR)* creation is a pre-requisite for exports to the regulated markets, it is recommended that expenditure incurred with regard to filing patents outside India be also eligible for weighted deduction U/S 35 (2AB). This is also

imperative in the new WTO-TRIPS regime, which has taken effect on 1st January 2005.

Strategic Actions:

Administration of the new intellectual property rights regime should be improved. This will be achieved by

- Encouraging science graduates to pursue law for better understanding of IPR related issues
- Inclusion of IPR related issues in curriculum of law colleges for facilitating filing of international patents, license negotiation, dispute resolution etc.
- Training scientists and technology transfer professionals in the strategy of intellectual property protection relating to assessment of patentability, prior art examination and technology transfer issues;
- Training patent attorneys on science subject(s) and improving mechanisms for IPR administration through reforms and creation of patent offices, patent codes and ensuring adequate availability of patent attorneys. This will be promoted to an effective inter-ministerial collaboration.
- Setting up of an arbitration council to redress IPR disputes
  The setting up of an arbitration council will help in improving the perception and increasing International confidence towards IPR protection in India.
- A Rs 50 crore budget be allocated to substantially improve the current Patent infrastructure and set up additional offices in cities such as Bangalore & Hyderabad.
- The Department of Biotechnology will engage in constant dialogue with the Government of India and WTO-TRIPS to address patentability issues in Biotechnology and their future inclusion in the Patents Bill through ammendments.

SECTION IV

CONCLUSION

The need for an integrated biotech policy with concurrent attention to education, social mobilization and regulation is considered to be an essential pre-requisite for an orderly progress of the biotech sector. Synergy between technology and public policy is essential for us to achieve an effective mobilization of the tools of new biology for adding both years to life and life to years.

The National Biotech Development Strategy has taken into consideration all the areas that will affect the Indian biotechnology industry. The Policy has clearly chalked out direction to strengthen India's academic and industrial biotech research capabilities, work with business, government and academia to move biotechnology from research to commercialization, foster India's industrial development, inform people about the science, applications, benefits and issues of biotechnology, enhance the teaching and workforce training capabilities and establish India as a preeminent international location for biotechnology**.**

It is imperative that India leverages resources through partnership and build regional innovation systems. The strategy will help develop local talent for a globally competitive workforce. While it recognizes private sector as a crucial player, the strategy also visualizes government to play a major catalyzing role in promoting biotechnology. The development strategy is based on a strong innovation promotion framework in which industry, academia, civil society organizations and regulatory authorities will communicate in a seamless continuum. The perspective for Indian biotechnology would be global while also concentrating on local issues.