'TRIPLE HELIX' :
University, Industry and Government Partnerships

(A Case Study of Biotechnology Sector in Delhi Region)

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CHAPTER . 1

INTRODUCTION and THE OBJECTIVES OF THE STUDY

1. Introduction and the objectives of the study

In the latter half of this century, large and growing expenditure on research, design and development (RD&D) have become a general feature of industrial economies. All the more, in recent decades, RD&D budgets have grown faster than the economies which support them because it is seen as the mechanism by which new and existing knowledge in science and engineering is translated into marketable artifacts or innovations. But there is no one to one relationship between RD&D and economic growth as RD&D does not guarantee success in innovations; companies have to develop and co ordinate many other areas (like marketing, production) of competence.

All analysts agree that the linear models of basic research leading on to applications and technological innovation is either over simplistic or no longer followed and advocated by policy experts and decision makers. Indeed, Akio Morita, Sony's Chairman, took as the title of the first UK innovation lecture, "S" Does Not Equal "T" and "T" Does Not Equal "I" [S = Science, T = Technology, I = Innovation] (Sir Nicholas Fenn, British High Commissioner to India , 1995)[1]. Of late it has been realized that getting wealth without systematic knowledge is not easy and straightforward affair. On the other hand, getting wealth from knowledge is not particularly easy either. (If that would have been the case all Professors would have been millionaires !). During the several years various perspectives have been put forward and came into sharp focus. National System of Innovation, evolutionary technological learning perspectives and 'other' non-linear models (some are discussed in the upcoming chapters). Among these perspectives, the 'Triple Helix' perspective, which advocates partnerships

[1] See chapter 1.2, "Key note address by H.E. Sir Nicholas Fenn" in White Michael & Wasi Jehanara (eds.); (1995).

between university, industry and government has come into prominence. But such interactions and partnerships are not easy to arrange or evolve, as the relationships are neither linear nor simple. As Prof. Appleton, draws our attention, it is like a process of 'academics kissing a frog'. Difficult to do, but with amazing results when it works! (Michael White, 1995).

In a cross sector study of 209 firms, Link and Rees (1990) found that the return on R & D expenditure is over 2.5 times higher amongst firms, which collaborate with units than amongst those, which do not. Similarly, Berman (1990) demonstrates that 'collaboration not only increases future industrial research, but also speeds up the transfer and utilization of academic research in industry. Etzkowitz (1997) and others (like Leydesdroff , Webster , etc.) in the last decade drew our attention to 'Triple Helix' as a new innovation strategy. Because of this, much attention has been focused in the past decade on those relationships which world wide have attempted to facilitate the transfer of knowledge from the research base to the industry through government mediation for creating wealth.

The above developments and realization seemed to have influenced India – both in government policy making bodies as well as Industry. Government representatives stress the need to support innovation in the new technology based industries and thus trying to promote commercialization of PSR through collaboration and technology transfer between academic and government laboratories and industry. Similar views are being echoed in the private industry sector. For instance Rajive Kaul (Vice President, Confederation of Indian Industry, 1995) observed [2]:

> "In India, with the opening up our markets and industrialists trying to integrate with global markets, it is necessary for us to be more innovative, to try to attain world standards. Indian Industry, must therefore, work closely with institutes

[2] See the Chapter 1.1, "Opening notes by Mr. Rajive Kaul" in White.M and Wasi.J (eds.),(1995).

and join hands with them in trying to achieve this technological excellence. CII believes that industry and institute interaction is one of the strongest linkages necessary for achieving this particular goal."

The last one and a half decade has witnessed a steady stream of literature concerning innovation studies from a variety of perspectives (e.g. – Nelson(1993), Lundvall (1992), Etzkowitz(1997), Leydesdroff(1997), Michael Gibbons(2000), Andrew Webster(1998) etc.). Whilst such studies draw attention to the importance of linkages between major actors in the national innovation system, the role of knowledge institutions have come to assume a primordial importance. In this line of thinking, the major institutional mechanism of networking between knowledge institutions, industry and the mediative role of government or state is seen as crucial in the success of innovation process, particularly in the commercialization of research and introduction of new process in the market. Metaphorically Henry Etzkowitz and Leydesdroff termed this networking between three major actors (university , industry and government) as 'triple helix'. This idea was originally put forward by them in a book "Universities in the Global Knowledge Economy: A Triple Helix of University-Industry-Government Relations' (1997); and in several other papers in various journals (see bibliography).

Over the years, triple helix is being put forward as a new innovation strategy to be adopted fruitfully in the S&T policy formulations – both in the developed and developing countries[3]. Even though the idea and role of University-Industry relationships in the success of the commercialization of innovations has been in vogue from the middle of 19th century, the phenomenal

[3] Already three 'Triple Helix international Conferences have taken place and the success of it can be gauged from the number of participants attending it :
1st conference took place in Amsterdam in 1996 –90 participants from over 30 countries participated.
2nd conference took place in New York – 160 participants from various countries participated.
3rd conference at Rio (2000) also generated much curiosity and people many developed as well as developing countries participated.

success of U.S. biotechnology and information and communication technology revolution and the significant role of U.S. academic sector has been effectively used by science policy experts and others to underline the importance of the concept of 'triple helix'.

In India, even though the concept of triple helix is yet to attract the attention of scholars, the underlying idea of 'tripartite linkages' between the three main actors (academia and public sector research laboratories, industry and government) assumed considerable importance in the policy discourse relating to S&T issues. The present study is specifically conceived to explore the concept of triple helix in the context of biotechnology sector in the Delhi region. This study is designed, though in a small modest way, to explore both the theoretical and empirical relevance of the concept of triple helix in the Indian context. Given the importance of modern biology in the present and future context, one important domain of this, namely, biotechnology is identified in this study. As the S&T policy related discourse in India in the recent decade stresses, research conducted in academic and government funded national laboratories in India are seen as crucial to the realization of future opportunities for industrial innovation in high-tech industries, especially biotechnology.

Further, it is also seen that potential is best realized by the establishment of close links between industry and the other two segments of the national innovation system. Hence, the present study addresses this issue in the case of biotechnology sector in the Delhi region.

OBJECTIVES OF THE STUDY

1. The major objective of the study is to explore the relevance of the concept of triple helix in the Indian context through the biotechnology sector. Given the limitations of time and scope of the study (restricted to

M.Phil level) a small sample of biotechnology institutions are selected in the Delhi region.

2. Given the centrality of linkages between three helices in the concept of triple helix, the second objective of the study is to explore the linkages between 3 different actors in the biotechnology sector. The exploration of linkages will be mapped through the structure of funding pattern of projects in evolving partnerships; and the structure of orientations of projects as reflected by scientists selected in the sample.
3. Given the limitations of time, scope and resources, the objective of mapping linkages of the industry component will be examined through the university and public sector research institutions. In other words, the role and influence of industry will be explored to the extent it is manifested in the two above components, through funding, perceptions of scientists in the public research institutes and other features.
4. Given the transformation of each of the helices in the triple helix becoming an important feature, the objective of this study will be to explore the extent of institutional and organizational changes that are taking place in the academic and public sector research institutions in the biotechnology in the Delhi region. Here effort will be made to explore the orientational changes of the professionals in the academic and public sector research (with respect to commercialization of science versus 'academic' orientations).
5. To what extent the concept or idea of triple helix finds its relevance as an innovation strategy in the Indian context and in what form? Given varying manifestations of triple helix in national contexts, this question is considered as one of objectives of the study from the point of S&T Policy studies.

In the light of the main objectives outlined above , this M.Phil dissertation project/study is structured as follows :

The section following the present one (Chapter 2), briefly encapsulates some recent studies on innovation by laying particular focus on 'national innovation system' and 'new modes of knowledge production'. These studies are stressed as example of 'non-linear' models. Extending this line of argument, the concept of triple helix (another example of non-linear model) is further explored and an effort is made to review the manifestation of this concept or idea in other national contexts including India. In a large measure, this chapter is meant to serve as review of relevant literature.

In a way review of literature relevant to the present study is further extended to Chapter 3 on 'Biotechnology in India'. In this chapter an effort is made to review the institutionalization and growth of biotechnology in India as the M.Phil dissertation project has identified the biotechnology sector in Delhi for its empirical research to examine the concept of triple helix.

The methodology (Chapter 4) follows next. Various facets of research design; reasons to select biotechnology sector in Delhi; questionnaire, sampling and interview related details; and the hypothesis governing the study are discussed in this chapter.

In Chapter 5, the empirical research undertaken is presented. The major finding arising out of this section are: two way linkages rather than the tripartite linkages seem to be meaningful. In other words, triple helix finds only partial relevance in the case of biotechnology in the Delhi region. This chapter goes on to further present certain important findings on the pattern of funding, structure of partnerships between different helices of triple helix, commercial orientation of researchers in the public sector research and academic settings and the extent of organizational changes observed in the settings.

The Chapter 6 presents certain concluding remarks and some S&T policy implications related to triple helix. In this chapter effort has been made to relate the hypothesis and questions framed at the beginning of undertaking this M.Phil dissertation.

CHAPTER . 2

BRIEF REVIEW OF SOME INNOVATION STUDIES

And

'TRIPLE HELIX' CONCEPT

CONTENTS

2.1 NATIONAL SYSTEM OF INNOVATION

2.2 MODE 1 AND MODE 2

2.3 TRIPLE HELIX MODEL OF INNOVATION

2.4 INSTITUTIONAL AND ORGANIZATIONAL CHANGE

2.5 BACKGROUND ON 'TRIPLE HELIX' AND NATIONAL VARIATIONS W.R.T THE PERSPECTIVE

2.6 INDIAN DEVELOPMENTS

2.7 SOME POSSIBLE FEATURES OF INNOVATION STRATEGY FROM A TRIPLE HELIX PERSPECTIVE

2.8 KEY RESEARCH QUESTIONS FROM THE REVIEW OF LITERATURE

2.9 WORKING HYPOTHESIS GUIDING THE RESEARCH

2. Brief review of some innovation studies and 'Triple Helix' concept

" We need systematic work on the quality of knowledge and the productivity of knowledge -- neither even defined so far . The performance capacity , if not the survival , of any organization in the knowledge society will come increasingly to depend on those two factors. But so will the performance capacity, if not survival , of any individual in the knowledge society."

--- Peter F. Drucker (1994)

"... Core competence is important , but not the most important thing. Instead , it is more important to evolve or acquire competencies. "

--- Richard Foster, Businessworld, 4th June ,2001

The global economic system is rapidly shifting away from the relatively stable hegemony of financial capital to the dominance of 'knowledge' as a driving force. In the emerging scenario, conventional locational advantages of host countries based on natural resources (with increasing dematerialisation of production) and cheap labour endowments (with increasing employment of flexible automation systems in production), protection, taxes and incentives are becoming relatively less valuable compared to the availability of knowledge creativity activities (Nagesh kumar : 1998).

The recognition of the role of technology as an instrument of competitiveness has prompted the governments of industrialized countries to support and protect the technological effort of national enterprises especially in new core technologies in a manner that has been termed 'technonationalism' and 'technoprotectionism' (Kumar and Siddharthan : 1997) to retain their market dominance. But herein lies an unprecedented opportunity for developing countries to do what development economists have long anticipated -- namely, leapfrog in their use of technology[1]. This implies that countries that begin their industrialization process as early immitators and innovators will be more successful in catching up (Prasada Reddy ,2000). However, leapfrogging is contigent on policy commitment to radical improvement in technological innovation capabilities -- in both qualitative and quantitative terms.

Similarly, a science based company can no longer be an island unto itself. In a highly competitive global environment, it is necessary to use outside sources of knowledge and technology. Companies increasingly look to universities, as well as to other firms and government laboratories as a potential source of useful knowledge and technology, especially in biotechnology. In this co-operative initiative which is emerging from both the academic and industrial spheres, often encouraged by government at both regional and national levels and by multinational organizations (Etzkowitz:1998), new forms of knowledge partnerships as key to future progress. Generation and application of knowledge will redivide the world into 'haves' and 'have nots'. This unprecedented discontinuity for current technologies, markets and businesses is potentially the biggest opportunity in the history of commerce and industry. Within this

[1] Conventional wisdom states that the most viable point of entry into the industrialization process for developing countries to be mature technologies because of low production costs and low skill requirements. But, according to **Perez** and **Soete** (1988) these are industries that have already exhausted their technological dynamism. Countries adopting this strategy may face the risk of getting caught in the low wage and low growth pattern. The catching up process, on the other hand, involves acquiring the capacity to improve upon the old and generate new technologies rather than simply being able to use them.

application of knowledge[2] in the form of technological innovation[3] will become more important than access to physical and financial resources achieving economies of scale and scope, or the ability to control markets and distribution system (Mauricio de maria Campos and Fernando Machado, 2000).

Because of this while traditional strategy[4] and management models concentrated on product attractiveness and appropriate positioning of companies

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[2] Knowledge is information put to productive use. Information is data arranged in meaningful sequences and data are simply description of things. To use an analogy, data are snapshots in time, information is a scrapbook and knowledge is a blockbuster movie (J.Botkin, 2000).

[3] Innovation = Invention + exploitation (Robert , 1988)

Innovation is the constructive response to the uncertain and unprogrammable developments which can not be easily imitated by competitors and can result in continuing profitability for an organization. They provide competitive advantage precisely because neither the experiences nor the assets can be reproduced by another firm. This represents a shift from resource based approach towards a dynamic capabilities approach to business strategy.

Innovation is a knowledge creation process. When organization innovate they do not simply process information from the outside -- they actually create new information and knowledge from the inside out. In order to redefine both problems and solutions and in the process recreate the environment.

Competence in innovation is redefined in terms of the ability to solve problems by selecting relevant data and skills and arranging what exists as novel ways to deliver insight. [Internal Journal of Technology Management . Special Issue on R&D]

Innovation is defined as the process by which new products and techniques are introduced into the economic system. Successful innovation results in the capability of doing something that could not be done before at least not so well, or so economically. In Scumpeter's terms (1912) innovation results in the establishment of a new production function -- a change in the set of possibilities that defines what can be produced and how. [David L. Sills (ed.), International Encyclopedia of the Social Sciences, Vol.7,The Mac Millan Comp. & the Free Press, 1968]

Schumpeter used the expression ' innovation' to connote the first introduction of a new product, process, method or system into the economy. As Schumpeter pointed out, there is many a slip between cup and lip in the development of an invention to the point of commercial introduction.

[4] (1) The first was developed within the neo-classical models of growth, using production function framework (basically, an input-process-output system). Inputs are called factors of production and include labour and capital which interact in a process of production of wealth that is limited by the current level of technology. The total maximum level of production or total output of the economy is given by $Y = F(K, L)$ in which Y is output, K is capital , L is labour and F represents the process of transforming the factors of production into outputs. **Adam Smith** first gave the idea that the pure accumulation f capital and labour is not sufficient to account for all the growth. However, it was **Solow** (1956) who first separated the effects of growth that went beyond the accumulation of physical capital to technological change .

in the market and industry as a basis for company success, recent changes in the technological, political and sociological environments of businesses have forced strategists to draw more attention to the "internal view" of business organizations. In this often more dynamic view of strategy, the foundation for sustainable competitive advantage lies in the current and future resource base (both at national level and firm level) and capability to grow and nurture them better and faster than the competition. In light of this evolution, it is no surprise that research and framework development within the strategic management field has recently embarked on a "**Knowledge management**"[5] route (Paul Verdin and Nick Van heck, 2000).

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1. The second traditional perspective is associated with **Schumpeter's economic theory**. According to him , businessmen and firms are not passive elements merely adjusting the prices to the idiosyncracies of the market . He argued that the expectations of profits would not only lead to price setting , but would also drive the " entrepreneurs " to innovate. The entrepreneurial drive toward innovation was due to the temporary monopolistic position from which the innovator would benefit. Schumpeter regard this position as temporary because the advantages from this privileged position would eventually perish in the vortex of the competition which streams after them, since other firms will copy the innovator (Schumpeter,1934) , following the process of creative destruction. Therefore, innovation appears at the forefront of economic progress during prosperity (Pedro Conceicao, Gibson and Manuel V Hector : 2000, page 1-4).

[5] It is significant to understand relationship between Knowledge management and innovation processes. It becomes more essential in today's competitive environments where a dynamic capability to meet rapid change is an essential ingredient in achieving sustainable business success in volatile global and national marketplaces.

At this juncture Knowledge management practices (KMPs) help to find a bridge between what had become distinct traditions in the study of knowledge management and innovation.

Knowledge management tends to concentrate on issues like classification of types of knowledge (i.e. 'Tacit' Knowledge and 'Explicit' knowledge). Nonaka further identifies four ways in which new knowledge is created :-

- Tacit to tacit creation of knowledge , which is a personalized form of knowledge growth in which one person passes on personal knowledge to another person.
- Explicit to explicit knowledge creation , by which new knowledge is gained by combining and synthesizing existing explicit knowledge.
- Tacit to explicit creation of knowledge, which occurs when someone takes existing knowledge, adds their tacit knowledge and creates something new.
- Explicit to tacit creation of knowledge , which occurs when new explicit knowledge is internalized within members of organization to create new tacit knowledge.

Innovation studies , on the other hand , have been particularly interested in the firm specific routines which create a distinctive organizational 'signature' in the manner in which a firm deploys knowledge to produce innovation. This indicates a dependency on the evolutionary path based on prior accumulated knowledge and experience within a given organizational culture , management style and set of operational routines.

KMPs are observable routines involved directly in the development and application of knowledge .
(Koh.A , 2000 and Hull,Coombs & Peltu , 2000)

Building technological capability requires a massive effort in developing human resources and institutions and in defining their purpose. Dahlman *et al.* (1987) concluded from their survey that although experience is important, technological capability is not acquired merely from experience. It comes from a conscious effort in monitoring and keeping track of developments throughout the world, accumulation of added skills, and responding to new pressures and opportunities (Nagesh Kumar and Siddharthan : 1997). There are number of studies which argue that most successful companies which have technological and economic advantage are increasingly dependent on universities as in the case of biotechnology firms in USA. New technology based firms are becoming increasingly dependent on the generation of knowledge in universities.

Since university undertakes the function of teaching and basic research etc.; it contributes to the accumulation of knowledge, specifically of skills, through the formal process of learning through education. For this reason, universities are becoming a key element in innovation policies throughout the world. And as knowledge increasingly becomes the key strategic resource of the future, our need to develop comprehensive understanding of knowledge process for the creation, transfer and deployment of this unique asset is becoming critical (Syed S.Shariq ,2000). So, this is primarily the reason that the nature of science and technology policies at the national level is changing from being mission oriented to being more diffusion oriented, through enhancing the mechanism of knowledge transmission and technology transfer and the exploitation of research results (Joao Caraca ,2000).

The relation between science and technology and economic growth is widely acknowledged to be very complex. Traditionally, successful commercialization of R&D was understood as being the result of a linear process, beginning with scientific research and the moving to technology development, before reaching the stages of financing, manufacturing and marketing. But recent advances in the understanding of innovation have sharply criticized **linear models of innovation** (Kozmetsky,1993) because no sustained connections among academic, business and government institutions were explored, beyond the expectations that universities produce science and business enterprises commercialize technology. In the earlier 'linear' model, there was an expectation that investment in basic research would yield economically beneficial results but no guarantee existed. Today, it is understood that there is more to relationships. An integrated and interactive approach blending scientific, technological, social-economic and cultural aspects is required to explain the dynamics of innovation (Pedro Conceicao, Gibson & Heitor,2000).

It is thus seen that *linear models of innovation*[6] *have been superseded by* ***non linear models*** that analyze the developments in terms of networks. Following is a brief discussion on these different perspectives on innovation :-

2.1 National System of Innovation –

According to Boulding (1985), the broadest possible definition of a system is 'anything that is not chaos'. Somewhat more specifically, a system is constituted by a number of elements and by the relationships between these elements. It follows that a system of innovation is in the production, diffusion and use of new, and economically useful knowledge and that a national system encompasses elements and relationships, either located within or rooted inside the borders of a nations state (Lundvall, 1992).

6

1. For comprehensive review see Forrest.J (1991).
2. See Faulkner and Senker (1995), pages 206-211 for critique of pipe line model and discussion on Chain linked model and Fifth Generation innovation process.

Using the terminology of Boulding, it is obvious that National System of Innovation is a social system. A central activity in the system of innovation is learning, and learning is a social activity, which involves interaction between people. It is also a dynamic system, characterized both by positive feedback and by reproduction. The analysis of systems of innovation thus helps us to understand and explain, why technology develops in a certain direction and at a certain rate, though a strong element of randomness always remain (Lundvall, 1992).

Though, the capability to innovate can not be assessed in isolation from efforts in science, research and development but not all important inputs the process of innovation emanate from science and R&D efforts. This is because the learning takes place in connection with routine activities in production, distribution and consumption and produces important inputs to the process of innovation. Everyday experience increases technical knowledge and gives idea about in which direction solution should be looked for. Such activities involve learning by doing, increasing the efficiency of production operations (Arrow, 1962), learning by using, increasing the efficiency of the use of complex systems (Rosenberg, 1982); and learning by interacting, involving users and producers in an interaction resulting in product innovation (Lundvall,1988) **(Lundvall,1992,**page 1-18**).**

It is the above premise which has guided theorists propounding National Innovation System :

Lundvall (1988) noted that the interactive terms between demand and supply in user -producer relations assume a system of refrence in addition to the market. The classical dispute in innovation theory had, in his opinion, referred to the role of demand and supply, that is, market forces, in determining the rate and direction of the process of innovation (cf. Mowery & Rosenberg,1979; Freeman,1982). If however the dynamics of innovation (e.g. Product competition) are expected to be different from the dynamics of the market (e.g. Price competition), an alternative system of refrence for the selection should be specified. For this purpose, Lundvall proposed to take the national system of innovation as the starting point when defining a system of innovation (Etzkowitz & Leydesdorff, 2000).

Lundvall added that the national system of production should not be considered as a closed system : "the specific degree and form of openness determines the dynamics of each national system of production". The focus on national systems reflect the fact that national economies differs regarding the structure of the production system and regarding the general institutional set-up. The basic difference in historical experience, language and culture will be reflected in national idiosyncracies in :

- Internal organization of firms
- Role of Public Sector
- Inter-firm Relationship
- Institutional set up of the financial sector
- R&D intensity and R&D organization
- National Education and training system

According to Lundvall, the first explicit use of the concept of National System of Innovation[7] was by **Freeman** in his book on Japan (1987) in which he referred both to the nation specific organization of subsystem and to the interaction between subsystems. Lundvall (1992) also states that his

[7] The first systematic and theoretically based attempt to focus on national systems of innovation goes back to Friedrick list (1841/1959) list makes a distribution between Adam Smith's 'cosmopolitan' approach which puts focus on exchange and allocation and his own national perspective focusing in the development of productive forces. This viewpoint included elements like protection of 'infant industries'; government responsibility for education and training; and developing an infrastructure supporting industrial development (Lundwall, 1992; page 16-18).

perception of National System of Innovation is more closely related to **Michael Porters'** (1990) conception, who has pointed four determinant affecting the competitiveness of a national industry : Firm strategy; factor conditions; demand conditions and supporting industries .

Though, in this period of increasing internationalization and transnational political regulation the traditional role of national government with respect to industrial policy and technology policy is challenged; but still the role of national government and public sector can not be totally discounted. In fact, in many ways, the central role of the public sector in creating, maintaining and developing modern National System of Innovation comparable with the one played by a pacer in a bicycle race. If public sector demand in both qualitative and quantitative terms races ahead it loses contact with the innovative capability of national suppliers. On the other hand, if public sector demand slows down their process of renewal and stick to pure routinising. Thus, what is required is optimal pacing leading to an upgrading of national systems of innovation requires a mutual understanding between the public and private participants in interactive learning and searching processes (Birgitte Gregersen, 1992).

As National System of Innovation calls for interaction between different actors of innovation so one can say that Triple Helix model that emphasizes the University-Industry-Government relationship can be considered as a variant of National System of Innovation. What differentiates National System of innovation and Triple Helix is that the former makes use of historical analysis and comparative analysis of different countries. Triple Helix on the other hand draws attention to the effectiveness of linkages between University-industry-Government partnerships for enhancing the effectiveness of innovation within the national boundaries to a large extent.

2.2 Mode 1 and Mode 2

Another important perspective related to the changing patterns of research system and the production of knowledge is the work of Gibbons *et al* (1995). In contrast to National system of innovation Gibbons *et al* have drawn our attention to the new mode (Mode 2) of knowledge production contrasting it with the existing Mode 1.

The concept of Mode 1 of knowledge production rests on the idea of complete autonomy for science and the disciplines of science had well marked out boundaries in which academic pursuit is carried out. In this, universities were considered to be place for teaching and conducting "pure research".

But this perception of university started changing, especially post world war in USA, when science was started being considered as so pervasive and central to generation of wealth and well being that production knowledge had become a social activity. Thus, a new regime of knowledge production started emerging alongside more traditional in which problems were set in the context governed by largely academic interest of scientific community. In new modes, problems are not set within a disciplinary framework rather there is close interaction of actors throughout the process of knowledge production; hence, knowledge production is more accountable. One of the characteristic of Mode 2 science is that knowledge is being generated in the context of application, science can not be regarded as autonomous space clearly demarcated from society, culture and economy. There has been development of more open system of knowledge and growth of complexity in society and increase in uncertainty in both. Thus, the former i.e. Mode 1 was generated under more benign economic and stable cultural conditions and on the other hand, second account reflects the anxiety of its era -- social effects of technology, environmental impact of technology and relentless on going process of industrialization causing increasing concern (Helga Nowonty, Peter Scott and Gibbons , 2001).

According to Gibbons (2000), the second academic revolution is a product and a further development of the first academic revolution in which the universities assumed the mantle of research and institutionalized it in the form of discipline based science. But as many universities and firms are discovering, research, unlike science, is transgressive, it spills out across disciplines, institutions, identities. And this observation by Gibbons can not be neglected while talking about new disciplines which have been created through synthesis i.e. synthesis of practical and theoretical interests, elements of older disciplines such as electrical engineering, a bit of psychology and philosophy and a machine, were made into computer science.

Thus some of the key features of Mode 2 can be briefly stated as below :-

- The growth of knowledge industries has not only led to an increase in knowledge workers and proliferation of sites of production but also there has been gradual erosion of demarcation between traditional knowledge Institutions such as universities and research institutes and other kinds of organization.
- There has been gradual emergence of small and medium sized high technology companies think tanks, formation of corporate universities, etc. This process has been accelerated by successive changes in step of productivity that have characterized the industrial development which have been in turn produced by new technologies.
- Mode 2 also represent an enlargement of participants in research and concept of research has been widened to accommodate new fields which are emerging with the advent of new technologies. The sites at

which knowledge is produced has multiplied and its social diffusion not confined to one restricted place or context.

- The Mode 2 knowledge production also implies an extension of quality mechanism to include new criteria, and new constituencies and not denying that demarcations between good and bad research can and indeed must still be established.
- The functional differentiation with the sphere of specialist activities which in turn have led to formation of specialized institutions which conduct research have been greatly enhanced by transgressive and instantaneous technologies, techniques and boundary objects that easily cross time and space, travel from one research site to the other.
- Mode 2 is marked by transformation in the science systems in terms of institutional features also in mode of funding and greater shift towards accountable to public.

Some of the important premises stating reason for change from Mode 1 to Mode 2 form of knowledge production according to Gibbons *et al* (1995) are –

- In Mode 1 nation states can be regarded as institutions which embody ideals of bureaucratic rationality, which are now being undermined by the emergence of suppressed local and regional loyalties as also by forces of globalization.
- The demarcation between public and private spheres with the state as guardian of the former has been eroded.
- The nation states' responsibilities to ensure fully employment, progressive social policies to build science and technology infrastructures have dwindled.
- Advancement of science and technology has also enlarged the territory of politically created need for an array for new regulations and regulatory frameworks. These regulations are preceded by elaborate negotiations,

mediations, consultations which takes place in public arena. State has now become mediator of market as well as efficiency being considered on the basis of deliverance of public services.

The way in which the transition from Mode 1 and Mode 2 is projected as a new perspective appears to be only partially relevant to developing countries like India. Even though the transitional characteristics of Mode 2 (as mentioned above) are emerging, it is difficult to accept the paradigmatic change which reduces the importance and centrality of the university. Indeed there is little evidence for the change even in the USA and in developing countries. The interaction and partnerships proposed by Triple Helix seems to be more realistically potential in the case of developing countries where universities and government labs are major producer of basic and applied knowledge. What is lacking is possibly the linkages between different actors, this is where the importance of Triple Helix lies.

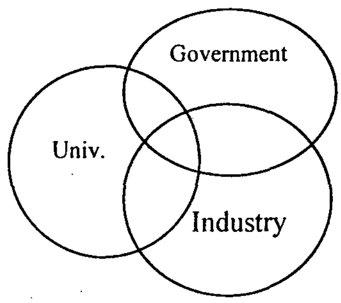
2.3 Triple Helix Model of Innovation[8]

Of the non-linear models of innovation, " Triple Helix" is considered to be the most evolving and dynamic. The triple helix model is a new framework for understanding and encouraging the innovation process. University, industry and government as relatively equal partners are identified as the key actors in creating new networks and hybrid organizations. There is no assumption of a fixed end point such as the development of market economy in this model. For example, the market is also a governmental instrument that assures the validity of contracts and the stability of transaction mechanism. The triple helix model takes the traditional forms of institutional differentiation among universities, industries and government, as its starting point (Etzkowitz,1998). The model takes into account the expanding role of knowledge sector in the

[8] There are three models of Triple Helix. These have been discussed later, but the perspective that we are considering is Triple Helix Model 3.

dynamic process of growth through technological innovation. Hence, the role of partnerships between the three sectors is seen as crucial.

'Triple Helix' esoteric meaning reflects partnerships between University-Industry-Government which lead to trilateral networks and hybrid organizations – this connotes nothing but Triple Helix III (Fig.1) model widely popular these days.



Model 3

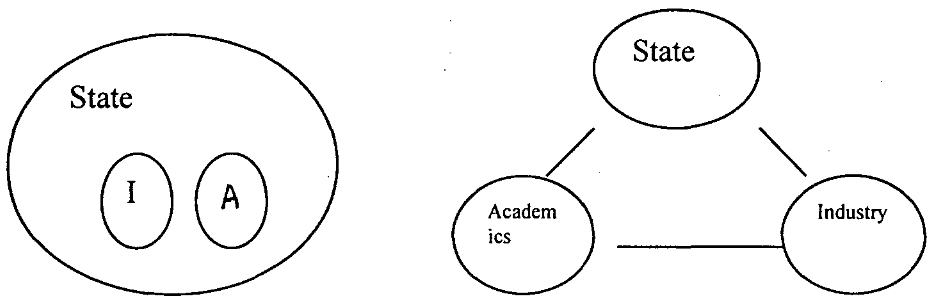
(**Figure. 1**)

In addition to it there are two other models which can be categorized under 'Triple Helix' configurations having its genesis from varying institutional arrangements developed in different cultures/ nations.

Triple Helix I or an Etatistic model of University-Industry–Government relations (Model1, Fig.2): In this configuration the nation state encompasses academia and industry and directs relation between them. Strong version of this model is found in former Soviet Union and in East European countries under socialist pattern, weaker versions were formulated in many Latin American countries. It is now largely viewed as failed developmental model as innovation was discouraged rather than encouraged due to strong "bottom-up" approach.

Triple Helix II or "Laissez-faire" model (Model2, Fig.2): This model consists of separate institutional spheres with strong borders dividing them and highly circumscribed relations among the spheres. This is exemplified in

Sweden and USA. This model is advocated nowadays as shock therapy to reduce the role of the state in Triple Helix I (Etzkowitz & Leydesdorff , 2000).



MODEL – I MODEL – II

(Figure. 2)

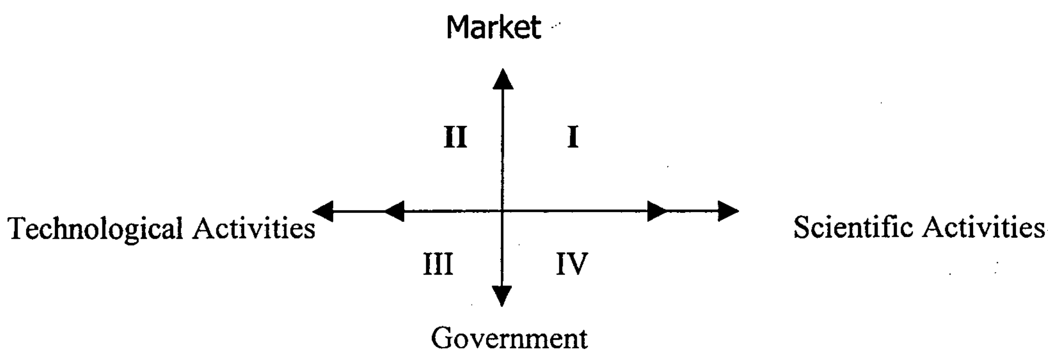
According to Etzkowitz and Leydesdorff (2000), triple helix model suggests that innovation is a spiral movement that captures multiple reciprocal relationships among institutional sectors (public, private and academic) at different stages in the capitalization of knowledge and thereby changes knowledge producing institutions (Giescke ,2000).

The four processes related to major changes in the production, exchange and use of knowledge which the 'triple helix' model puts forward are : 1.) internal transformation in each of the helices 2.) influence of one institutional sphere upon another in bringing about transformation 3.) creation of new overlay of trilateral linkages, networks and organizations among the three helices , serving to institutionalize and reproduce interface as well as stimulate organizational creativity and regional cohesiveness 4.) the recursive effects of these inter institutional networks representing academia, industry and government, both on their originating spheres and the larger society (Etzkowitz *et al.* , 2000).

The solution of the production puzzle typically brings government into the picture shifting the dynamics from double to triple helix. Trilateral networks and hybrid organizations are created for resolving social and economic crises. The actors from the different spheres negotiate and define new projects such as invention of venture capital firms, spin off firms, technology incubators, science parks etc. Thus, a triple helix dynamics of university-industry-government relation is generated endogenously (Henry Etzkowitz,1998).

To get an insight into it, it would be better to look into environmental conditions that affect the direction and rate of agents' knowledge seeking activities (viz. as knowledge is increasingly being seen as resource generator). Four abstract environments are : the basic scientific environment; the techno-economic environment; the scientific-economic environment and the techno-government (Mc Kelvey , 1996). These are based on analysis and synthesis of two broader postulates :-

- Scientific [science is about understanding nature through the production of knowledge—Faulkner (1994)] and technological [technology is about controlling nature through the production of artifacts – Faulkner (1994)] are two dominant knowledge seeking activities.
- There are two sources of influence on the direction of such activities namely market and government. Each of the four environments is defined in terms of these two dimensions : the purpose of activities and the source of allocatory power .



(Figure. 3)

The axes in Fig. 3 represent scales rather than four closed boxes, thus following four environments :-

- IV Quadrant (Scientific environment): These search activities are designed to increase generalized knowledge, the traditionally internal world of basic research. Government supports these through science policy at the same time trying to delegate powers and responsibility to scientists.
- II Quadrant (Techno-economic environment): These activities are technological in the sense of striving for functioning artifacts and knowledge as well as economic in the sense of resulting in new or improved processes, products, and organizations. Traditionally this has been the preserve of firms but recent discussion about strategic innovation policy by governments also. Technological knowledge deals not with the general or the universal, but with the specific and the particular. This implies that the novelty generated and the technical alternatives selected, conform to criteria that emphasize the improving of useful, particular technologies rather than general solutions for a category of problems [the emphasis is on firm/product survival and profit making].

- I Quadrant (Scientific-economic environment) : It encourages scientific activities that have potential economic returns, although those consequences may be quite intangible and long term.
- Owing to continuing importance of basic scientific evaluation, agents competing in this environment are expected to need to move back and forth between scientific-economic and basic scientific environments.
- III Quadrant (Techno-government environment): Like basic scientific environment, it is also partially isolated social and cognitive context but agents in this environment form less independent community than has traditionally been the case in the basic scientific environment. Instead of giving them a free hand in developing whatever the technologies they wish, governments have tried to steer technological development according to the principle of providing public good such as military protection.

The specification of all four environments --- rather than only the two traditional ones – thus gives us analytical tools with which to understand the changing roles of universities, firms and governments.

The concept of the 'triple helix', thus, might lead to the emergence of new hybrid institutional structures and perhaps an institutional convergence between the three sectors of academia, industry and government, as all participate in the commercialization of the knowledge base within the contemporary innovation system.

This model is also based on the promise that in a knowledge based economy, the university becomes a key element of the innovation system both as human capital provider and seed bed of new firms (Etzkowitz *et al.*, 2000).

Triple Helix Model of Innovation assumes that increasingly innovation is seen as the principal way for firms and nations to remain competitive. It is thus, competitive advantage of firm increasingly lies in the ability to generate new knowledge. But it is at the same time in the interest of the universities too, to be in knowledge production. The reasons put forward for this by Etzkowitz *et al* (1998) are -- 1) Universities involvement in the process of economic development (Second Academic Revolution) and 2) Resource crunch being faced by universities. **But according to Michael Gibbons** (2000) one has to look afresh into the nature of competition to distinguish between its static and dynamic modes because, resource constraint, to some extent, have always been there.

Static mode of competition is based on an image of equilibrium, which is mainly about allocating resources efficiently so as to achieve equilibrium or making minor adjustments in the pattern of allocation to re-establish it if it gets awry. By contrast Dynamic competition is less about allocating resources than generating them. This puts a higher price on creativity because, in a world where comparative advantage needs to be created, innovative success demands access not only to financial resources but to intellectual resources as well. It is here the importance of knowledge producing institutions assume importance.

Traditionally, industries come to universities/ public sector laboratories when they have a specific problem and they want to get it solved by paying for it. But this transaction presupposes no change in the relationship between the two institutions. In the regime of dynamic competition, by contrast, when firms are trying to identify the fundamental technologies they are going to need i.e. when the search is on for **robust design configuration** (Utterback,1994), they seek a different relationship with other institutions which have access to knowledge, including universities[9]. The logical extension of this is the interdependence of different actors in innovation (Government laboratories, universities and firms) where knowledge generation component assumes considerable importance.

Innovation, thus, now is not so much a matter of having a new, clever idea or even a product. Rather, it is a matter of identifying a robust design configuration which will allow the production of a stream of new products and network with other actors. But to get a new design configuration, there has to be a systematic two way or three way relationship between industry, university and public sector research. It is this that lends more credence to triple helix model representing dynamic interaction among the three actors.

Some of the main reasons for public research especially universities being seen to hold a prominent stage in triple helix perspective as well as in the current understanding of innovation studies are :

- In the new technologies (Biotechnology, Information and Communication technology, new materials etc.), there is growing importance of increased science base because of which there is large and growing expenditures on research, design and development (RD&D). Infact, in recent decades, RD&D budget have grown faster than the economies that supported them. RD&D has come to be seen as an important source of industrial and economic growth. More precisely, it is the mechanism by which new and existing knowledge in science and engineering is translated into marketable artifacts. Universities are seen to play an important part in this.

[9] Knowledge is the foundation of the university, because the university exists to create and disseminate knowledge in a systematic and structured way. In this context, knowledge is the source of authority in the university as suggested by Rosovsky.

- Success in the global market place requires restructuring and rethinking of all aspects of business management; including, in the case of technology based companies, how technology is acquired and improved. Because new technology development is often so risky in either cost or time to the market place and available from so many external sources, it is vital that companies learn how to tap into these external sources as effectively as they have managed their own internal R&D organizations for long. And the major source for getting appropriate scientific knowledge are universities and government laboratories (Maclachlan Alexander, 1995).

New technology is also becoming increasingly dependent and intertwined with science. Biotechnology is a good example of this. The experience of biotechnology in USA shows that how new firms are dependent on universities. The decade of 1990's witnessed unprecedented corporate involvement in universities for biotechnology research.

- An innovation gap has emerged from the shortening of R&D time scale, the resources available to firms and increase in technological competencies and inputs required to accomplish innovation. In order to shorten this innovation gap, firms strategically engage themselves in short term needs of product development while delegating longer term research to universities and government laboratories.

2.4 Institutional and Organizational Change

Since, public sector research especially universities are considered to be the most important element of " triple helix" model, it is imperative to discuss in brief the changes in institutional character of university in what Elzinga (1985,1988) has called an epistemic drift toward measuring the utility of science in terms of criteria that are steered by market considerations (Etzkowitz.H, Webster.A & Healey Peter,1998, page 10).

- The capitalization of knowledge has replaced disinterestedness (defined by Merton as the expectation that scientific knowledge would be freely distributed with researchers taking their rewards in recognition from peer). This has led to shift in the orientation of the academic and public research culture from being devoted exclusively to the research and training interests of professional staff toward being open to more entrepreneurial activity and receipt of private profit for research pursued (this could take various forms like consultancy, equity in a company, spin off firms etc.).

- All these could manifest into scientists being reluctant to publish their work fully and freely because of professional competition and commercial pressures.

- The issue of management of Intellectual Property has gained prominence even in public sector research in recent years.

- A change in student, faculty and administration relation as a students' best chance at job and future carrier may lie in establishing their own company on the basis of their research (Etzkowitz, Healey and Webster , 1998).

- A change in funding system which is supposed to be the key mechanism of change in the norm system since its reward structure influences the performance (Benner and Ulf Sandstrom , 2000).

- According to Libert (1977) and Hackett (1990), there has been change in assessment of performance. In many fields the size and number of research grants have come to be a "quick and dirty" indicator of the disciplinary prestige (Karen Louis and Melisa S. Anderson , 1998).

- Apart from the commercialization of academia in the sense of a growth in the corporate instrument of and participation in research activities. There has of course been a rapid growth in the internal commercialization of academia. Most higher education and research institutes have established agencies designed to exploit their own intellectual property. e.g. - technology transfer offices are being established which are either developed out of existing administrative units such as campus legal departments or entirely new organizational structures[10] (Webster and Etzkowitz , 1998).

In the light of these examples, present project has the objective to map and record the important organizational and institutional changes in the biotechnology sector in Delhi.

2.5 Background on 'Triple Helix' and National Variations w.r.t the perspective

Though, 'triple helix' as a model of technological innovation or new innovation strategy has been formalized and propagated by Henry Etzkowitz and Loet Leydesdroff recently[11], but University-Industry-Government interaction has a considerable history of its own, the vestige of it could be traced to the growth of German Dye industry in mid 19th century by exploiting

[10] The process of capitalization has occurred in three stages : first, the securing of intellectual property : secondly, the restructuring of research groups to generate a large intellectual property base and thirdly the establishing of corporate vehicles - such as spin off firms - within universities to maximise the return on intellectual property (Etzkowiz, Healey and Webster : 1998).

[11] Karl Marx was a prescient forecaster of the emergence of academia-industry relation . taking note of Perkin's research on dyestuffs in England during the 1840s , Marx predicted the growth of science based industries . Although a synthetic dyestuff industry based on chemical research did not appear in England at that time , one soon emerged in Germany in the mid 19th century .

A century and a half later , the bilateral mode of science based economic development adumbrated by Marx is still at an incipient stage , even as trilateral mode is appearing (Etzkowitz, 1998).

product/technology developed in university. But it was only in the beginning of this century in USA that this relationship was started seeing as vital for economic development and it was mainly cases of prosperity from this linkage in USA that it started being taken by others seriously. In 1862, the **M**orill **A**ct of USA assigned government owned land to a special class of universities to support the development of agriculture. It is only because of the vast support of universities that the government was able to increase the pace of innovation in agriculture (Etzkowitz *et al*,2000).

Then in 20th century the first real step taken towards building academic-industrial link, notably originated at MIT by Vannevar Bush and his colleagues at MIT. Similarly, the Research Corporation, founded by Frederick Cotrell a Professor of chemistry at University of California , Berkeley, introduced the principle of utilizing income generated by patents to seed fund new research. A potentially self generating system of research funding was initiated that was subsequently expanded by government. The impetus to it was given by the recognition of issue that there should be sufficient mechanism to transfer practical outcomes of research results in academia to the industry.

This partnership between academia-industry was further legitimated by the framing of new act in 1980 i.e. **Bayh-Dole Act** (This gave ownership of intellectual property, arising from federally funded research to the universities. Universities were obliged to make an effort to commercialize the rights.) and **Stevenson-Wydler Act (as amended in 1986)** (This authorized Federal Laboratories to transfer technology to industry, establish centers for industrial technology at universities and non profit institutions and foster the exchange of scientific and technical personnel among universities, industry and federal laboratories) (Etzkowitz *et al*, 2000 and Lee.Y.S. , 1996).

Some National Variations

Off late one can see the growth of this partnership in other countries too, though the reason to it may be varied i.e. necessarily not the organic way it developed in USA. Examples :-

- In UK it is mainly the reduction of research funding and the growth in perception of economic development related research that it has forced University-Industry partnerships (Etzkowitz *et al*, 2000).

- In other countries like France, Germany, S.Korea etc. -- it has been the systematic policy of government to initiate these partnerships in order to give boost to industrialization or regain competency in upcoming frontline technologies (Etzkowiz *et al*, 2000 ; Giesecke.S , 2000 and Jolly & Ramani, 1996).

- In both, Australia and China Government has played its role in fostering University-Industry links[12] but in many cases it is seen that research alliances are driven primarily by academic 'entrepreneurs' who have learned to transcend traditional corporate sector and university boundaries. In these cases personal networks typically provide the key ingredients for the development of new 'start-up' or 'spin-off' enterprises. An important features of these links is that they are often supported by or deeply embedded in a university structure. The developments of such links tends to rely on a matrix

[12] Involvement of Australian Government in **CRC Program** by way of funding and support.
In China, indirectly the ' market reforms' started by government are giving way to new alliances between universities , research institutes and industry.

of research grants and industry investment (Tim Turpin and Sam Garrett-Jones,2000).

- In Japan, this partnership is mainly growing due to change in thinking of industrialists. They want now universities to train students with advanced degrees rather than just equipping them with graduation degree and onus of further training retaining to themselves. For this they are supporting universities both monetarily and technologically (Etzkowitz *et al*,2000).

Thus, universities such as MIT and Stanford, which had been anomalies within the USA academic system, now became the models for other universities to emulate. In Europe, Cambridge and Oxford universities in UK can also said to be the models of university–industry relationship, which have historical standing as MIT and Stanford. The Universite Joseph Fourier in Grenoble (France) also has long tradition in cooperating with industry, which have spurred many emergent initiatives. University of Bergen's Geology department has grown because of the growing importance and influence of the oil industry in Norway (Magnus Gulbrandsen, 1997).

In Latin America too, Autonomous National University of Mexico (UNAM) has nurtured partnerships with industries successfully.

Taiwan's Hsinchu Science based industrial park was also developed strategically in the vicinity of well known Industrial Technology Research Institute, National Chiaotung University and National Tsinghua University (Xue Lan ,1997).

Similarly, Tsukuba Science Park (Japan), Singapore Science Park (Singapore) and Daedok Science Town (S.Korea) can also be counted in success stories when it comes to university-industry partnership spurred by government (Gwynne Peter,1993).

In order to get more clear understanding of the importance of regional dynamics let us take two universities. Which have pioneered University-Industry relationship : Cambridge University in UK and Joseph Fourier University at Grenoble in France:-

It is considered that in Cambridge priority is given to the basic research and education. At the same time collaboration with industry has always been common in Cambridge which perhaps has reduced the need for an institutional strategy to promote industrial relations.

- Lately Cambridge University seems to have combined an informal and formal approach to strategic management (or policy making). Long periods of almost pure bottom-up initiatives have been followed by important formal and top down strategies. The famous **Mott Report**, which launched the Cambridge Science Park and other activities in Cambridge is a good example of the latter (Magnus Gulbrandsen ,1997).

In case of Cambridge, local authorities have played no role in its development; rather they have often tried to restrain it, for instance by placing strong restrictions in the construction of new buildings and the use of property.

Science Park of Cambridge shows signs of functional specialization. Here the start-up of new firms generally takes place in different organizations and buildings than the other usual science park activities like technology transfer to and between existing companies.

Similarly, The Universitie Joseph Fourier in Grenoble also has long tradition in cooperating with industry, which have spurred many emergent initiatives in the city too. Though, there are important resemblance between Cambridge and Grenoble but still there are few vital differences in their developments which is mainly due to their own special history and characteristics.

- Unlike Cambridge, the latter has chosen somewhat more formal strategy. Detailed documents concerning the pricing of contract research results have been developed. The documents nevertheless form stronger boundaries than those in Cambridge for individual 'researchers' and departments' behaviour.

- In Grenoble, local authorities even in the 1960s were very positive towards entrepreneurship and growth in high technology firms and took concrete moves to facilitate such growth, foe instance by establishing ZIRST Science park (Magnus Gulbrandsen ,1997).

Thus from the above we see that though linkages and partnerships among different components of triple helix can be seen growing in different nations/ regions of the world. But on a closer look one finds that the reasons and patterns of it are quite varied in tandem with the socio-cultural milieu of the region . e.g. - The Americans being more risk taking, it is the venture capitalists and the industrialists who have spurred this relationship; while Germans and French being conservative, it is mainly the government which have tried to build these partnerships.

Similarly it has taken varied shapes in different countries. e.g.- In USA, the universities have achieved the central position and one sees the rise in number of research universities; in Europe there is more emphasis on development of Research Centres and in South East Asia and Japan one finds growth of Science Parks.

2.6 Indian Developments

In India too, one can historically trace university-industry relationship to the formation of Bengal Pharmaceuticals at the turn of the century in collaboration with the Chemistry group of the Presidency College -- through the efforts of Sir P.C.Ray, the father of Indian chemistry. In 1930s at the University Chemical Laboratories, Lahore Dr.S.S.Bhatnagar successfully collaborated with oil companies on chemical research. The royalties obtained were converted into scholarship and further foster industrial research. Dr.S.S. Bhatnagar, the man behind Centre for Scientific and Industrial Research (CSIR), was thus a strong promotee of public research collaborating with Indian industry(Krishna,1993) .

The chemical industry in Mumbai and Gujarat region, especially the Reliance Petrochemical, have closely cooperated with University Department of Chemical Technology (UDCT), Mumbai and chemistry departments of other local universities. National Chemical Lab (NCL), Pune interacts closely with UDCT, Mumbai. UDCT has also developed close partnerships with industry from the last three decades. Dr. Reddy of Dr. Reddy Laboratories (an Indian pharma company) is also alumni of UDCT as one of Ambani brothers (of Reliance Industries). Even in recent times, **the study conducted by UNESCO (1996)** -- "Strategies for university-industry Cooperative Programme in Science, Technology and Engineering in India", gives a clear indication of level of cooperation .

Apart from various other things the UNESCO study reflected on the following four vital points which can be considered barometric refrence for the university-industry partnerships and linkages :-

- Policy for seeking out industry
- Collaboration with industry
- Whether increase in activity in terms of collaboration
- Universities with industry liasion units

According to UNESCO study (1996) :

1. 100% Premier and Engineering institutes and 80% universities had policy for seeking out industries.
2. 100% premier institutes, 73% engineering institutes and 45 % universities have collaboration with industry.
3. 100% premier institutes, 54% of Engineering institutes and 13% of universities have increased in activity in terms of collaboration.
4. 100% premier institute, 94% engineering institutes and 13% universities have Industry Liasion Units.

2.7 Some possible features of Innovation strategy from a Triple Helix perspective

2.7.1 Innovation Strategy

In today's world as knowledge becomes driver of growth, any firm has to operate within a spectrum of technological and market possibilities arising from the growth of world of science and technology and the world market. Changes in the technology and the market and the advances of their competitors compel them to try and keep pace in one way or the other. There are various alternative strategies which they may follow, depending upon their resources, their history, the technology they are in and their management attitudes (Chris Freeman and Luce Soete,1997). But collaborating with universities and public research institutes gives a firm comparative advantage in terms of being able to explore various technological possibilities in a given constrain of time and various resources. This is demonstrated by the university-industry relationships in biotechnology in USA.

Excellence in technology strategy does not imply the finest products imaginable. Rather, it implies the corporation's ability to balance technological potential against the needs of operational effectiveness, the market viability of the results, and the nature of the barriers to competition. A well defined and executed technology programme provides the firm with defensible strategic advantage in the in the market place. Such a technology programme requires strategic resource allocations over considerable time periods and effective coordination throughout the organization. The dual mission of technology programmes is to develop intellectual capital in support of the firm strategic objectives and in support of operational effectiveness. Both are proactive stances. This is best represented by considering the development of intellectual capital as the primary objective of the firm and product or process innovations as by-products. This, of course, is the opposite of the traditional way of thinking about technology (Richard.A.Goodman, 1999).

The modern biotechnology sector is designated as a high-tech industry where companies spend a large amount of R&D, with national as well as transnational programmes enhancing the development and commercialization of biotechnology products. The common feature of organizations form a quite heterogeneous group with respect to competencies, target markets and strategic orientation.

However, faced with turbulent environments and global businesses, collaboration has become a common way to organize economic activities. Freeman (1991) points out that external collaboration plays a vital role for successful innovations. This seems to be more important for high technology industries[13] (like biotechnology) with inherently high uncertainty and complexity.

Public-private partnerships involving various research institutions, universities, administration and companies are evolving to bundle competencies and facilitate technology transfer. The partnerships often are initiated or promoted by government. The main features drive biotechnology industries towards collaboration are :-

- High expenditure in research
- High complexity
- Global competition
- Closeness of basic research, development and commercialization
- Public interest

(Ursula Weisenfeld ; J.C.Reeves and Astrid Hunck Meiswinkel, 2001).

Public Research (especially universities) and Private are increasingly accepting that their symbiotic collaboration work is to the advantage of both of them.

[13] Definition of so called ' high technology industries' vary but generally are associated with issues like high R&D activity coupled with high uncertainty . The acquisition of know-how (R&D expenditure , scientific technical base) , the commercialization of results (patents, innovations and the handling of risk (familiarity with state of the art) are central to the respective organizations .

According to E.M.Rogers *et al* (2001), Research Universities[14] in the US play an increasingly important role in technology transfer and are generally considered to be relatively more effecting in transferring technology than are Federal R&D Laboratories. The nature of technology transfer from research universities in US is a process through which 1) research expenditures 2) lead to research activities 3) that lead to invention disclosures 4) that lead to active technology licenses 6) which lead to technology licenses capable of generating income 7) which lead to technology royalties and start-ups and 8) thus to jobs and wealth creation.

Today almost all research universities have technology transfer office/ office of technology licensing. Their rapid spread in USA has been due to --

- Bayh-Dole Act
- The growing importance of life science research (especially in biotechnology) in creating patentable technologies.
- Attraction of having a "big winner" technology that will earn millions of dollars. e.g. -- Michigan State University has earned $ 160 million from two cancer related inventions -- Cisplatin and Carboplatin (Blumenstyk,1999); the $143 million that the Stanford University earned for the recombinant DNA gene splicing patent (Odza , 1996). A "big winner" can dominant the total technology royalties at a research university; for example, $18 million of Michigan State University's $ 18.3 million technology royalties in fiscal year 1998 came from two cancer related drugs. Pursuit of a "big winner" technology provides motivation for the rapid diffusion of technology created in university and more generally movement of US universities towards academic capitalism[15] which is also indicated by a university having a research foundation, a technology incubator for start-ups, a venture capital

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[14] A Research University is a university whose main purposes are --- to conduct research and to train graduate students in how to conduct research.

[15] Academic capitalism is defined as the degree to which a research university becomes involved in the transfer of university conducted research into commercialized products and services.

fund, a research park and for taking an equity position in start-ups (Etzkowitz, 1983).

2.7.2 Public sector research and Universities as source of New Firms

Now after having discussed the monetary gains that university is reaping because of their shift towards developing market based technologies, let us discuss the importance of universities as being engines of growth in biotechnology sector, by their role in establishing start-up companies which have become fore-runner in developing new technologies. One can get an inkling of this by considering following examples :-

Prof. Herbert Boyer of the University of California at San Francisco , was co-founder of Genetech (now a major biotech company) in the mid 1970s to exploit the commercial potential of work that had been initiated in his university's molecular biology laboratory. The professor became infact a multimillionaire due to very positive response of investors to the offering of Genentech stock in Oct. 1980 , which hightened an already widespread awareness about the possibility of academic research in this field. This led to establishment of many start-ups like Biogen (by Walter Gilbert, founder and Chief Executive Officer , Nobel Prize winner in Biochemistry , professor in Harvard University); Calgene (Formed by Prof. In University of California at Davis); Synergen (Formed by 3 Profs. from molecular biology department of the University of Colarado) and Cetus . These are now highly successful companies (Etzkowitz ;1983).

There are also indications that this collaborative arrangement by virtue of having created innovative technologies is having an impact on the economy of the area and are becoming growth engines for regional economic development through the technology transfer process (De Vol , 1999). e.g. -- MIT's office of technology licensing had 360 invention disclosures, filed 200 new patents, was issued 134 patents, had 17 start-up companies and earned $21.2 million in technology licensing income (Massing, 1998). MIT's 205 active patent licenses by 1993 have led to almost $1 billion investment and had created 2000 jobs (Pressman *et al* ,1995). Spin off companies from MIT accounted for 35% technology licenses, yet created 77% of the induced investment and 70% of employment (Rogers *et al* , 2001).

2.7.3 Industry - University Dependence

Until the 1980's, research in universities and pharmaceutical companies was carried out separately. Since the beginning of the 1990s however the range of methods for successful innovation has grown so large that no firm, however well endowed, can hope to be proficient at all of these research approaches (Tapon and Thong,1999). Thus, firms have been relying increasingly on public research especially university laboratories for ideas on candidates for the drug discovery process. Strategic alliances with universities allow these small biotechnology firms to do the most esoteric state-of-the-art research, using equipment that they would not be able to afford . As a result of these alliances, small size is not a disadvantage in the basic research, drug discovery stages of the R&D process and small firms can compete very effectively with large well equipped companies (Tapon; Tung and Bartell :2001). There are many studies which substantiate the viewpoint that increasingly Public Research- Private collaboration is taking place in order to retain technological competence by increasing intellectual base and thus various profitable innovations. It is being seen by industries as part of their innovation strategy. A credence to this idea is lent by Dan Elron and Steve Wick (2001), according to whom :

> " Sure, even high-tech companies can miss key technology trends . But those that succeed share a number of critical qualities and capabilities...... These companies all have cultures built on experimentation and they maintain alliances and ongoing dialogues with venture capitalists , universities and think tanks ."

- A Delphi Questionnaire study completed by George.M.Scott (2001) evaluated the relative importance of management of technology problems as perceived by Management of Technology expert participants in industry and academia. According to the study, 'Need for extensive communication and interaction among technologists' is perceived as the third most important issue (of 21 issues ranked in order of importance) to be addressed while strategic planning for technology products.
- Bibliometric analysis done by Diana Hicks (1998) have detected a steady strengthening in some of these connections, co-authorship and patent-to-paper citations in particular. More than half the research performed in the UK is now produced in institutional collaboration (Hicks and Katz, 1996). According to Gibbons *et al* (1994) a new mode of research is evolving in which the interconnection between institutions are fundamental (Hicks and Katz, 1996).
- Study conducted by Mc Millan, Narin and Deeds (2000) based on examination of the reliance of biotechnology companies on public science since the date of their IPO through 1997 i.e. all the patents they acquired since going public. Their results indicate that the biotechnology industry depends on public science much more heavily than other industries and that dependency is especially high for basic scientific research. The paper at one point also states that though many companies bemoan the academic approach to research (mainly because of difference in values of publishing and patenting by public research scientists and academic research scientists respectively). They report that they rely on it quite heavily. Mansfield (1998) found that drug and medical product companies reliance on academic research went from 27%of their new products in the 1975-85 period to 31% in 1986-94.
- In a study of four successful Canadian Biotech firms (Allelix, QLT, Biomira and BioChem Pharma); it was found that all the firms had links with university laboratories through alliances and joint ventures for basic

research. It was found that three out of four firms (in this study) carried out basic research in university laboratories. It was also found out that three out of four firms in study were started by university researchers.

Importance of academic research can be gauged from the transcript of a senior university scientist (interviewed during this study) who was offered a top R&D job in Biochem Pharma. According to him, first CEO of the firm insisted him to be a full time employee of the company but then agreed that the professor retain his university job on the pretext that company would lose all benefits of his labs and his interaction on the academic side (Tapon, Thong Bartell; 2001).

As Public Research Linkage is considered so vital for product development, innovation and basic research that many governments have taken initiative in this direction all over the world. e.g.-

- French government initiated a number of programmes whose common aim was to stimulate public research and promote conversion of fundamental discoveries in the biological sciences into products of economic value through facilitating the interface between public research and industrial research. Of the four phases in which government charted out its strategy, the 'initial stage' concentrated on establishing links between the academic community and the industrial community (Jolly and Ramani, 1996).
- Even the Department of Biotechnology (Government of India) takes special care to foster it and has this in its charter. This is reflected in the study conducted by Kavita Mehra (2001) on the Indian System of Innovation in biotechnology by taking up a case of commercialization of Plant Tissue Culture technology in the case of Cardamom. This specifically highlights the interface between public research-industry-government. [The technique developed in National chemical Lab was transferred to A.V.Thomas and Co. with support from Ministry of Commerce, Indian Cardamom Research Institute, Spice Board and DBT].

Drivers of success of this emerging industry have been closely related to the existence of strong scientific capabilities, venture capital markets and new product development and marketing experience. In newly industrialized economies, it is hard to find the above mentioned elements in place. Though there exist a great interest to develop a biotechnology industry but structural limitations pose entry barriers to compete in this promising market. It is therefore very unlikely that firms in less advanced countries will be able to follow the "American Paradigm" of development of biotechnology business. From the case studies done by Jose Luis Solleiro *et al* (1996)[16], different approaches to firm development and sound innovation strategy in follower firms have come to light. It is interesting to note that in every strategy a role for Public Research especially universities have been emphasized. e.g. - the "mouse strategy" -- In this the company expressly looks for technology options in different locations and diverse institutions but to remain alert is crucial. For this reason, they try to know everything that universities, research centres and companies are doing in technology. It specially mentions that whenever possible firms prefer to work with universities under contract research agreements because "universities have the most qualified people and the best facilities to conduct research".

Role of public research-industry linkage (especially in developing countries and industries in those countries) becomes more clear when one looks at the following figure showing some of the options in various innovation strategy:-

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[16] See the chapter by Mason.R.M., Lefebure.L.A and Khalil.T.M.. in "Management of Technology V : Technology Management in changing world , Proceedings of the 5th International conference on management of technology" ; Elsevier Advanced Technology, Oxford.

High

Resources required	Low complexity of technology	High complexity of technology
High	**Expansion to new markets, increase of production base** • License external technology • Create a small R & D group with labs to universities • Priority is assimilation • Negotiate government support • Build collaboration links to associations of producers	New businesses based on mew products • Establish joint-ventures and alliances • Negotiate based on your strengths: knowledge of niche markets • Establish long-term programs with university labs • Create your R & D capacity • Invest in people
Low	Improvement of productivity and quality • Hire specialists • Monitor technical information • "Adopt" a graduate student • Create internal function of process improvement • Invest in training	Exploration of long-term opportunities • Improve your monitoring system • Open a window to science: long-term links to universities • Invest in capacity building • Match funds for long-term projects with government programs

Low — Complexity of technology — High

Source : (Jose Luis Sollerio *et al*, 1996)

Figure 4 .

Thus, we see that all the three actors i.e. industry, government and public research have come to realize the potential of 'triple helix' model of innovation as a new innovation strategy for the research, design, development and commercialization of new technologies.

Though, as discussed earlier these Industry-University-Government relationships exists in India but still concrete results in the form of economic development could not be seen. The viewpoint similar to this was put forward by

Dr. Swaminadhan (Member, Planning Commission) in seminar organized by British Council and Council for Indian Industries (CII) :

> " .... Though, this interaction is taking place at some local levels , tangible results are not emerging . therefore , we need some central coordination mechanism to promote and uphold this kind of interaction between universities and industries. Keeping in view your resource adequate situation ...."

It is in this context, he believes that a boost could be given by effective government intervention by means of correct policy decisions.

But while promoting University-Industry-Government relationship care should be taken of the above discussed points as well as ground realities i.e. cultural, institutional, organizational environment for science, technology and innovation. Because of this Dr.Swaminadhan has come up with his own model for University-Industry-National R&D Laboratories interaction for country's economic development which could be taken as akin to 'Triple Helix Model of Innovation in Indian Context '.

While UNESCO study is significant but in order to concretize effective policy guidelines it is imperative that such studies are conducted on sectoral basis especially in new technologies.[17]

[17] Though in Information Technology, the role of university as a large scale, diversified research lab is decreasing in importance , a probable outcome is the emergence of a number of specialized independent labs or cooperative lab facilities where researchers can conduct off site research either on a fee-for-use basis or as a part of larger private practice. Similarly it has been observed that learning will be less concentrated in time and physical location will no longer define accessibility to knowledge.
But Andretch and Stephan (1996) found that geographical proximity was important in the University-Biotech relationship , even with e-mail, faxes and other electronic communications and that the specific role played by the university scientist dictated the geographic necessities. (McMillan, Narin and Deeds, 2000)

This study is an effort in this direction to get insight into the University-Industry-Government relationship in Biotechnology sector in Delhi region.

2.8 Key research questions from the review of literature

1. Exploring the concept of 'Triple Helix' linkages and partnerships in the context of Delhi region to examine its relevance as an innovation strategy.

2. What is the structure and nature of linkage and partnerships taking place between University-Industry, Government Research Centres-Industry and University-Industry-Government in Biotechnology in Delhi region ?

3. What are the organizational and institutional changes that are being introduced in the Public R&D Institutions and Universities as part of the emerging Triple Helix Linkages and partnerships ?

4. As the concept of Triple Helix involves both structural changes between different institutes and as well as the orientation of practitioners --- it will be pertinent to ask what are the changes (that is from the previous era or Pre-liberalization era) in the orientations of scientists and academicians in biotechnology in various institutes in the Delhi region. A related important question is on the mobility of personnel between different actors of Triple Helix.

5. Given the dependent nature of biotechnology industry on the universities in USA and Europe, it is pertinent to explore whether universities and public R&D institutes in biotechnology in the Delhi region are the source of new firms, products, devices and core elements in R&D chain which are crucial for commercialization of research results.

2.9 Working hypothesis guiding the research

1. Even though the concept of Triple Helix has universal relevance, the main justification of the concept at the level of operation or practice varies in different socio-economic and national contexts.

2. The variations at the level of practice or operation is determined by the structure of linkages between different actors i.e. university-industry-government, of the Triple Helix.

3. In the Indian context (especially present context of Delhi region in biotechnology) bilateral linkages and partnerships [university-industry, university-national laboratories, industry-national laboratories, government-university, government-national laboratories etc.] appears to be more relevant and meaningful than tripartite relationships.

CHAPTER . 3

BIOTECHNOLOGY IN INDIA

CONTENTS

3.1 INTRODUCTION

3.2 SETTING UP OF DEPARTMENT OF BIOTECHNOLOGY : A LANDMARK DEVELOPMENT

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3. Biotechnology in India

3.1 Introduction

Biotechnology can be defined as the use of new tools and techniques for bringing about specific man made changes in DNA (genetic), in plants, animals and microbial systems leading to useful products and technologies. The discovery of DNA structure by Watson and Crick in 1953 and unraveling of the genetic code to define the structure of gene have revolutionized our knowledge of modern biology at the cellular and molecular levels. Biotechnology is an array of multidisciplinary technologies that can be applied by a number of industries. The technologies include molecular and cellular manipulation, DNA synthesizing, enzymology, X-ray crystallography, computer modeling, bio-molecular instrumentation, industrial microbiology, fermentation, cell culturing, embryo manipulation, and transfer, separation and purification technology. With the emergence of new biotechnological tools, biotechnology has ushered in a new era all over the globe and recent developments in this field have opened up countless exciting opportunities. The sweep of biotechnology is very vast as it embraces many sectors -- food and agriculture, drugs and pharmaceuticals, energy and environment.

Development of nuclear and space technologies in 60s and 70s revolutionized the industrial and scientific progress and as we move into 21st century, there is optimism from the field of biotechnology that it would find its application in fulfilling the basic needs of humankind as also for protecting the environment through development of environment friendly biotechnologies.

India being blessed with enormous natural resources, tropical environment and large technical and scientific manpower; it is well recognized that biotechnology offers immense commercial and socioeconomic potential to developing countries such as India.

With the population of India increasing every year, there is pressing need for increased food production, better health care facilities, rapid industrial development, environmental protection and increased energy generation. Since, conventional technologies are likely to prove inadequate, biotechnology will inevitably play a major role in meeting this immense demands for sustainable growth and development.

Seeing the growing potential of biotechnology and increasing interest by developed countries in this field along with need to fulfill our demands, it dawned on government of India early in 1980s to promote this field. Though, earlier biological sciences were their in the country but to give impetus to this particular interdisciplinary bio-science government took various initiatives to institutionalize it by :

setting up a government department to steer its growth, laying down various rules and regulations for it, setting up various infrastructural facilities, determining social and ethical issues related to it and taking appropriate measures for the same, developing manpower, looking into its commercialization aspects etc.

The seriousness on the part of Government of India could be gauged from the increase in budgetary allocation/ spending by Department of Biotechnology over the years[1]. The budget has grown up more than 10 times since the establishment of DBT : Rs. 17.94 crores in 1986-87 (as revised estimates) to an astounding Rs. 150.89 crores in 2000-2001 (revised estimates).

The Table 3.1 clearly indicates the high level of priority being given to this sector. If one looks at the DBT budget on recent years i.e. 1997-98 to 2001-2002, one will notice that the amount has been growing at an elevated rate of

[1] This does not reflect in totality the Government of India spending or Biotechnology as many BT related programmes are supported by other agencies also (like UGC, DST, CSIR, ICMR, ICAR, DRDO, etc). The availability of break-up of each of these agencies spending on DBT has been taken to reflect upon the importance being given to this sector.

almost 20% almost each year (sans 1999-2000, in which it grew at approximately 12%).

TABLE : 3.1 DBT Budget [1986-87 to 2001-2002]

Year	(in Rs. crore)
1986-87 (Revised estimates)	17.94
1987-88 (Budget estimates)	40.99
1988-89	Not Available
1989-90 (Actual expenditure)	53.82
1990-91 (Actual expenditure)	59.35
1991-92 (Actual expenditure)	64.03
1992-93 (Actual expenditure)	76.13
1993-94 (Actual expenditure)	81.04
1994-95 (Actual expenditure)	84.01
1995-96 (Revised estimate)	88.14
1996-97 (Actual expenditure)	91.38
1997-98 (Actual expenditure)	95.44
1998-99 (Actual expenditure)	114.25
1999-2000 (Actual expenditure)	127.77
2000-2001 (Revised estimate)	150.89
2001-2002 (Budget estimate)	186.34

Source : DBT ANNUAL REPORTS (1986-87,1993-94,1996-97 to 2000-2001) & PERFORMANCE BUDGETS (1991-92 to 1996-97), DST ; MINISTRY OF S&T, New Delhi.

3.2 Setting up of Department of Biotechnology : a landmark development

The Government of India vide the notification dated 27th Feb.,1986 announced the formation of a separate department of Biotechnology (DBT) in the Ministry of Science and Technology. The government had earlier in 1982 formed an interagency apex body, the National Biotechnology Board (NBTB), for the identification of priority areas and for evolving a long term plan for the country in biotechnology as well as to initiate and promote such activities as conducive for further development of various areas in biotechnology. The multi-agency board chaired by the Member (Science), Planning commission consisted of the DST, CSIR, ICAR, ICMR, DAE and UGC and Secretary, Department of expenditure as its members. With the formation of the DBT, which took over all the functions of the board, the NBTB ceased to exist.[2]

3.2.1 Organizational structure

The DBT is organized on modern lines of management i.e. reducing vertical hierarchy and promoting horizontal interaction amongst the scientific groups and officers. The Department, since its inception, has functioned with the advice of two high powered committees, viz., the Scientific advisory Commit (SAC-DBT)[3] and Standing Advisory Committee (overseas) SAC-O[4]. In addition, a

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[2] The DBT was established in 1986 with the following mandate :-

- Support R&D and manufacturing in biological techniques
- Identify and set up centers of excellence for R&D
- Promote large scale use of biotechnology
- Integrated program for Human Resource Development
- Establishment of Infrastructure
- Facilities to support R&D and production
- Serve as nodal point for the collection and dissemination of information relating to biotechnology
- Promote university and industry interaction
- Evolve Bio safety guidelines
- To serve as nodal Point for Specific international Collaborations
- Manufacture and application of cell based vaccines
- Responsibility for autonomous Institutions

[3] <u>SCINTIFIC ADVISORY COMMITTEE OF DBT (SAC- DBT)</u>

To provide professional and independent advice on general science policy and programmes in biotechnology matters to the DBT , a Scientific Advisory Committee for DBT was constituted on 4th July , 1986 with secretary , DBT as its Chairman and other members representing the Heads of various scientific agencies, research institutes , national institutions and manufacturing concerns.

SAC -DBT mainly gives advice to the department on following matters :-

- Short and long term programmes in different areas of biotechnology for financial support by government.
- Recommend developing linkages between academic institutions and R&D system on one hand and industry on the other.
- Advise on scientific , technical and industrial activities on Biotechnology based industries.
- Assess the technological status of Indian Biotechnology Industry with a view to update Indian technology and strengthen /start R&D programmes for meeting the future technological requirements of the country.
- Putting forward views on the IPR and technology transfer related to biotechnology.

Biotechnology Research Promotion Committee (BRPC) [5] and several expert task forcers[6] comprising eminent scientists, provide useful advice to the department in the pursuit of its goals to promote R&D activities in the country.

- To advise on any other matter as may b referred to it by the DBT.

[4] **STANDING ADVISORY COMMITTEE - OVERSEAS (SAC-O)**

The SAC-O was initially set up in 1988 for four years . No meeting could take place in the year 1991-92 due to certain reasons , so its term was extended for one more year i.e. upto July, 1993. But even after that , this committee was maintained in the structure because of its valuable contribution to DBT .

The SAC-O consists of eminent scientists from abroad (US, UK and Germany) , who provide valuable inputs to the DBT for advancement of this field. During SAC-O meetings wide rang of issues related to biotechnology are discussed ;-

- programmes related to Biotechnology in the areas of agriculture, medicine etc. That need to be started so that India develops competitiveness vis-à-vis global developments in that area.
- Assessment of programmes and ways to improve them
- Assessment of infrastructural facilities and ways to improve it.
- Patenting related issues.
- Initiation of biotechnology related programmes for the socioeconomic upliftment of rural masses.
- Joint scientific collaboration with some research institutions abroad with the help of some SAC-O members.
- Certain policy related issues to give impetus to this sector.
- Discussion on biological standards and facility for the same.
- Discussion on setting up of Science parks.
- Help identify certain appropriate specific technologies for transfer to India both at pilot and commercial scale.
- Interaction with Sc. Counselors of Indian missions abroad to help willing Indian scientists settled there to find suitable placements in India or to assist in the placement of Biotechnology Associates and other trainees from India in various laboratories and specialized fields.

[5] **BIOTECHNOLOGY RESEARCH and PROMOTION COMMITTEES (BRPC)**

BRPC was constituted in April 1997, to consider and recommend all projects costing above Rs. 45 lakhs. During the fourth meeting, the terms of reference of the BRPC were revised. The new procedure for consideration of proposals is as follows: -

1. BRPC would consider only proposals costing above Rs 1 crore
2. Individual proposals costing Rs 1 crore and above after peer review would b placed before the task force. Only proposals recommend by task force would b considered by BRPC.
3. Proposals of program support , mission projects, integrated multi institutional projects and generated projects costing above Rs 1 crore would be placed directly before BRPC , for consideration after obtaining the comments of the respective expert committees .

The BRPC also constituted Monitoring Committees for the recommended projects costing above Rs 1 crore. Each committee comprising 3-4 experts in the related subject area will monitor the projects and report to BRPC.

[6] **TASK FORCES :-**

Under the auspices of SAC , DBT has constituted 13 task forces in the areas of : agriculture and marine biotechnology; animal biotechnology & veterinary sciences; animal husbandry & leather biotechnology;

3.2.2 Some other aspects in institutionalization of biotechnology in India

Rules and regulations for Biosafety

Biosafety regulation is a tool for the safe deployment of biotechnology applications into the environment. It is a special form of environmental impact assessment, focussing on the direct biological consequences of applying *genetically modified organisms* (GMOs). As part of this assessment, the nature of the organism, the environment where the organism is to be released, and the species interaction are analyzed.

Biosafety regulation in most developing countries is still in its infancy. The ecological and economic importance of such regulation, however, is undoubted. Appropriate biosafety regulations are on of the prerequisites for a successful transfer of biotechnology to and among developing countries. Major issues in the debate on biotechnology are the field trials, harmonization of regulations and capacity building in developing countries. India is one of the few countries in Asia that has instituted biosafety regulations as well as proper institutional mechanism for implementation of guidelines.[7]

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basic research; emerging areas and R&D facilities; biochemical engineering; downstream processing & instrumentation; bioinformatics; biological pest control; environmental biotechnology; Fuel, fodder, biomass, horticulture and plantation crops; Sericulture; industrial biotechnology; integrated manpower development; medical biotechnology; microbial biotechnology; plant molecular biology and agricultural biology.

The main work of the task force is to generate time bound programmes with clan objectives so that each activity leads to specific goals. In short it is to assess the feasibility of a project and monitor it till its completion.

[7] Keeping this in view the GOI has issued Rules and procedures (Rules) for handling GMOs and hazardous organisms through a gazette notification No. GSR 1037(E) dated 5th Dec. 1989 from Union Ministry of environment and forests. It details about following things: -

- Tips of containment's (Biological, Physical and Chemical)
- Biosafety levels
- Guidelines for DNA research activities
- Release to the environment
- Import and shipment
- Quality control of Biologicals produced by rDNA technology
- Containment facilities and Biosafety Practices
- Recombinant DNA Safety considerations (w.r.t. Microorganisms, Large scale operations, Plants and agriculture and environment)

International Collaborations

Considering the potential of absorption and adoption of recent developments which have been taking place in the field of biotechnology in the world and their implications on the overall industrialization and modernization process, the international programmes are formulated. There has been a steady increase in the number of international cooperation programs in biotechnology with both the developed and developing countries. This can be categorized into: -

- Bilateral Programmes
- SAARC Programmes
- G-15 Programmes
- Farmer Centred Agriculture Resource Management
- International Centre for Genetic Engineering and Biotechnology

Recent Developments

Jai Vigyan National Science and Technology Missions

Seeing the need of certain technologies Government of India has from time to time started "mission oriented" programmes for implementation for their immediate implementation in the desired thrust areas. During the inception of DBT during 7th five year plan, it was decided to put few programmes in mission mode --

- Production of vaccines and R&D of new vaccines
- Tissue culture propagation of high yielding types of Coconut and Oilpalm.
- Embryo transfer technology for Cattle Herd Improvement
- Immunodiagnostics

In more recent times Government of India has taken up 21 Jai Vigyan National science and Technology Mission projects[8] concerning all Science Ministries and departments. These projects are time bound and targeted with clear milestones and time schedules.

National Bioresource Development Board

The Finance Minister had, in his budget speech (2000), announced the setting up of the National Bioresource Development Board under the chairmanship of Minister of S&T. In pursuance of this DBT had sought the approval of the government for the establishment of the same. Approval for its setting has been received with Board having several ex-officio and expert members.

New pending Acts

As India takes steps to enact the provisions of WTO in letters and spirit, steps are being taken to promulgate three new pending Acts --- New Patents Act, Protected Plant Varieties Act and Biological Diversity Act ----- which encompasses wide ranging issues related to biotechnology, is a step in this direction .(See Appendix 1 for details relating to each of the pending acts).

3.3 Research and Development

The Government of India is keen to develop the indigenous capabilities in biotechnology sector , for which DBT is spending a substantial part of its budget on R&D.

[8] The projects identified are in the areas of Food Security; sustainable plant genetic resource management; nuclear medicine; development of new generation of vaccines; herbal product development; mirror site for gnomic research; establishment of national Botanical garden both for recreation and research purposes ; medical electronics; ocean energy thermal conservation; a programme on thalassemia; rheumatic fever, technology for visually handicapped etc.

TABLE 3.3(a) DBT Spending on R & D

Year	Rs. in Crores	% of Total Budget (approx.)
1986-87 (Revised estimates)*	1.28	7.1
1987-88 (Budget estimates)	3.1	7.6
1989-90 (Actual expenditure)	12.88	23.9
1990-91 (Actual expenditure)	18.07	30.4
1991-92 (Actual expenditure)	22.71	35.5
1992-93 (Actual expenditure)*	28.63	37.6
1993-94 (Actual expenditure)	34.02	42.0
1994-95 (Actual expenditure)	36.77	43.8
1995-96 (Revised estimate)	39.49	44.8
1996-97 (Actual expenditure)	37.9	41.5
1997-98 (Actual expenditure)	34.97	36.7
1998-99 (Actual expenditure)	43.22	37.8
1999-2000 (Actual expenditure)	51.56	40.4
2000-2001 (Revised estimate)	43.35	28.7
2001-2002 (Budget estimates)	77.25	41.5

Source : DBT ANNUAL REPORTS (1986-87,1993-94,1996-97 to 2000-2001) & PERFORMANCE BUDGETS (1991-92 to 1996-97), DST ; MINISTRY OF S&T, New Delhi.

* Research Schemes funded from NBTB core fund + New projects & Research Proposals.

Following are some of the key areas in biotechnology for which GOI is keen to develop capabilities and hence are being promoted by DBT, various research institutes, national laboratories and universities :-

- Basic research and emerging areas
- Agriculture biotechnology
- Biological control of plant pests, diseases and weeds
- Biofertilizers
- Tree and woody species, application of tissue culture
- Bioprospecting of biological wealth using biotechnological tools
- Medicinal and aromatic plants
- Seribiotechnology

- Biodiversity conservation and environment
- Medical biotechnology and immunodiagnostics
- Human genetics and genome analysis
- Vaccine research and development
- Animal biotechnology
- Aquaculture

The following data gives reflection about the level of importance attached to each of the above by government of India :

TABLE 3.3(b) DBT BUDGET OF BASIC and PRODUCT BASED R&D PROJECTS

(in Rs. Lakhs)

	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97
Veternary BT	11.75	39.1	98.95	236.8	126.36	238	150	250
Aquaculture & Marine	2.3	77.6	91.62	53.52	102.2	121	100	100
Medical	128.53	298.17	527.46	487.1	523.76	538	600	500
Fuel, Fodder, Biomass Green Cover BT	80.54	72.79	139.65	157.16	237.87	291	284	250
Microbial & Industrial	18.87	47.29	364.46	258.69	325	470	400	400
Biochemical Engg. Process optimisation & bioconservation	0.87	28.93	243.74	114.06	58.15	79	100	4
Biological Control of Pests, Diseases & Weeds through BT	39.62	89.74	96.24	330.71	403.88	283	250	330
Immunological Approaches to Fertility Control	189.72	177.4	104.6	66.65	125.22	119	130	130
Other R & D	243.85	449.04		658.47	684.48	6	0	0
Plant Molecular & Agri BT	572.18	526.52	137.76	236.44	372.76	515	450	350
Basic Research & Emerging Areas				233.34	394.86	445	900	400
Environmental						103	150	130
Medical & Aeromatic Plants								100

Source : DBT ANNUAL REPORTS (1986-87,1993-94,1996-97 to 2000-2001) & PERFORMANCE BUDGETS (1991-92 to 1996-97), DST ; MINISTRY OF S&T, New Delhi.

The Table 3.3(b) clearly reflect that the priority area for development is medical biotechnology. The R&D spending in this has increased from Rs. 128.53 lakhs (1989-90) to Rs. 538 lakhs (in 1994-95) and the spending on this front is still steadily increasing. India, traditionally being an agri based country the government seems committed to major R&D spending on this front. But this has been gradually declining from 572.18 lakhs (in 1989-90) to Rs. 515 lakhs (in 1994-95). This is perhaps in keeping with economic maturity of the country – from agri based economy to industry and service sector based. The government (in agriculture sector) seems to be now targeting consolidate the gains of 'green revolution' by spending more on environment friendly preservation of crops i.e. biological control of pests, diseases and seeds through biotechnology. Realizing food in bolstering the 'protein' requirements in food consumption pattern in India, spending on Veterinary and aquaculture & marine biotechnology has been increasing. It is important to note from the data that government spending on 'fuel, fodder & biomass green cover' has suddenly increased in 1991-92, and has been increasing since then – this might be attributed to an increased amount of sensibility generated towards this emerging environmental movement worldwide and Rio conference (1991). More so one can figure out allocation of Rs. 100 lakhs especially for environmental biotechnology (under separate heading from the precious) in 1996-97.

DBT has been spending on basic research and emerging areas extensively (currently under this head but earlier called as 'other R & D'). This is basically an investment to build on scientific capabilities in front end biotechnology.

3.4 Human Resource Development

Recognizing the special requirements of manpower development in this area, the DBT has been making earnest effort in this direction from the moment it was set up and gradually it has been making improvements to keep it in tune with new developments.

An integrated Human Resource Development Program is being implemented to generate adequate and appropriately trained personnel in the area of biotechnology. For this DBT has been spending a sizeable proportion of its budget towards the manpower development.

TABLE 3.4 DBT BUDGET FOR MANPOWER DEVELOPMENT

Year	In Rs. Crores	% of Total Budget (approx.)
1986-87 (Revised estimates)	3.65	20.3
1987-88 (Budget estimates)	6.50	15.9
1989-90(Actual expenditure)	6.74	12.5
1990-91 (Actual expenditure)	7.46	12.6
1991-92 (Actual expenditure)	5.54	8.7
1992-93 (Actual expenditure)	4.22	5.5
1993-94 (Actual expenditure)	5.81	7.2
1994-95 (Actual expenditure)	7.80	9.3
1995-96 (Revised estimate)	6.5	7.4
1996-97 (Actual expenditure)	6.43	7.0
1997-98 (Actual expenditure)	7.05	7.4
1998-99 (Actual expenditure)	9.46	8.3
1999-2000 (Actual expenditure)	9.82	7.7
2000-2001 (Revised estimate)	10.0	6.6
2001-2002 (Budget estimate)	10.0	5.4

Source : DBT ANNUAL REPORTS (1986-87,1993-94,1996-97 to 2000-2001) & PERFORMANCE BUDGETS (1991-92 to 1996-97), DST ; MINISTRY OF S&T, New Delhi.

Sustained efforts over the years in generating trained human resource has given rich dividends in bringing excellence in this field and providing the skilled human resource for research and industry :

DBT launched M.Sc./ M.Tech./ Post Doctoral courses in six universities in 1985-86 : Madurai Kamraj University, Jawahar Lal Nehru University, University of Poona, MS University of Baroder, Jadavpur University and Indian Agricultural Research Institute. To this six others were added in 1986-87 : Indian Institute of Technology, Delhi; Indian Institute of Technology, Kharagpur; All India Institute of Medical Sciences, Delhi; Banaras Hindu University; Indian Institute of Science, Banglore and Indian Veternary Research Institute, Izatnagar. By 1988 P.G. and Post Doctoral teaching programme in biotechnology had already started in 17 universities/ institutions. In 1988-89 CCMB, Hyderabad and in 1989-90 Bose Institute, Calcutta in association with DBT started 2 year post-doctoral training programme in Biotechnology.

In addition to the existing programmes, M.Sc (Biotechnology) was sponsored by DBT in 5 other institutions and M.Tech. in one, in 1990-91. In 1992-93, proposal to start M.Sc./ M.Tech. course in Bioprocess Technology in University Department of Chemical Technology, Bombay was approved. During 1994-95, M.Sc. (Biotechnology) programme was introduced at Himachal Pradesh University, Shimla; Banasthali Vidyapith, Banasthali and University of Calcutta, Calicut and financial assistance was provided towards the strengthening of M. Sc./M.V.Sc. biotechnology teaching programmes in Punjab University, Pondicherry University and Tamil Nadu Veterinary and Animal Sciences University. Thus, by 1994-95, DBT was supporting programmes in 32 institutes. This tally has increased little since then with major introduction being of Dekhi University in recent times.

- The first batch of 106 M.Sc. (Biotech) students passed in 1981. Thereafter, batches of about 160-200 students were supposed to pass each year thereafter. By 1989-90, more than 500 students have passed out of various courses. By 1990-90 almost 650 students have passed out from the various institution. And in 1991-92 number of students being admitted was increased to 250.
- By 1991-92 about 800 students have passed out. In 1991-92 around 300 students passed (thus taking total tally to 1100 students passed since inception of various programmes) and similar number of students passed yet again in 1993-94 (total tally = 1400). Since programmes were launched in quite a few universities in 1994-95, this increased intake to

almost 400 students each year. And currently almost 400-450 students pass out each year.

3.4.1 Some other initiatives in Human Resource Development :-

- Biotechnology Associateships are given with the objective to train scientists in research in frontier areas of biotechnology in leading research institutions in the country (National Associateships) and abroad (overseas Associateships).
- Training programmes
  --- Short term training courses for mid career scientists
  --- Post M.Sc and M.Tech training in industries
- Visiting scientists from abroad are invited for specific duration in research institutes / universities. To initiate collaborative research programmes or take part in teaching activities .
- Golden Jubilee Biology Scholarships to 10+2 level students to encourage them to take Biology as career
- Golden Jubilee Biotechnology Fellowships
- Popularization of Biotechnology
  --- Biotechnology publications
  --- Popular lectures by experts
  --- Exhibition
- Seminars/Symposia/Conferences

Results of the above programmes :

Several short term courses ranging from 10-16 every year has been conducted since 1983. There were about 200 programmes conducted between 1983-96 and around 1800 people were trained under this programme.

Till 1996, around 280 people have taken advantage of overseas associateships, which is expected to fill the gaps in capabilities and demand for highly skilled manpower in the country (Visalakshi , 2001).

3.4.2 Changing manpower requirement in biotechnology :

An effort to assess the requirement of manpower in Biotechnology by the year 2000 in India was commissioned By DBT. The result of the analysis showed the following :

- An increase in the manpower requirements is estimated.
- This increase could be seven times by 2000 or three times by 1995, both at minimal (conservative) and maximal (liberal) estimates.
- The variation between the maximum and minimum in the estimates by the peers ranges from approximately 1500 in 1992 , approximately 3000 in 1995 and approximately 9000 in 2000.
- The progressive shift in the requirement of different specializations is predicted.
- This shift is from traditional disciplines (like chemistry, Zoology, Botany, etc.) to modern disciplines (Molecular biology,Biotechnology, Protein Chemistry, etc.)
- Though R&D remains a major function requiring manpower which increases by approximately 3-4 times from 1992-2000, the increase in the requirement of manpower for functions like production, marketing and extension would be at higher proportion i.e.
    1. Production 16-20 times (approximately)
    2. Marketing 4 times (approximately)
    3. Extension 4-7 times (approximately)

TABLE 3.4.2 MAXIMUM and MINIMUM MANPOWER ESTIMATES IN BT in 2000

Estimates in # for various functions		Specialization			Total
	Genetic Engg.	Hybridoma	Plant Tissue Culture	Enzyme Engg.	
Research Max Min	 4,000 1,500	 1,000 700	 2,000 700	 800 700	 7,800 4,600
Production Max Min	 2,000 1,000	 500 500	 8,000 6,000	 600 500	 11,200 8,000
Marketing Max Min	 500 500	 500 200	 500 300	 200 200	 1,700 1,200
Extension Max Min	 - -	 4,000 2,500	 300 200	 - -	 4,300 2,700
Training Max Min	 800 400	 700 400	 500 500	 200 200	 2,200 1,500
Total Max Min	 7,300 3,400	 6,800 4,300	 11,300 8,700	 1,800 1,600	 27,200 18,000

Source : Visalakshi,2001.

In addition to the shift in specialization of personnel required, it is observed from the analysis that there is a shift in requirement of qualifications of the personnel . This shift again could be explained by the prediction of a shift in emphasis of various functions associated with biotechnology by the year 2000.

Following the above prediction of a shift in emphasis on production and marketing (commercialization phase) over R&D (preparatory phase) the demand for skills are at the level of upscaling, downstream processing, packaging, management, marketing, in-house training, etc.

According to the study of Visalakshi and Sharma (1993) the requirement of personnel with Ph.D or above increases by 1995 from 776 in 1992 to 2076 (approximately 2.5 times) to approximately 5 times by 2000. But the requirement of postgraduates in various fields of science increases by approximately 7 times by 2000 and the increase is more for all other functions like production, marketing and extension compared to the requirement for doctorate degree holders who were required more in numbers for research and training by 2000.

Coming to the status of graduate and non-graduate personnel involved in various functions, the total requirement for personnel with these qualification increases by approximately 6 times for graduates and approximately 9 times for non-graduates (from 1992 levels to 2000 estimates).

Thus one, the requirement for graduates and postgraduates is higher than doctorates by the year 2000, mainly contributed by the increased requirements for production, marketing and extension activities (Visalakshi , 2001).

3.5 Infrastructural facilities

DBT has been spending almost 11% (approximately) of its budget on developing infrastructural facilities. The exception were early years (during which the percentage of spending on infrastructure was sufficiently high) and this is expected as to establish, the development of infrastructure is must.

Spending on development and updating of infrastructure is must in new technology like biotechnology, where development on scientific and technological front is rapidly taking place and the rate of obsolescence is fast. This seems to be one of the main reason for major spending on infrastructure by DBT. (See Appendix 2 to know about the kind of research going on India in various Universities and Laboratories).

TABLE 3.5 DBT spending on building Infrastructural facilities

Year	Rs. in Crores	% of Total Budget (approx.)
1986-87 (Revised estimates)*	7.95	44.3
1987-88 (Budget estimates)*	22.5	54.9
1989-90 (Actual expenditure)	11.33	21.1
1990-91 (Actual expenditure)	8.48	14.3
1991-92 (Actual expenditure)	9.61	15.0
1992-93 (Actual expenditure)	10.19	13.4
1993-94 (Actual expenditure)	8.15	10.1
1994-95 (Actual expenditure)	9.1	10.8
1995-96 (Revised estimate)	7.5	8.5
1996-97 (Actual expenditure)	7.94	8.7
1997-98 (Actual expenditure)	12.3	12.9
1998-99 (Actual expenditure)	10.23	8.9
1999-2000 (Actual expenditure)	8.27	6.5
2000-2001 (Revised estimate)	25.95	17.2
2001-2002 (Budget estimates)	11.0	5.9

Source : DBT ANNUAL REPORTS (1986-87,1993-94,1996-97 to 2000-2001) & PERFORMANCE BUDGETS (1991-92 to 1996-97), DST ; MINISTRY OF S&T, New Delhi.

* Includes 'Infrastructutral Facilities' + 'R & D units for New Products generation'.

In recent years recognizing the importance of biotechnology, DBT has launched Biotechnology Information System[9] (BTISnet) in 7th Five Year Plan and this has grown rapidly. Presently, the BTISnet comprises on Apex Center at the DBT, nine specialized Distributed Information Centers (DICs) in identified major areas of biotechnology and 38 Distributed Information Sub-Centers (Sub-DICs). All the centers are interlined through satellite communication system, each providing information support in specific areas of biotechnology and helping in the diffusion of scientific information across the network. All these centers will henceforth be called "Bioinformatics Centers". Six national facilities for Interactive Graphics based computational requirements and two long term

[9] Modern biology and particularly biotechnology are very much information dependent fields. In fact, the symbiosis between IT and BT today is as intricately entwined as the two strands of DNA. ' Bioinformatics ' may, therefore , be defined as a scientific discipline that encompasses all the aspects of biological information viz. Acquisition, processing , storage , distribution , analysis and interpretation that combines the tools and techniques of mathematics, computer science and biology with the aim of undertaking the biological significance of a variety of data.

educational programmes started during the 8th plan are additional components of the programmes.

3.6 Biotechnology industries in India

TABLE 3.6(a) DBT budget for Demonstration/ Transfer of Technologies & Manufacturing Activities

Year	Rs. in Crores	% of Total Budget (approx.)
1986-87 (Revised estimates)	N.A.	N.A.
1987-88 (Budget estimates)	N.A.	N.A.
1989-90 (Actual expenditure)	8.29	15.4
1990-91 (Actual expenditure)	6.22	10.5
1991-92 (Actual expenditure)	6.6	10.3
1992-93 (Actual expenditure)	5.26	6.9
1993-94 (Actual expenditure)	6.22	7.7
1994-95 (Actual expenditure)	9.2	11.0
1995-96 (Revised estimate)	9.3	10.6
1996-97 (Actual expenditure)	7.06	7.7
1997-98 (Actual expenditure)	10.29	10.8
1998-99 (Actual expenditure)	9.19	8.0
1999-2000 (Actual expenditure)	10.79	8.4
2000-2001 (Revised estimate)	11.18	7.4
2001-2002 (Budget estimates)	11.0	5.9

Source : DBT ANNUAL REPORTS (1986-87,1993-94,1996-97 to 2000-2001) & PERFORMANCE BUDGETS (1991-92 to 1996-97), DST ; MINISTRY OF S&T, New Delhi.

The table 3.6 does reflect that DBT gives due care to commercialise and put in service the technologies developed but still (till date) the commercialization aspect in biotechnology is not so impressive. [Effort has been made to shed light on the reasons for it in the following chapters].

In India the companies are still not into front end biotechnology area. Of the about 800 companies working in various fields of biotechnology, hardly 25 companies are into front end biotechnology area. (For details see: www.biotechsupportindia.com).

Biotechnology field wise break up of number of companies (having some recognizable presence in the market) are given as below :

Table 3.6(b) Number of important companies in each field of biotechnology

Type of companies	Number of Companies
Animal	3
Antibiotic	16
Aquaculture	12
Biofertilizer	34
Bioinformatics	9
Biopesticides	1
Diagnostic	27
Enzyme	18
Food	3
Health	6
Industrial	12
Plant	51
Vaccines	23
Veterinary	30
Environmental	1

Source : www.biotechsupportindia.com

To develop effective linkages with the industrial sector for the commercialization of biotechnology the **Biotechnology Consortium India (BCIL)** was conceptualized in April,1990 and inaugurated by the then Prime Minister on 20^{th} Dec.,1990.This was promoted by DBT and All India Financial Institutions like IDBI, IFCI, UTI etc.

BCIL has a Scientific Advisory Committee (SAC), to provide expert advice and guidance for the planning and execution of its activities. The members of this are eminent scientists, economists and technologists in the field of biotechnology and related fields. The Board of Directors of this is represented by nominees of government, financial institutions and industry.

One of the prime objectives of BCIL is to ensure closer interaction between R&D institutions, industry, academic, and financial institutions for R&D and pilot plant studies, market testing, certification and technology development, to forge commercial success. BCIL would also assist in identification of need based technologies, product and technical capabilities available in the country for speedy commercialization, preparation of pr-feasibility report and also detailed project reports.

Likewise ASSOCHAM and CII are also forming separate units to look into the growth as well as various aspects (like government policies , government-industry interface , commercialization , etc.) of biotechnology sector in India .

(To get further details about current consumption and anticipated future demand of biotechnology products in India refer to Appendix.3)

CHAPTER . 4

METHODOLOGY

CONTENTS

4.1 INTRODUCTION
4.2 STEPS IN FORMULATING THE RESEARCH PROBLEM
4.3 THE RESEARCH DESIGN, SAMPLING, COLLECTION OF DATA, QUESTIONNAIRE , INTERVIEW AND LIMITATIONS OF DATA COLLECTION
4.4 CLASSIFICATION AND INTERPRETATION OF DATA
4.5 KEY RESEARCH QUESTIONS FROM THE REVIEW OF LITERATURE
4.6 WORKING HYPOTHESIS GUIDING THE RESEARCH

4. Methodology

4.1 Introduction

Research in common parlance refers to search for knowledge. The Advanced Learner's Dictionary of Current English lays down the meaning of research as "a careful investigation or inquiry specially through search for new facts in any branch of knowledge". According to The Concise Oxford Dictionary of Current English: "the systematic investigation in order to establish facts and reach new conclusions". Some people consider research as a movement, a movement from the known to the unknown. The inquisitiveness is the mother of all knowledge and the method, which one employs, for obtaining the knowledge of whatever the unknown can be termed as researcher. D.Slesinger and H. Stephenson in the Encyclopedia of Social Sciences define research as "the manipulation of things, concepts or symbols for the purpose of generalizing to extend, correct or verify knowledge, whether that knowledge aids in construction of theory or in the practice of an art". In short, the search for knowledge through objective and systematic method of finding solution to a problem is research.[1]

The field of social research[2] is virtually unlimited, and the materials of research endless. Every group of social phenomena, every phase of social life,

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[1] See chapter 1(page 1-2), in Kothari.C.R.; 1999.

[2] According to Donal Slessinger and Mary Stevenson:

> Social research may be defined as a scientific undertaking which, by means of logical and systematized techniques, aims to: 1) discover new facts or verify and test old facts. 2) analyze their sequences, inter-relationships, and casual explanations which were derived within an appropriate theoretical frame of reference. 3) develop new scientific tools, concepts and theories, which would facilitate reliable and valid system of human behavior. Stated in other words, social research is a systematic method of exploring, analyzing and conceptualizing social life in order to "extend, correct or verify knowledge whether that knowledge aid in the construction of a theory or in the practice of an art".

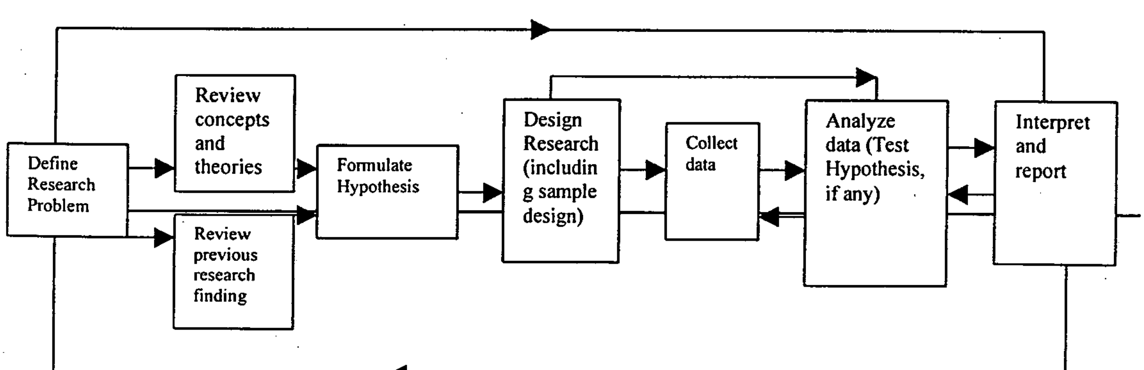
Note : The above mentioned has been drawn from book by Young.P.V.(1996).

every stage of past and present development is material for the social scientists. But at the same time C.H. Combs points out, that we are tempted to measure something, even if we cannot measure it. "Such ....compulsiveness defeats our basic objective of remaining maximally faithful to the events, which we observe. The proper solution to this dilemma of rigor vs. faithfulness lies not in abandoning either objective but in reassessing the means by which rigor is attainable, given that a certain sort of event is to be investigated".

So, it is impressed that both strategy and planning are important for any research. Strategy means mere than planning a study and more than decisions made as to its execution. Strategy refers also to personal values and standards of conduct during investigation. While, the investigator is intent on obtaining reliable, verifiable, measurable data, but he must do this without embarrassment or harassment to the informants or agencies from which data are secured or by which they are verified.

Research Planning on the other hand is nothing but series of actions or steps necessary to effectively carry out research and the desired sequencing of these steps. There are various steps involved in a research process, which are not mutually exclusive; nor they are separate and distinct, they do not necessarily follow each other in any specific order and the researcher has to be constantly anticipating at each step in the research process the requirements of the subsequent steps. However, the following flowchart effectively illustrates the Research Process.

Flow Chart (source : Kothari.C.R. , 1985) **Figure 1**



Given the limitations of data, time, scope and other resources needed for carrying out a modest M.Phil dissertation, an effort is made here in this project to follow various steps given in the above flow chart. Even though in principle the steps were followed, a complete following up of feedback in the interpretation of conclusions was not possible in this project.

4.2 Steps in formulating the research problem

At the very outset the researcher must single out the problem one wants to study i.e. one must decide the general area of interest or aspect of a subject matter that he would like to inquire into. Initially, the problem may be stated in a broad general way and then the ambiguities, if any, relating to the problem be resolved. Then, the feasibility of a particular solution has to be considered before a working formulation of the problem can be set up. It is at this stage, to avoid confusion and superficiality and promote classification one should delimit the scope of inquiry. It is necessary to keep research within manageable limits, that is, within the ability of the mind to grasp the implications and to explain them plus look into other resources available i.e. time, money, etc.

Though, a beginner is especially inclined to undertake too wide a scope not suspecting at first the far reaching and complex implications of his study. But due training one would come to realize the wealth and variety of social reality are well-high indescribable. Even a complete study of a segment of this complex reality would require more than a student's lifetime to gain a glimpse of the proverbial forest through seeing clearly its trees.

Thus, initiation is the most crucial part of any inquiry. According to F.S.C. Northrop (philosophies of science) (1937) :

> "One may have the most rigorous method of investigation, but if a false or superficial beginning is made, rigor later on will never retrieve the situation beginning is made, rigor later on will never retrieve the situation. It is like a ship leaving port for a distant

destination. A very slightest erroneous deviation in taking one's bearings at the beginning may result in entirely missing one's mark at the end, regardless of the sturdiness of one's mark at the end, regardless of the sturdiness of one's craft or the excellence of one's subsequent seamanship". [3]

Essentially two steps are involved in formulating the research problem viz. understanding the problem thoroughly and rephrasing the same into meaningful terms from an analytical point of view.

During my research, at the very outset I tried to understand the complexity of "University–Industry–Government partnerships" by –

- Examining all available literature – both concerning the concepts and theories and the empirical literature consisting of studies made earlier which are similar to one proposed.
- Discussing it with supervisor and taking his help.
- Discussing it with other faculty members.
- Discussing it with colleagues.

After having done that I tried to delimit the scope of study/ research and thus zeroed on "University–Industry–Government Partnership" in Delhi Region with respect to biotechnology sector only.

4.2.1 Reasons to take Biotechnology sector for the study.

Biotechnology is a very interesting case for understanding the contemporary changing roles for universities, firms and government and for the changing division of labour in knowledge seeking activities quite simply because it is the important segment of new technologies and the sudden interest in this sector all over the globe because countless

[3] The above mentioned has been drawn from book by Young.P.V.(1996), page130.

exciting opportunities it has opened up (e.g. in food and agriculture, dyes and pharmaceuticals, energy and environment). Modern biotechnology has been linked to many attempts to change the relationships between different kinds of organization and to change cognitive and institutional environments. Despite a dominating picture of science push, (even here there have been many different types of relationship between firms and universities, firms and government laboratories, government laboratories and universities etc.) agents producing different kinds of knowledge are redefining what they are doing and why, partly in response to changes in others, when this occurs overtime agents are creating new environments and/or redefining the conditions of existing ones.

4.2.2 Reasons to take Delhi as the region for study.

One of the main reasons to take Delhi as the region of study was the limitation of the project (this being an M.Phil dissertation) and the constrain of time and resources available for the study.

Delhi has also been chosen as the region of study as it is supposed to have many government laboratories, universities of high repute and autonomous academic institutes which are conducting research in various field of biotechnology. At the same time institutes based in Delhi are actively engaging in technology transfers (see Table 4.2.2) as compared to institutes based in other regions, which makes it ideal for conducting study on budding relationship between University-Industry-Government in biotechnology sector. One can partially justify this claim by the data released by Department of Biotechnology, Government of India, on the technologies transferred which were generated out of the projects supported by the department.

According to the Data (DBT) :

Total No. of technologies transferred = 41 (100%)

Technologies transferred by Institutes based in Delhi = 21 (51.22%)

TABLE 4.2.2 Technologies Transferred by various Institutes In Delhi with support from DBT

Institutes based in Delhi	No. of technologies transferred
NII	10
Delhi University	4
TERI	4
CBT	1
AIIMS	1
National Centre for Plant Genetic Resources	1
TOTAL	**21**

Source : Web site of DBT

Thereafter, care was taken to define the objectives in the form of key research questions unambiguously as that will help discriminating relevant data from irrelevant data. Prof. W. A. Neiswanger[4] correctly states that the statement of the objective is of basic importance because it determines the data which are to be collected, the characteristics of the data which are relevant, relations which are to be explored, the choice of techniques to be used in these explorations and the form of the final report.

4.2.3 Extensive literature survey –

There are no short cuts or substitutes in gaining concrete knowledge about social problems which need fundamental understanding (Young,1996: page 21 &34).

[4] The above mentioned has been drawn from book by Kothari.C.R.,1999,(page16).

So once the problem was formulated, a brief summary in the form of "M.Phil Proposal" was written down. At this juncture extensive literature survey connected with the problem was undertaken. For this various resources were tapped – academic journals; conference proceedings; government reports; university/ institute reports; books, etc.

4.2.4 Formulating working hypothesis –

According to M.R. Cohen and E. Nagel (1934): "1) the function of a hypothesis is to direct our search for the order among facts.... 2) It is of considerable advantage of a systematic inquiry is begun with a suggested explanation or solution of the difficulty which originated it. Such tentative explanations are suggested to us by something in the subject matter and our previous knowledge".[5]

Working hypothesis is formulated after extensive survey of literature is over. Working hypothesis is tentative assumption made in order to draw out and test its logical or empirical consequences. They arise as a result of *a priori* thinking about the subject, examination of the available data and material including related studies and the counsel of experts (Kothari,1999). These assumptions are made on the basis of probabilities, shrewd guesses and profound hunches (Young,1996: page 103).

Importance of working Hypothesis –

Without a working hypothesis the explorer finds it very difficult, laborious and time consuming to make adequate discrimination in the complex interplay of factors before him. According to George Lundberg, experienced social researcher and theorist: "The only difference between gathering data without an hypothesis and gathering them with one is that in the latter case we deliberately recognize the limitations of our field of investigation so as to

[5] The above mentioned has been drawn from book by Young.P.V.,1996,(page 20).

permit a greater concentration of attention on the particular aspects which past experience leads us to believe are significant for our purpose".[6]

Nature of good hypothesis – A sound hypothesis is generally a simple one; but simple does not mean obvious. Simplicity, as an essential requirement of an exploration, demands insight. Presumably, the more insight the researcher has into a problem, the simpler will be his hypothesis about it (Young,1996).

Looking into the importance of working hypothesis, I tried to formulate few hypothesis for this research work.

4.3 The research design , sampling, collection of data , questionnaire, interview and limitations of data collection.

4.3.1 The research design

After the research problem have been formulated in clear-cut terms, it is imperative to prepare a research design i.e. the conceptual structure within which research would be conducted. The design results from translating a 'general scientific model' into varied 'research procedures'. The design has to agreed to the available time, energy and money; to the availability of data; to the extent to which it is desirable or possible to impose upon persons and social organizations which might supply the data. Research designs may be conveniently described into following four categories (Kothari,1985) :-

I. Exploration: A flexible research design which provides opportunity for considering many different aspects of a problem is considered appropriate if the purpose of the research study is that of exploration.

[6] The above mentioned quote has been drawn from book by Young.P.V.; 1996.

II. + III. <u>Description and Diagnosis:</u> When the purpose happens to be an accurate description of a situation or of an association between variables, the suitable design will be one that minimizes bias and maximizes the reliability of the data collected and analyzed.

IV. <u>Experimental Research design:</u> When systematic study of social life is carried on under condition of control and experiment. In this researcher tries to test causal relationship between variables.

E. A. Suchman (1954) states [7]:

> "There is no such thing as a single or 'correct' design .... Research design represents a compromise dictated by the many practical considerations that go into social research.... [Also] different workers will come up with different designs favoring their own methodological and theoretical predispositions... A research design is not a highly specific plan to be followed without deviations, but rather a series of guideposts to keep one headed in the right direction".

It is obvious that no single scientific technique in gathering and analyzing these complex data would suffice. Research studies generally utilize not only a variety of techniques but approach the subject from a variety of new points. This procedure rests on the assumption that no one point of view or scientific discipline can encompass total social reality. No single technique of study is regarded as sovereign. Each is a complement to others.

My research study includes components of both Exploratory as well as Diagnostic/ Descriptive.

[7] The above mentioned quote has been drawn from Young.P.V.;1996,(page 131).

Components of Exploratory design in my research –

- Non probability sampling design – The data gathered from the concerned persons are not included under random sampling. Rather it is purposive in nature.
- The research tried to shed new insights into the problem.
- Charted new horizons in scientific explorations, advanced and tested new principles of procedure and suggested new concepts.

Components of Descriptive/ Diagnostic design in my research –

- It is a rigid design, which makes enough provisions for protection against bias and tries to maximize reliability.
- It is preplanned design for analysis.
- Structured instruments for collection of data.
- Advanced decisions about operational procedures.

My Research also has following features –

1. It is applied in nature, since the results obtained after analysis and interpretation of data, have practical implications to restructure and organize the partnerships and formulate policies accordingly.

   It can also be of fundamental importance since the theory on which the study is based is being tested for its correction in Indian scenario and with that verify it and if possible project a new dimension to it in Indian context.
2. The research can also be classified as conceptual since the study is firmly grounded on previous theories. (i.e. Mode 1, Mode 2, Triple Helix, National Systems of Innovation). At the same time it is an empirical work as all the data gathered are from exhaustive fieldwork.
3. The research is based both on the quantitative data as well as qualitative data.

4.3.2 Sampling and collection of data

There are several ways of collecting the appropriate data, which differ considerably in context of money costs, time and other resources at the disposal. The primary data can be collected either through experiment or through survey. Data are gathered in experiment in controlled set up. Whereas in survey the researcher cannot manipulate the subjects. (Techniques applied to gather data while surveying – Observation; Personal Interviews; Telephone interviews; Questionnaires; Schedules).

The data can also be gathered by secondary means – books, journal; published/unpublished works; previous research work; government documents; proceedings of conference etc .[8]

This research is said to be strongly empirically grounded because of the following steps applied in the collection of data :

Since this research tries to explore various research questions (previously mentioned) related to University-Industry-Government partnerships in biotechnology sector in Delhi region from hindsight of public sector research; so, it was imperative to first determine the institutes where field work was to

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[8] William. I. Thomas was the first sociologist to introduce new foundations of scientific thinking by stressing the necessity of objective, detailed field studies, which would concern themselves with total social situations and their basic antecedent elements. His empiricism is an outgrowth of his kind imported by American Scholars who had studied under certain General Social scientists.
Volkart shares the studied opinion of many other sociologists that "much of the contemporary emphasis on empirical fieldwork, interdisciplinary research and the close tie between theory and data, stem from Thomas' efforts along those lines".

Note : The above mentioned quote has been drawn from Young.P.V. ; 1996, (page 43).

be carried out. For this, it was decided to rely on DBT report which provided list of technology transfers that were carried out by it from one institute to an industry (thus reflecting a concrete University-Industry-Government partnerships). Of this it was observed that 6 institutes from Delhi were involved: -

- NII (National Institute of Immunology)
- DU (Delhi University)
- AIIMS (All India Institute of Medical Sciences)
- CBT (Centre for Biochemical Technology)

+TERI (Tata Energy research Institute) and **NCPGR (**National Centre for Plant Genetic Resources **)**

* It was decided to leave TERI out of study as this research tries to explore the research questions from hindsight of Public Sector Research and TERI is a private research institute. So, it was decided that IIT, Delhi be taken instead of it because IIT is a premier technology institute with good industrial links.

* It was decided to leave NCPGR and instead NBPGR for field study because JNU is already being covered in field work and NCPGR being located in JNU (though an independent institute) has drawn many scientists from it. By taking NBPGR there were two gains – 1) taking one of the premier institute working exclusively on 'agri' bio-field 2) representing an ICAR institute.

Research being carried out in these 6 institutes covers almost all the frontiers in the field of biotechnology[9] and thus these institutes can be treated as

[9] To get an insight into the areas of research in each institute see Appendix No.5

true representatives with respect to various fields of research in BT and all the institutes are highly rated.

After selecting on institute, the next important step followed was to identify scientists/professors in each of these from whom data was to be collected. For this latest Annual Reports from each of the institutes were collected. From this the project leaders/professors involved in biotechnology projects (and not any Bio/life sciences project) were identified irrespective of their source of funding. Thus, the sample which was taken was not based on random sampling but was purposive in nature.

To collect data, Questionnaire (Questionnaire administered is attached at the back of this Chapter) was administered to each of the project leaders/ professors identified. [10]

In total 50 scientists/professors were identified in the 6 institutes. Questionnaire was distributed to them. Of this 28 people responded i.e. **response rate was 56%.** These scientists were asked to respond on on-going projects which were in operation for the last 3 years . As it came out, 74 projects in all were reported by the scientists. (For details on these 74 project see Appendix 4).

After having gathered data by questionnaire it was decided to go for semi-structured interviews of few of the scientists in order to further explore and gain insight into the complexities of the problem reflected by gathered data. This qualitative exploration by interviews led to giving more credence to quantitative data.

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[10] If the respective project leader / professor Was not available temporarily then it was decided to take data from other junior scientist or other scientist involved in that project or scientist involved in similar kind of some other research. But if the project leader / professor had left the institute then it was not considered and above exercise not taken.

Since DBT is the major government agency concerned with all aspects of biotechnology so few semi-structured interviews were also taken from high-ranking officials involved in policy making.

The list of People interviewed is attached at the end of this chapter.

All this led to giving a holistic view on the problems under study.

4.3.3 Limitations of data collection :-

- It was very difficult to get data out of respective institutes or government departments. Some of the reasons were : bureaucratic hurdles, secrecy factor, non availability of reports etc.
- Non availability of few scientists/ professors due to various reasons i.e. their other engagements; they being out of station; working in the Lab; few having left the institute; etc.
- Not very enthusiastic response from scientists – mainly because of their lackadaisical approach towards this research work (as it was of no concern or benefit to them or perhaps they could not judge the importance of this). This led to 56% collection of Questionnaire; even though time, energy and money spent was huge.
- Many scientists did not stick to their words regarding handing over of Questionnaire – this led to many rounds being made to the institute and waiting for long hours just to collect the Questionnaire which had been given many days earlier (though Questionnaire was framed in such a way as not to take more than 10-15 minutes of each scientists).
- Few scientists approached for interview refused to give time (due to certain reasons) and some could not give interview (because of their engagements) after giving time.

- Also because of the limitation of time, resources and scope of study (this being an M.Phil dissertation) just two components of 'triple helix' (i.e. government and public sector research) was studied through the secondary sources (Annual Reports etc of the institutes , DBT etc.) and questionnaire and interviews of the scientists in these various sample institutes. (So, basically this study tries to reflect on the issues concerned from the perspective of public sector research scientists).

4.4 Classification and interpretation of data

Data gathered are no mere collection of accurate facts. Facts become meaningful when they are logically connected with other relevant facts and sorted according to their essential nature and to the chain of evidence, which mutually explain each other. So, once the data was collected then it was properly classified, put in tabular form and then a detailed analysis of it was carried out.

4.5 Key research questions from the review of literature

1. Exploring the concept of 'Triple Helix' linkages and partnerships in the context of Delhi region to examine its relevance as an innovation strategy.

2. What is the structure and nature of linkage and partnerships taking place between University-Industry, Government Research Centres-Industry and University-Industry-Government in Biotechnology in Delhi region ?

3. What are the organizational and institutional changes that are being introduced in the public R&D institutions and universities as part of the emerging Triple Helix Linkages and partnerships ?

4. As the concept of Triple Helix involves both structural changes between different institutes and as well as the orientation of practitioners --- it will be pertinent to ask what are the changes (that is from the previous era or Pre-liberalization era) in the orientations of scientists and academicians in biotechnology in various institutes in the Delhi region. A related important question is on the mobility of personnel between different actors of Triple Helix.

5. Given the dependent nature of Biotechnology industry on the universities in USA and Europe, it is pertinent to explore whether universities and public R&D institutes in biotechnology in the Delhi region are the source of new firms, products, devices and core elements in R&D chain which are crucial for commercialization of research results.

4.6 Working hypothesis guiding the research

1. Even though the concept of Triple Helix has universal relevance, the main justification of the concept at the level of operation or practice varies in different socio-economic and national contexts.

2. The variations at the level of practice or operation is determined by the structure of linkages between different actors i.e. university-industry-government, of the Triple Helix.

3. In the Indian context (especially present context of Delhi region in biotechnology) bilateral linkages and partnerships [university-industry, university-national laboratories, industry-national laboratories, government-university, government-national laboratories etc.] appears to be more relevant and meaningful than tripartite relationships.

SAMPLE QUESTIONNAIRE USED IN THE STUDY

UNIVERSITY-INDUSTRY-GOVERNMENT PARTNERSHIP :

A CASE STUDY OF BIOTECHNOLOGY SECTOR IN DELHI

QUESTIONNAIRE FOR PROFESSORS / PROJECT LEADERS / SCIENTISTS

RESPONDENT'S PERSONAL PROFILE

INSTITUTE'S CODE NO. : ....

DEPARTMENT / LAB : ....

RESPONDENT'S CODE NO. : ....

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1. **Please list main BIOTECHNOLOGY PROJECTS carried out by you during the last 3 years , as below :-**

Project Title	Sponsoring Agency / Company	Approx. Budget (Rs. Lakhs)	Type of Relevance *

i. ....

ii. ....

iii. ....

* **[Direct Industrial Relevance -- 1 ; Indirect Industrial relevance -- 2 ; Academic Relevance -- 3]**
(Please use extra sheet if need be .)

2. **How much importance would you give to the following :**

i. Exploration and adding to systematic knowledge [ ]
ii. Patenting (Process) [ ]
iii. Designing of products / kits etc. [ ]
iv. Solving a problem for a client / industry etc. [ ]
v. Specify (if any other) ....

{ 5 - Highly important ; 4 - Important ; 3 - moderate ; 2 - little ; 1 - no importance }

3. In your research collaboration with industry how much importance you assign on various items given below ?

	5	**4**	**3**	**2**	**1**
• New product Ideas					
• Feedbacks on existing products/ processes					
• Routine problem solving					
• New research equipments					
• New R&D procedures / methodologies					
• Skills in experimentation and testing					
• New Product / Process technology					
• Any other					

{ 5 - Highly important ; 4 - Important ; 3 - moderate ; 2 - little ; 1 - no importance }

4. During the last few years , would you claim that research in your project led to :

- **New firms / companies etc. Yes ( ) No ( )**
- **Improving the manufacturing process / products etc. Yes ( ) No ( )**

5. How much importance your institute / organization gives for commercialization of knowledge ? ....

{ 5 - Highly important ; 4 - Important ; 3 - moderate ; 2 - little ; 1 - no importance }

6. Do you think that there is conflict between commercialization of research , patenting and Publication of research results ? Yes [ ] No [ ]
If No, How do you manage all the three together ? ....

...

7. Do you think that peer review , publishing in eminent science journals are as important as commercialization of knowledge ? Yes [ ] No [ ]
If No , which is given more importance ? ....

8. Compared to earlier period do you think professors / Project Leaders now have to perform roles like fund raising , as personnel managers , publicity agent and research director of a team of researchers? Yes [ ] No [ ]

9. Are students / Research scholars in your project involved in Industrial Collaboration ? Yes ( ) No ( )
If yes, kindly indicate on the elements given below :

- **Participation in University - Industry meetings . Yes [ ] No [ ]**
- **Working directly with industrially related projects . Yes [ ] No [ ]**
- **Research scholars being sponsored by firms directly . Yes [ ] No [ ]**

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LIST OF PEOPLE INTERVIEWED

1. Dr. P.K. Ghosh , Chief Advisor, DBT.
2. Dr. T.S. Rao, DBT.
3. Prof. J.K.Deb , Department of Biochemical Engineering and Biotechnology, IIT.
4. Prof. S.K. Kar , Centre for Biotechnology, JNU.
5. Prof. Uttam Pati , Centre for Biotechnology , JNU.
6. Prof. Neera Bhalla Sarin, School of Life Sciences , JNU.
7. Mrs. Prema Jagganathan , Assistant Finance Officer , Project Cell, JNU.
8. Prof. I. Usha Rao , Department of Botany , Delhi University.
9. Prof. C.R. Babu , Department of Environmental Biology , Delhi University.
10. Dr. M.V. Rajam, Associate Prof. , Department of Genetics , Delhi University.
11. Dr. Ravi Dhar , Scientist , Technology Transfer and IPR Department , NII.
12. Dr. S.N. Sharma , Scientist , R&D Planning and Business Development Unit , CSIR.

CHAPTER . 5

EMPIRICAL STUDY : PRESENTATION OF DATA and FINDINGS

CONTENTS

5.1 INTRODUCTION
5.2 SOURCE OF FUNDS
5.3 STRUCTURE OF RELEVANCE OF PROJECTS
5.4 DIMENSIONS OF SCIENTIFIC RESEARCH IN INSTITUTIONS
5.5 ORIENTATIONS OF SCIENTISTS TO COMMERCIALIZATION OF RESEARCH
5.6 INSTITUTIONAL AND ORGANIZATIONAL CHANGES
5.7 RELEVANCE OF 'TRIPLE HELIX' : SOME FINDINGS

5 Empirical Study : presentation of data and findings

5.1 Introduction

The major objective to explore and understand the relevance of triple helix in the case of biotechnology sector in the Delhi region is dealt in this empirical research. As mentioned in the methodology chapter, the methodological tools employed in this section are: a) questionnaire and b) semi structured interviews with scientists and faculty members in various biotechnology institutions. Further some secondary sources of data are also utilized at arriving at the findings of empirical results of the study.

Keeping in view the objectives and hypothesis framed for this study, data and findings presented in this chapter relates to sources of funding pattern in biotechnology; structure of relevance of research projects with reference to industry, academia etc.; structure of linkages between different actors; the role of industry; and institutional and organizational changes observed in different settings. One of the major findings arising out of the empirical research is that the concept of triple helix finds only a partial relevance in the biotechnology sector in the Delhi region.

5.2 Sources of funding

The sources of funding for research projects reveals, to a large extent, the relevance of projects and orientation of researchers. In various studies the funding pattern of research is taken as a parameter or indicator to understand the orientation of institutions and researchers. In the present study as mentioned already in the methodology, 7 institutions in the Delhi region were selected for the study and effort was made to identify biotechnology related projects. As the Table 5.2(a) shows, there are in all 74 projects which have come out in the study in 7 institutions, out of which, Delhi University accounts for one-third of the projects.

Table 5.2(a) Distribution of Projects in Institutions

Institutes	Number of Projects
Delhi University	25 [33.78%]
IIT	8 [10.81%]
CBT	10 [13.51%]
AIIMS	4 [5.41%]
JNU	8 [10.81%]
NBPGR	13 [17.57%]
NII	6 [8.11%]
Total	74 [100%]

Source : Data from the Questionnaire.

Note : For the complete list of projects see Appendix 4.

The question to explore the sources of funding for research projects was administered to members of respective projects in institutions. In all as mentioned in the methodology, 28 scientists responded on these projects. The responses to this question are shown in Table 5.2(b).

Table 5.2(b) **Sources of Funding to Projects in Different Biotechnology Institutions in Delhi Region**

Q. Please list main BIOTECHNOLOGY PROJECTS carried out by you during the last 3 years , as below :-

Project Title | Sponsoring Agency / Company | Approx. Budget (Rs. Lakhs) | Type of Relevance *

INSTITUTE	Govt. funded	Industry funded	Others *	Total
AIIMS	3	0	1	4
CBT	10	0	0	10
Delhi Uni.	19 ^	3 @	3	25
IIT	5	3 $	0	8
JNU	11	0	2	13
NBPGR	8	0	0	8
NII	6	0	0	6
TOTAL	62 [83.8 %]	6 [8.1%]	6 [8.1%]	74 [100%]

Source : Data from the Questionnaire.

Note :

^ : 1 project is Government funded as well as Others .
@ : 1 project is funded by government as well as Industry.
$: 1 project is funded by Industry as well as government.
* : Others include European Union, Indo-Swiss Cooperation, Indo-US cooperation etc.

Generally when a project is jointly funded by Industry as well as government , then it is put under the Industry head as the industry funding it is given preference when coming to exploiting the gains out of it.

As seen in Table 5.2(b) , bulk of the projects in universities and national laboratories (83.8%) are being funded by Government of India – Department of Biotechnology/ Department of Science and Technology and other Government agencies like ICAR, CSIR, UGC, CPCB, DRDO etc . Industry is found to be involved in just 8.1% projects. Even the individual break up reflect the same trend (i.e. maximum projects being funded by GOI) in almost all the institutes (universities and national laboratories) covered under the study – Delhi University (76%); IIT (62.5%); CBT (100%); AIIMS (75%); JNU (84.6%);

NBPGR (100%); and NII (100%). The percentage here indicates the extent of government funding for biotechnology in these respective institutes.

In this study effort to establish the extent of Public Sector Research - Industry- Government partnerships was attempted so as to confirm that whether this trend is catching up in India with respect to biotechnology sector. Extent of University-Industry-Government partnerships was attempted by taking a detailed account of 'projects' that a scientist/ professor is having with him/her and the source of funding for the same. At the same time actual funding by a source have also been tabulated so as to establish monetary backing for the projects from different sources.

Table 5.2(c) Actual financial support for Biotechnology Projects. (in Rs. Lakhs)

Q. Please list main BIOTECHNOLOGY PROJECTS carried out by you during the last 3 years , as below :-

Project Title	Sponsoring Agency / Company	Approx. Budget (Rs. Lakhs)	Type of Relevance

Institutes	Government	Industry	Industry + Government	Others* + Government	Others
NII	74	0	0	0	0
NBPGR	307	0	0	0	0
JNU	195	0	0	0	54.2
AIIMS	10	0	0	0	2
CBT	71.5	0	0	0	0
IIT	89.4	4.2	30	0	0
Delhi University	598.93	33	69	86	101
TOTAL	1345.83 [78%]	37.2 [2.2%]	99 [5.7%]	86 [5.0%]	157.2 [9%]

Source : Data from the Questionnaire.

- Government funded Projects = Projects Funded by DST + DBT + Other Govt. Agencies (ICAR/ CSIR/ UGC/ MOEF/ CPCB/ OIDB/ NII/ DRDO/ NATP/ etc.)
- * : **Others include European Union, Indo-Swiss Cooperation, Indo-US cooperation etc.**

The table 5.2(c) tries to understand orientations by taking note of actual amount involved in R&D in public sector research (i.e. government laboratories and universities) under sponsored or collaborative projects (as reflected by data provided by individual professors/scientists through Questionnaire).

Again, as the table clearly shows that a very high proportion of the funding is given by government (78%). And the projects in which funding was solely by some industry accounts for just 2.2% share in total funding pattern. Proportion of funds involved in projects, which were sponsored jointly by government and foreign institutes/agencies (like World Bank, European Union etc.) or solely by foreign agencies is approximately 14.0% (5.0% and 9.0% respectively).

Even, the break up of funding in individual institutes reflect that in almost all of them proportion of funding accounted solely by Government of India or its agencies was greater than 70%. This in itself shows the level and direction of partnership in India.

Thus, table 5.2(c) makes quite clear that much hypothetically talked about tripartite partnerships (Public Sector Research-Industry-Government) is yet to emerge in the Delhi biotechnology sector as industry funding accounts for a very meager sum compared to other total funding. In a number of ways, if the biotechnology sector considered in this small study can be taken as a representative sample of the Indian situation, this initial result indicates the low level of industry partnership emerging in the biotechnology institutions. A major private industry (Ranbaxy Laboratories) is located within the National Capital Region of Delhi, but in so far as its partnership links with other public sector research institutions are concerned, no significant indications emerge.

5.3 Structure of relevance of projects

Under the pattern followed by India soon after independence – the promotion of public sector research–industry[1] collaboration was accompanied by an increase in R&D funds for universities and research institutions, but in present scenario (especially post liberalization in India) the call is clearly aimed at linking a research sector whose funding has already begun to shrink – and is likely to shrink.

Such a view as above has also been reflected by R.A. Mashelkar (DG, CSIR) in his Vision 2005 document where he emphasizes the need for strong public sector research–industry link so that most of the funding for research in public sector research is generated by Industry.

It is important to shed light on the imperativeness of public Sector Research to forge link with industry which to a large extent depends upon the type of projects. Table 5.3 sheds light on this point. Researchers (i.e. Professors/ Scientists) in various institutes were also asked to categorize projects that were listed by them according to its relevance.

The table 5.3(a) shows number of projects, sponsored or under collaboration with a specific category of agency, in each category of 'relevance'. The total preview of the table shows that almost equal number of projects are distributed in each of the category – Direct Industrial (32.4%); Indirect Industrial (31.1%) and Academic (36.5%). This indicates that majority (63.5%) of projects have some relevance (either direct or indirect) to industry. In other words, even though majority of the projects receive

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[1] Earlier Research – Industry collaboration was mainly between National labs and Universities catering to the Public Sector Companies, due to government intervention. These views are expressed by 2 scientists in JNU.

Table 5.3(a) **Reflection of Projects under each type of relevance by a funding source**

Q. Please list main BIOTECHNOLOGY PROJECTS carried out by you during the last 3 years , as below :-

Project Title	Sponsoring Agency / Company	Approx. Budget (Rs. Lakhs)	Type of Relevance *

*** Direct Industrial Relevance -- 1 ; Indirect Industrial relevance -- 2 ; Academic Relevance -- 3**

Funding Source	Direct Industrial	Indirect Industrial	Academic	Total
Government	18 [24.3%] +	19 [25.7%] #	26 [35.1%] *	63 [85.1%]
Industry	5 [6.8%] ~	1 [1.4%] $	0 [0.0%]	6 [8.1%]
Others	1 [1.4%]	3 [4.1%] @	1 [1.4%]	5 [6.8%]
TOTAL	24 **[32.4%]**	23 **[31.1%]**	27 **[36.5%]**	74 **[100%]**

Source : Data from the Questionnaire.

Note :

: 4 Projects have indirect + academic relevance.
* : 4 Projects have indirect + academic relevance. And 1 project has Direct+Academic relevance
+ : 1 project has direct industrial relevance but is jointly sponsored by 'government' and 'others'
~ : 1 project is of academic and direct industrial relevance. And 1 Project is of direct industrial relevance but is jointly sponsored by Industry and government.
$: 1 project has indirect industrial relevance but is jointly sponsored by 'government' and 'industry'.
@ : 1 project has academic as well as indirect industrial relevance.

Many projects were either jointly funded and had one type of relevance or sometimes it was funded by one source but had two 'types' of relevance or even at times it was funded by two different sources and had two types of relevance.

So, in order to map this table it was decided to optimize it to the best possible way (avoiding bias at the same time). This was done as follows ;

Generally when a project is jointly funded by Industry as well as government , then it is put under the Industry head as the industry funding it is given preference when coming to exploiting the gains out of it. And when it is government but others , the former is given importance.

If the project has two relevance like academic as well as industrial , then the latter has been given importance : as more emphasis is laid on the commercialization aspect these days.

If the total no. of projects having two relevance under a category of funding source is even ; then to reduce the bias and optimize it they have been divided equally between the two heads. E.g. 4 projects having academic + indirect industrial relevance being funded by government are divided as 2 projects under academic and 2 under indirect relevance of ' government' . If it is odd then the above is applied and the line project is categorized according to priority stated above.

Note : In this table there is a bit of discrepancy in the total number of projects being funded by each funding source compared to 5.2(b) . This has happened as this table was optimized according to above set rules in order to lessen the bias in this. But still the overall projection in both the tables are almost similar.

government funds, they have considerable relevance to industry in the perception of public sector research scientists.

Almost all the projects being sponsored by 'industry' have some relevance to industry – this is expected as industry is more inclined in applied research or the type of research having some 'business' use for them.

But even apart from it, the projects being sponsored by government (either directly or by its various agencies) reflect a very high component of industrial relevance – this shows that government too is keen to see that 'science' is in some way accountable to the public money that is pumped by it into research and thus is beneficial to society. At the same time 'pure' basic research is also not being neglected as almost 41.3% (26 out of 63) of the projects being sponsored reflect 'academic' relevance.

The data, which is based on the perceptions of researchers, seems to indicate a balanced view which has due concerns for industry and economy but at the same time not neglecting the basic relevance of research in science.

As mentioned previously 63.5% of projects have some relevance (direct or indirect) to industry. But a closer look reveals that of this 63.5%, almost 50% of projects are being sponsored by Government (DBT + DST + other government agencies). And the industry participation in this segment of 63.5% is of meager 8.2%. This data is especially of vital importance as it raises the concern of why 'industry' is not forthcoming in sponsoring projects going on in public sector research despite the fact that public sector research are now increasingly showing interest in projects having some relevance to industry. As to be expected out of 36.5% projects showing 'academic' relevance, 35.1% are being sponsored by government.

Table 5.3(b) Institute wise break up of projects under each type of relevance

Q. Please list main BIOTECHNOLOGY PROJECTS carried out by you during the last 3 years , as below :-

Project Title	Sponsoring Agency / Company	Approx. Budget (Rs. Lakhs)	Type of Relevance *

*** Direct Industrial Relevance -- 1 ; Indirect Industrial relevance -- 2 ; Academic Relevance -- 3**

INSTITUE	Direct Industrial	Indirect Industrial	Academic	Total
AIIMS	0	1 @	3	4
CBT	5 +	2 $	3 #	10
DU	8 *	9 &	8 !	25
IIT	5	3	0	8
JNU	3	4	6 ^	13
NBPGR	3	3	2	8
NII	0	2 ~	4	6
TOTAL	24	24	26	74

Source : Data from the Questionnaire.

Note :

~ : 1 project has indirect + academic relevance.
^ : 1 project has indirect + academic relevance.
@ : 1 project has indirect + academic relevance.
# : 1 project has indirect + academic relevance.
$: 1 project has indirect + academic relevance.
+ : 1 project has direct + academic relevance.
* : 1 project has direct + academic relevance.
& : 2 project has indirect + academic relevance.
! : 2 projects have academic + indirect industrial relevance.

In order to map this table it was decided to optimize it to the best possible way (avoiding bias at the same time) , much like the Table 5.4. This was done as follows ;

- If the project has two relevance like academic as well as industrial , then the latter has been given importance : as more emphasis is laid on the commercialization aspect these days.
- If the total no. of projects having two relevance under a category of 'institute' is even; then to reduce the bias and optimize it they have been divided equally between the two heads. E.g. 4 projects having academic + indirect industrial relevance being funded by 'X' institute are divided as 2 projects under academic and 2 under indirect relevance of 'X' institute . If it is odd then the above is applied and the line project is categorized according to priority stated above.
-

Note : In this table there is a bit of discrepancy in the total number of projects under each category of relevance with respect to table 5.3(a). This has happened as both the tables were optimized according to above set rules in each in order (according to the orientation of each table) to lessen the bias in them. But still the overall projection in both the tables are almost similar.

The table 5.3(b) shows institution wise break up of number of projects under each category of 'relevance'.

The break up percentage of projects of specific type of relevance in individual institutes are varying to each other and does not show a uniform pattern. But a closer look reveals that percentage of projects showing some relevance (i.e. direct or industrial) to industry in Delhi University (68%); CBT (70%); JNU (53.8%) and NBPGR (75%) are to a large extent in keeping with the cumulative figure (63.5%)[2].

100% of projects in IIT, Delhi, seem to show some relevance to industry – this can be expected from one of the India's premier technology and engineering institute, which has good industrial connections. And as has been shown in various studies that engineering institutes have more industrial links than traditional universities. (The same has been reflected in UNESCO study conducted in India). Majority of projects in AIIMS and NII are categorized as 'academic' relevance. Being India's one of the leading institutions, the perceptions of researchers seem to give higher weightage and importance to academic orientation.

It will be pertinent here to summarize some of the justifications for government domination of research funding as revealed by the interview data. Some of these opinions are as below :

➢ A faculty member from JNU ,School of Life Sciences, observed :

> "At times there are many claims by various scientists (mostly these elite group) that a certain product developed by them is of immense importance for public and industry. But actually most of the time it is not so... whenever such incidence comes to light, it makes industry wary of collaborating with PSR/ Universities/ Institutes."

[2] Though in each Institute individual break up under category of 'direct industrial' and 'indirect industrial' is varying.

➢ An official at Department of Biotechnology observed ;

"Many a times when MOUs were well written and were accepted by both the parties, while implementing them in situation of difficulty relating to various aspects of the products improvement (beyond the normal clause of MOU) the institutions could actually do much less than expected to enable the sustenance of the products in the market. This led to distrust and bitterness between the Institute and Industry. Reasons for this could be –

- Industry did not have adequate in-house R & D capability to improve the products.
- The institutions did not find such product developmental work much rewarding to their ground level investigators from their career development point of view.
- Lack of proper communication between the two.
- The tendency among institutes that after having developed a technology, the last word have been said by them and that there is no further scope for improvement."

➢ A Professor from Delhi University throws light on another vital aspect which emerges out of public sector research– industry partnership, which might be one of the important reasons that make scientists vary of taking Industrial projects.

According to him :

"Profs./ Scientists are very wary of interacting directly with industries as Industry would like to employ only those (and pay them handsomely) who research in such a fashion that his research generates results which suits the industry's needs and keeps it in good light (mainly as it happens in biochemistry, microbiology, pharmacology, etc). Because of this, Industry gains out of the propaganda of positive research and when on later date if something happens Industry coolly shrugs off its responsibility by putting complete blame on the scientists concerned and its PSR institute."

5.4 Dimensions of Scientific Research in Institutions

There is an appreciation world wide of the importance of public sector research to industry. It is a feature of capitalist free market, mixed economies and socialist and post socialist economic systems. Most governments, either for their own reasons or at the instance of international agencies such as the World Bank and the UNIDO have focused on the intersection of academia and industry as a potential fulcrum of future economic development (Ogbimi,1990)[3].

This has led to generally following steps being taken in series in the process of capitalization of knowledge[4]:

- Securing of intellectual property.
- Restructuring to generate a large intellectual property base in order to exploit it for designing products, improving process etc.
- Establishing contact with industry to capitalize knowledge by solving their problem – either by sell off of products or improving process.
- Establishing of corporate vehicles – such as spin off firms.

According to Etzkowitz (1998), these changes imply a shift in the orientation of the academic and public sector research culture, from being devoted exclusively to the research and training interests of professional staff toward being open to more entrepreneurial activity. In the light of this perspective, combining with various dimensions of scientific research in the Indian context, an effort was made to understand the orientations of researchers

[3] See 'Introduction' (Page 2) by Etzkowitz.H, Webster.A & Healey Peter; 1998.

[4] The phrase "capitalization of knowledge" has gained currency mainly with origin of "third mission" for the university (i.e. economic development) , in addition to teaching and research . Because of this , a variety of ways have been created , going well beyond traditional means such as graduation of students and consultation. It has led to creation of intermediary offices , spinoff firms , science parks and other interface mechanisms . This has led to a new set of issues about the role of academia in society , beyond traditional concerns about community service , on the one hand , and academic freedom ,on the other. (Etzkowitz.H, Webster.A. & Healey.P ; 1998 , (Foreward)).

in institutions. Here, the idea was to understand how much importance is given to various aspects of research in the laboratories.

Table 5.4(a) The level of importance attached to each step in the process of capitalization of knowledge

Q. How much importance would you give to the following :
Exploration and adding to systematic knowledge
Patenting (Process)
Designing of products / kits etc.
Solving a problem for a client / industry etc.

Scale : 5-highly important, 4-important , 3-moderate, 2-little , 1-no importance

	Important	Medium	Low Importance
Exploration & Adding to systematic knowledge	27 [96.4%]	1 [3.6%]	0 [0%]
Patenting	14 [50%]	12 [42.9%]	2 [7.1%]
Design of Products/ kits	21 [75%]	4 [14.3%]	3 [10.7%]
Solving a problem for a client/ Industry	20 [71.4%]	3 [10.7%]	5 [17.9%]

Source : Data from the Questionnaire.
*** For convenience (5) &(4) have been taken as 'important' and (1)&(2) as 'low importance'.**

As the Table 5.4(a) shows, exploration and adding to systematic knowledge is still high on the agenda of public sector research scientists as 96.4% say that this is important for them. This reflects that traditional value and importance of 'basic research' is still very much retained their orientations. But this inertia to remain fixed to 'basic' research seem to be breaking as more and more scientists are now open to the idea of capitalization of knowledge and public accountability for research being carried out by tax payer's money. 75% of scientists say that designing of products is important to them and almost the same percent (71.4%) say that solving a problem for a client/ industry is important. In a large measure, the survey results from the responses given above shows some sort of 'orthogonal orientation' (see also responses in Table 5.4(b)). In other words, orientation to 'academic science' or 'basic science' does not appear to be antithetical to 'practical' orientation in research, which emphasizes designing products, patenting, etc.

But quite out of tune with above, about 50% scientists state that patenting is important (and 42.86% state that patenting is of medium importance to them). The possible reason for it could be :

> Generally in sponsored projects it is the sponsoring agency, which organizes for the funds and other legal support when patents have to be taken out. But as the level of interaction with industry is very low, the support and incentive for patenting is not any great . Also there is no organizational support (i.e. support by institution). Last but not the least, scientists too are not very sure of various rules and regulations.[5]

What we can derive from the fact that only 50% scientists give importance to patenting is the low level or non existence (except , IIT-Delhi) of institutional mechanisms for intellectual property facilitating unit.

From Table 5.4 (c) we conclude that almost 42.9% of scientists claim that their research has improved manufacturing process/ products.

And data from Table5.4(b) reflect that researchers seem to be very keen to collaborate with industry for commercial gains out of their research as 95.45% of scientists say that they give high importance to sharing new product ideas with industry. Quite expected and in tune with the above data 86.36% of researchers are keen to collaborate with industry to develop new products/ process technology. Apart from this a majority of scientists are not averse (in fact give high rating) to other channels by which industry could look forward for collaboration – feedback on existing products/ processes (72.73%); new R&D procedures/ methodologies (72.73%) and skills in experimentation & testing (63.64%).

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[5] The views are expressed by 2 Professors from IIT, Delhi and School of Life Sciences , JNU.

Table 5.4(b) **Level of importance as Reflected by Scientists/ Profs. to the ways of interacting with Industry.**

Q. In your research collaboration with industry how much importance you assign on various items given below ?

5 4 3 2 1

- New product Ideas
- Feedbacks on existing products/ processes
- Routine problem solving
- New research equipments
- New R&D procedures / methodologies
- Skills in experimentation and testing
- New Product / Process technology
- Any other ....

Scale : 5 - Highly important ; 4 - Important ; 3 - moderate ; 2 - little ; 1 - no importance

	Important	Medium	Low
New product ideas	21 [95.4%]	0 [0%]	1 [4.6%]
Feedback on existing products/ processes	16 [72.7%]	2 [9.0%]	4 [18.2%]
Routine Problem Solving	10 [45.5%]	5 [22.7%]	7 [31.8%]
New Research Equipments	9 [40.9%]	7 [31.8%]	6 [27.3%]
New R & D procedures/ methodologies	16 [72.7%]	4 [18.2%]	2 [9.1%]
Skills in experimentation & testing	14 [63.6%]	7 [31.8%]	1 [4.6%]
New Product/ Process Technology	19 [86.4%]	3 [13.6%]	0[0%]

Source : Data from the Questionnaire.

- The idea was derived from the list of 'Impact of STI to Innovation' as prepared by Faulkner and Senker . Some changes were made mainly to adapt the 'question put in questionnaire' based on this to M. Phil research need + for it to be suitable to Indian context.
- **For convenience (5) &(4) have been taken as 'important' and (1)&(2) as 'low importance'.**

Table 5.4(c) **Data showing Scientists claim to improving Products / manufacturing processes**

Q. During the last few years , would you claim that research in your project led to :

- **New firms / companies etc. Yes /No**
- **Improving the manufacturing process / products etc. Yes / No**

Institutes	Yes	No
Delhi University	3 [33.3%]	6 [66.7%]
IIT	3 [100%]	0 [0%]
CBT	3 [75%]	1 [25%]
AIIMS	1 [100%]	0 [0%]
JNU	1 [25%]	3 [75%]
NBPGR	1 [25%]	3 [75%]
NII	0 [0%]	3 [0%]
Total	12 [42.9%]	16 [57.1%]

Source : Data from the Questionnaire.

According to data only 45.5% of respondents give importance to routine problem solving. However there persists a good deal of stress by the researchers on traditional 'ethos of science' which relates to 'basic research'. Perhaps this might be the reason for which they give moderate importance to 'routine problem solving' kind of exercise. And another reason could be that generally industry seek to solve its routine problems internally.

Scientists in public sector research are also moderately inclined to collaborate with industry for 'new research equipments'. The main explanation for this could be that in India biotechnology industry is not so highly developed that it can either afford the latest and the most sophisticated instruments. In fact incentive for industry researcher is perhaps more to collaborate public sector research, which are well equipped because of tremendous amount of government support. In a large measure, the main thrust of respondents through Table5.4(b) shows the importance to product and practical output oriented perception in dealing with the industry . As noted earlier, even though much of research is funded by public money in public sector research institutes, the orientation to industry is rather quite positive.

5.5 Orientations of Scientists to Commercialization of Research

(Creation of firms , Patenting ,Publications, etc.)

From a sociology of science perspective , it has long been recognized that scientific knowledge generates various forms of intellectual capital. Today scientists working within the public sector research are encouraged to commercialize their intellectual capital into more material forms (Berman, 1990; Bozeman and Crow, 1991; Dorf and Worthington, 1990; Etzkowitz, 1989; Mansfield, 1991) From the policy marker's perspective, patenting activity, which has grown substantially over the past decade, demonstrates the way in which researchers have become much more effective at technology transfer since patents can provide leverage in commercial markets and deliver new ideas to the markets much more quickly than traditional forms of dissemination such as publishing. Not surprisingly then one can find many surveys that report a strong correlation between economic strength and dominant patents that mark out the utility, non obviousness and novelty of a set of related knowledge claims around a particular 'invention' (Archibugi, 1992; Narin, 1994)[6].

Krishna (1998) also states that with the increasing importance of intellectual property rights , the popularity of patents , design and software use etc. is gaining ground to the detriment of open publication.

Keeping in view Merton's ethos of Science[7], this small empirical research attempts to survey and explore the changing orientations of scientists to commercialization of knowledge. The commercialization of knowledge has affected the inward calling of science as well as the material condition of scientists (Etzkowitz,1997). The capitalization of knowledge view stands in contrast to disinterestedness as a norm of science. This new orientation has arisen not only from the practices of individual science but from the external influences on the university and also from government policies on liberalization and globalisation. The emergence of entrepreneurial dynamic within academia is also one of the important reasons for this change. This is largely related to corporate industrial investments in academic settings.

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[6] See the chapter by Webster.A and Packer.K in Etzkowitz.H & Leydesdorff.L (eds.) ; 1997.

[7] Cultural expectations related to academic research behavior, as defined by the classic work of Robert Merton (1942), are based on four key norms. First is norm of *universalism* or the separation of scientific statements from the personal characteristics of the scientist. This norm ensures that the quality of academic work will be evaluated on the basis of the work itself, not the scientist's prestige or lack thereof. The second is *communality*, the sharing of research results and approaches with all other researchers. Communality ensures that research will be open to all challenges, subject to verification by replication, and widely disseminated. The third norm, *disinterestedness*, requires research to be detached from personal motives, pursued only for the sake of truth and intellectual progress. Finally, *organized skepticism* demands the critical and public examination of scientific work so necessary to ensure sound theoretical structures and correct deductions. (Louis.K.S. & Anderson.M.S ,1998 :page 74)

Opportunities for commercial utilization of scientific research have been often available to scientists, but the traditional ethos of science generally stood in the way to protect the boundary between science and private, profit-seeking business. But in the more recent period, academic/public sector research scientists in the North Amercian context have often been eager and willing to direct or participate in programmes of research and development, aiming at commercial application (Etzkowitz, 1983).

Let us begin in this section by first exploring question of the public sector research scientists taking up administrative role and creation of new firms by public sector research scientists, and then go on to explore the feature of commercialization versus other aspects noted above.

Table 5.5(a) Reflection of researchers on performing Administrative Role

Q. Compared to earlier period do you think professors / Project Leaders now have to perform roles like fund raising , as personnel managers , publicity agent and research director of a team of researchers? Yes / No

Institute	YES	NO
DU	9	0
IIT	3	0
CBT *	3	0
AIIMS	1	0
JNU	4	0
NBPGR	4	0
NII	3	0

- 1 did not respond.
- **Source :** Data from the Questionnaire.

Table 5.5 (a) clearly reflects that almost all the scientists have responded affirmatively to, they taking up administrative role. The performance of the above mentioned administrative roles can be considered to reflect the changing orientation of scientists towards the commercialization of their research.

Table 5.5(b) **Data Showing the Scientists claim about the establishment of new firm because of the technology developed by them.**

Q. During the last few years , would you claim that research in your project led to :

- **New firms / companies etc. Yes / No**
- **Improving the manufacturing process / products etc. Yes/No**

Institutes	Yes	No
Delhi University	0 [0%]	9 [100%]
IIT	2 [66.7%]	1 [33.3%]
CBT	1 [25%]	3 [75%]
AIIMS	0 [0%]	1 [100%]
JNU	0 [0%]	4 [100%]
NBPGR	1 [25%]	3 [75%]
NII	0 [0%]	3 [100%]
Total	4 [14.3%]	24 [85.7%]

- Source : Question No. 4 in the Questionnaire.

In response to the above question as shown in Table 5.5(b), just 14.3% of scientists claim that their research has led to the establishment of new firms or companies. A closer look at the table reveals that out of total 4 scientists who responded favorably to this 2 were from IIT. As expected this reflects that engineering institutions have established closer ties with industries. This finding, in way, has also been indicated in various research studies conducted abroad. For instance, the survey conducted by UNESCO , India (1996) also reflect quite the same thing – engineering institutions especially the premier institutes have better industrial connections and perhaps this is the reason that professors their show more entrepreneurial zeal because of their long experience with industries.

The reason why public sector research institutions in biotechnology, compared to various experience in Western Europe and North America , are very slow needs a far more in-depth study. But at this stage with limited exploration of scientists and institutions, the author's feeling is the facilities such as 'incubators' or pilot plant support systems are lacking in public sector research institutions in the biotechnology sector. This view has been reflected by some scientists interviewed in NII, JNU and Delhi University.

Let us now look into the perspective of scientists that whether there persists any conflict between publication and commercialization of knowledge. The perceptions of researchers explored are shown in Tables 5.5(c) and 5.5(d).

Table 5.5(c) **Reflections about the scientists perception about the conflict between commercialization of knowledge, patenting and publication.**

Q. Do you think that there is conflict between commercialization of research , patenting and Publication of research results ? Yes / No

	YES		NO	
Institute	Nos.	%	Nos.	%
NII	2	66.7	1	33.3
NBPGR	4	100	0	0
JNU	3	75	1	25
AIIMS	1	100	0	0
CBT	3	100	0	0
IIT	3	100	0	0
DU	8	88.9	1	11.1
Total	24	88.9	3	11.1

- 1 did not respond.
- **Source :** Data from the Questionnaire.

Table 5.5(d) Reflection about scientists' perception about peer review , publishing in eminent science journals vis-à-vis commercialization of knowledge.

Q. Do you think that peer review , publishing in eminent science journals are as important as commercialization of knowledge ? Yes / No

	YES		NO	
Institute	Nos.	%	Nos.	%
NII	1	33.3	2	66.7
NBPGR	4	100	0	0
JNU	4	100	0	0
AIIMS	1	100	0	0
CBT *	3	100	0	0
IIT	3	100	0	0
DU	9	100	0	0
Total	25	92.6	2	7.4

- 1 did not respond.
- **Source :** Data from the Questionnaire.

We see that still 88.9% of scientists (see Table 5.5(c)) believe that there is a conflict between commercialization of research, patenting and publication. And 92.6% (see Table 5.5(d)) of scientists still think that peer review, publishing in eminent science journals are as important as commercialization of knowledge.

From a reading of both the tables and the data from previous tables, one would infer that though majority of the scientists feel that they should capitalize the knowledge and are in favor of procedures and modalities that goes with it but they still give priority to the traditional ethos of science noted earlier. Given a situation where there is a conflict in interest in terms of commercializing their knowledge and publishing in a highly reputed journal, they are more likely to opt for latter.

Some factual information collected from Annual Reports and other documents of various institutions throws more light on this subject :

21 research papers were published in journals and books by professors at Department of Biochemical Engineering and Biotechnology, IIT,Delhi during 1998-99 but no patents were filed by them during the same period.

From School of Life Sciences and Centre for Biotechnology, JNU during academic year 1998-99 faculty contributed 98 research articles and papers, which were published in various journals. This seem to be quite a big achievement by a single institute. But only 5 patents have been obtained by the faculty till date and that too not all in the same academic year i.e. 1998-99. (Of this 5 patents 4 belongs to one person)

During 1996-98, scientists from CBT were able to publish almost 62 research articles. And during the same period almost 14 patents were filed. This ratio of publication to patenting is really very impressive given the Indian scenario. Similarly, from NII 57 peer reviewed research papers were contributed by the scientists during 1998-99 and almost an impressive tally of 9 patents were obtained in 1998-99.

Thus, we see that it is mainly the mission based institutions are taking the lead in changing to patenting mode. Results at IIT,Delhi does seem to be anomaly but given the fact that IIT's are mainly established for engineering sciences , bio-field not being its forte. [FITT (a technology transfer wing at IIT, Delhi) data does reflect that 100 applications for patents have been filed in last 4 years compared to just 15 IPR applications filed in the previous 20 years]. Even the pattern of patenting by India's two premier National Laboratories – CBT and NII, reflect that the change towards patenting is a very recent development in India .

Table 5.5 (e) Data showing pattern of patents obtained by CBT and NII

	CBT	NII
Before 1991	0	5 (18.52%)
1991 – 1995	7 (31.82%)	12 (44.44%)
1996 – 2000	15 (68.18%)	10 (37.04%)

* For CBT data is complied on the basis of Patents filed and accepted till 1998.

** For NII data is complied on the basis of Patents accepted till 2000.

*** Each project may have got patents from various countries. In that case number of countries that it obtained patent from is taken as total number of patents generated.

Thus, one can surmise that the advancement of systematic knowledge, the prominence attached to open publications, the high premium placed on professional rewards and the constitution of peer review groups from the discipline based scientific elite, which remained the hallmark of academic science and governed the scientific communities in the post war era, are undergoing a change but despite such forces of change, scientists are unlikely to completely give up their cultural need to make their research results or findings public. The outcome of these changes will be a delicate balance between the two i.e. continue to publish but only after carefully scrutinizing certain critical elements of direct commercial value. (Krishna., 1998)

The study further attempted to explore the situation of students working with various senior researchers in the institutions of our sample. The Table 5.5(f) shows the response.

Table 5.5(f).1 Status of Research Students in emerging Knowledge Economy.

Q. Are students / Research scholars in your project involved in Industrial Collaboration ? Yes/No

If yes, kindly indicate on the elements given below :

- **Participation in University - Industry meetings . Yes / No**
- **Working directly with industrially related projects . Yes / No**
- **Research scholars being sponsored by firms directly . Yes / No**

	YES		NO	
Institute	Nos.	%	Nos.	%
DU	4	44.4	5	55.6
IIT	2	66.7	1	33.3
CBT *	1	33.3	2	66.7
AIIMS	0	0	1	100
JNU	1	25	3	75
NBPGR	0	0	4	100
NII	0	0	3	100

- 1 did not respond
- **Source :**.Data from the Questionnaire.

Table 5.5(f).2

	Delhi University		IIT		CBT		JNU	
	Y	N	Y	N	Y	N	Y	N
Participation in University meetings	1	3	0	3	1	0	0	1
Working directly with industry related projects	3	1	3	0	1	0	1	0
Research Scholars being sponsored by firms directly	2	2	0	3	1	0	0	1

- Y = Positive response ; N = Negative response
- **Source :** Data from the Questionnaire.

Table 5.5(f) reflect that almost 33.3% scientists state that their students are involved with industry. Of the 9 scientists (i.e.33.3% of scientists who responded favorably to the mentioned question) – 2 (one from CBT and the other from Delhi University) stated that their few students participate in University–Industry meetings; 8 (3 from Delhi university, 3 from IIT, 1 from CBT and 1 from JNU) stated that the students are working directly with industry related projects and 3 (2 from Delhi university and 1 from CBT) stated their few research scholars are being sponsored by firms directly. Though, the tally is not quite impressive in itself regarding the above said change in orientation of research students vis-à-vis new structure but still it indicates a gradual metamorphosis taking place in that direction.

5.6 Institutional[8] and Organizational[9] Changes :

Institutions, by their very nature , regulate the relations between people and groups of people within as well as between and outside the organizations. This means that that the pattern and the content of communication and interaction in the economy is affected by its institutional set-up. Since we regard innovations as mainly resulting from interactive learning processes, it follows that institutions affect innovations. (Charles Edquist & Bjorn Johnson,1997)

Innovation theorists think of institution in accordance with the everyday meaning of the term, as rather concrete things that deal with the organization and utilization R&D; for example, technical universities, industrial research institutes, R&D Departments in large firms, consulting agencies, patenting offices, technology consulting institutes, etc. This way of using the concept is not based in institutional theory or any other theory. It builds upon generalizations from empirical observations to the effect that these things are crucial for processes of innovation. (Charles Edquist & Bjorn Johnson,1997)

Analysis of the emergence of new forms of institutional structures is important especially when it can respond to the theoretical issues discussed earlier. e.g. The ways in which commercialization of knowledge :

- Tends to steer scientists toward setting research agendas that are not merely applied but also overly accommodating to the commercial interest of their sponsors.
- Generates forms of normative conflict.

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[8] Institutional changes here refer to how science as social institutions based on Merton's ethos of science' is undergoing changes to incorporate variances subscribing to commercialization of science (secrecy, patenting, profit motive in research, etc.)

[9] Organizational changes here refers to the changes that universities and national laboratories (i.e. public sector research institutions) are undergoing in the era of liberalization and globalisation to institute mechanisms for commercialization of scientific research . These relate patenting mechanisms . opening

- Leads to institutional/ organizational change.

As we have seen in earlier sections and tables, it is rather difficult to assume that the institutional ethos of scientists and researchers in biotechnology institutions (i.e. referring to perceptions) have undergone a transformation. But there are indications that researchers in public sector research institutions are positively inclined towards the needs and demands of the industrial clients as it has clearly come out in the overall responses in several questions that a majority of scientists give considerable importance to various dimensions of scientific research which are highly valued by industry.[10]

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legal / patent cells , technology transfer offices, venture capital mechanisms to aid start up companies etc. , in the campus of public sector research institutions.

[10] Even the linkages (understood as : participation of scientists in guest lectures, conferences, symposiums etc. of one institute to the other ; cooperation among scientists of different institutes on a research project ; etc.) between different actors can reflect upon the Organizational changes taking place . As per Mertonian ethos generally linkages were seen between universities or university and government labs , Public Sector Research linkage with Industry was almost non existent.

Analysis of secondary source (mainly Annual Reports) reveal that Institutes under study have mainly links with other universities and national labs at National and international level but there are no signs of links with industry . e.g.—

- **JNU** – school of Life Sciences in JNU have link research activities with other institutes in the country like National Science Centre , NII, AIIMS, Centre for Cellular and Molecular Biology (CCMB) , Tata Institute for Fundamental Research , Institute for Nuclear Medicine and Applied Science, International Centre for Genetic Engineering and Biotechnology (ICGEB) , and several other universities. Many faculty members also have collaborative research programmes with Germany, France , Russia, Poland, USA, Israel and several other national and international institutions.
- **Delhi University** – Bio departments in Delhi University (South Campus) by the above stated criterion also seem to have arrangements with many Indian universities and National labs , like – CCMB, Punjab University, Indian Institute of Chemical Biology, JNU, Jamia Hamdard , National Botanical Research Institute, ICGEB, IARI, Rajasthan Univ., etc. Many Profs. have also links with foreign universities like – Utah Univ., Salt Lake City,USA; Nagoya Institute of Technology , Japan; Toyohashi University of Technology, Japan; New South Wales University, Australia; etc.
- **NII** – Scientists at NII have research links with scientists from universities and national labs both in India as well as abroad. E.g.—Regional Research Lab, Jammu; RMRC, Bhubaneshwar; NCBS, Bangalore; ICGEB, Delhi; Jamia Hamdard; AIIMS; Wild Life Institute of India, Dehradun, NDTB Centre, Delhi; JNU; Institut Pasteur , France; CDC,Atlanta, USA; Wayne State Univ., USA; Hyogo Medical College, Japan; Univ. Of Virginia, USA; Univ. of Edinburgh , UK; Warsaw Medical academy , Poland; etc.

Thus, we see that Institutionally mostly the research links are between Universities or University-National Labs.

Organizational changes in Institutions

Table 5.6(a) Scientists perception about the level of importance given to commercialization of knowledge by their respective Institutes.

Q. How much importance your institute / organization gives for commercialization of knowledge ?
....

Scale : 5 - Highly important ; 4 - Important ; 3 - moderate ; 2 - little ; 1 - no importance

Institutes	Important	Medium	Low Importance
Delhi University	4 [44.5%]	2 [22.2%]	3 [33.3%]
IIT	3 [100%]	0 [0%]	0 [0%]
CBT	4 [100%]	0 [0%]	0 [0%]
AIIMS	1 [100%]	0 [0%]	0 [0%]
JNU	1 [25%]	2 [50%]	1 [25%]
NBPGR	1 [25%]	1 [25%]	2 [50%]
NII	0 [0%]	1 [33.3%]	2 [66.7%]
Total	14 [50%]	6 [21.4%]	8 [28.6%]

- **Source :** Data from the Questionnaire.

The table 5.6(a), is aptly able to capture the perception of scientists about the level of importance that their respective institutes give to commercialization of knowledge. This is important as it bears direct correlation to the organizational changes taking place (if any) in tandem with the new governing norms in science. The data clearly reflects that hardly 50% of scientists feel that their institute gives due importance to commercialization of knowledge. [It is mainly scientists from IIT, AIIMS, DU and CBT, who subscribe to the view that their institutes give importance to commercialization of knowledge].

- NII – It does have a small department which helps scientists in guiding writing of Patent, educating in patent laws, filing patents, transferring and discussing of technology, etc, etc. It has also very lucrative policy for scientists for commercializing their technology – the amount of money received by transferring of technology or by royalty payments. It is divided equally between the institute and the group of investigators. (This clause is again being revised so as to increase the share of investigator)

- CBT – This being CSIR laboratory – all the CSIR rules and regulations are binding on it. At the organizational level i.e. CSIR, it has two major developments in the form of establishment of following crucial departments.

A .) Intellectual Property Management Division (IPMD) – This department has the following mandate:

- To advise on all matters relating to Intellectual property protection.
- To secure and safeguard IP generated IP generated in CSIR under appropriate legislation in India and abroad.
- To maintain patent databases and disseminate technical information contained in patent documents amongst scientists.
- To maintain Patents Inspection Center established under the Indian Patents Act, 1970.
- To organize various programs for enhancing awareness about the Intellectual Property Law and their operation at national and international levels.
- To train scientists in the labs about the identification. If patentable inventions and their legal protection.

b.) R & D Planning and Business Development Division – Though this department had been in existence in one form or the other but it was given this name and new mandate (given the new requirements) during 1995. It was established with following mandate –

- To interact with planning commission and Ministry of Finance for (a) Five year & Annual plan allocation for CSIR and (b) integrating CSIR programs with the plans of socio-economic departments & ministries.
- To review and allocate financial resources to CSIR labs.
- To catalyze business development by interfacing with national level industry associations, user agencies, financial institutions and technology licensors.
- To promote and facilitate marketing of CSIR's knowledge base and services.
- To maintain information/ database on CSIR's R & D output and marketable knowledge base and its utilization.

CSIR has also policies, which give sufficient incentives to its scientists to develop marketable technologies –

- Contract/ Collaborative research – It distributes 40% of the Intellectual fee (X) among the scientific staff in following ratio:

  40% to principal innovators; 35% to S & T and other staff; 20% to the entire lab/ Institute excluding above two categories and 5% deposited as welfare fund for scientists.

- Consultancy –
  - Advisory Consultancy – In this 2/3rd of the amount obtained is distributed; 95% of this 2/3rd given to the principal scientist or group whereas 5% deposited as welfare fund.
  - Technical Consultancy – In this also 2/3rd of the amount obtained is distributed: 65% of the 2/3rd to team of consultants; 15% to support scientific staff; 15% to other supporting staff from admin, accounts etc and 5% to welfare fund.

  In this earlier there was an upper limit set in monetary terms for scientists but since 1992 this monetary limit has been removed but still 50 man days of limit is there so that check is maintained on scientists.

- In-house Projects – In this 40% of the amount received by selling technology is distributed among scientists concerned. (The ratio on which this 40% is distributed is in the same pattern as of Contract/ Collaborative Research). These transfers are carried by respective Institutes (granting them bit of autonomy). Institutional change has also taken place in CBT where the Institute has also established. IPR (1996) and Business Development unit so as to help its scientists.

- **IIT** – In recent years many institutional changes have taken place in IIT. Industrial Research and Development Unit (IRD Unit) of IIT has been very active in giving concrete shape to Institute's policies regarding IPR issues. In 1994 it came out with definite guidelines regarding Intellect property rights generated in IIT. It also elaborates the Institute's policies regarding licensing of technology; ownership rights to a technology generated in different modalities: standard terms and conditions regarding contract research and consultancy; copyright issues, trademark issues, control and evaluation of IP generated; etc, etc. The incentive provided to professor is also high when it comes to commercialization of their technology. They get 60% of revenue generated, the rest 40% is divided equally between institute and development.

Apart from this, an organization has been formed by professors of the institute (FITT), which also very actively participates in promoting University – Industry interface. (To get an idea about the function of FITT see Appendix 6).

❖ **AIIMS, JNU and DU** :

AIIMS has shown little progress in this direction. Its, 'Research Project Unit' just carries out the administrative work like maintenance of account etc, regarding funded projects (mostly government funded projects). And for this it charges just 3% of total amount as its administrative fees and rest 97% of the amount is for the project concerned (since almost all projects are government funded so there is little scope for profit etc.). But the institute never provides any help concerning transfer of technology to industry, obtaining of patents, collaborative or consultancy work given by industry etc etc. For this Professors mainly take help of DBT, DST, TIFAC, NRDC or any other government agency.

Delhi University also has not made much progress in this direction. It does not help its Profs. In any of the aspect concerning IPR; interface with industry; set guidelines for transfer of technology, consultancy and contract/ collaborative research. Any industrial project coming to Profs. are their individual initiative. And while transferring of technology, obtaining of patents etc. professors try to take help from government agencies like DBT, DST, NRDC, etc. The only guideline regarding this aspect is about the revenue sharing between Principal investigator, Department concerned and University (60:20:20).

The same is the case with JNU which also has failed to bring in adequate organizational/institutional change. Though it has a set of guidelines for professors for accepting consultative or similar assignments. e.g. –Professors may be allowed to retain a fee upto 30% of their basic pay in a year , and if the fee received in any year is in excess of the 30% ceiling limit , the excess should be shared by the faculty members and the university in the proportion of 75 and 25 respectively (These rules are under consideration to be reviewed).

- We thus ,see that as reflected by scientists in CBT and IIT – these institutions have brought about perceptible institutional changes to put in place structure to facilitate

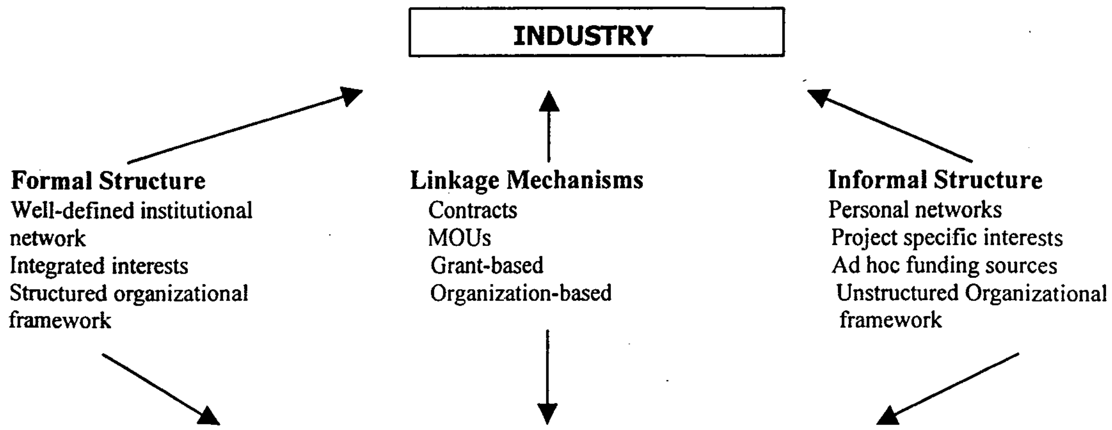
University-Industry interface. In JNU and Delhi University though many scientists do feel that their institutions do not lay much emphasis to commercializing knowledge but there does seem to be an organizational effort in that direction.

- There seems to be an anomaly in AIIMS and NII, when considered the data vis-à-vis organizational changes. In AIIMS, this can be accounted for a very small sample (just one respondent) , whereas for NII it requires a more detailed research (beyond the purview of this research).

Constraints to change :-

In order to truly account for the constraints to change it is worthwhile to do a comparative study of institutional structures that have come up in USA and Europe but have failed to come up in India. If these institutional structures that are truly accountable for highly successful Industry-University collaborative effort there.

Following partnership modalities as stated by Konishi (2000) can form the base of discussion here :-



University-centered Institutional Arrangements		Noninstitutional Arrangements
Off-Site Arrangements	**On-Site Arrangements**	**Projects/ Programmes**
1.Cooperative research center consortia 2. Research Parks 3. Science Parks 4. Incubators 5. State Coordination Agencies 6. Industry Association and Consortia	1. Research Centres 2. Applied Research Institutes 3. Firm sponsored Laboratories 4. Industrial Extension 5. Centres of Excellence 6. Small Business Dev. Centre 7. Technology Transfer Network 8. Continuing course 9. Short course &Distance Learning 10. Personnel Exchange 11. Training Centre 12. Cooperative Education	1. Industry-University Projects 2. Small Business Technology Transfer Programmes 3. Testing, Calibration, Repair

Source : Konishi (2000)

Figure 1.

Off Site Arrangements : Research Parks, Science Parks and Technology Incubators that have come up in USA, UK, France, Singapore, Japan, Taiwan, etc. due to definite government policy initiatives as well as the effort on the part of Universities, have spurn University-Industry interface leading to establishment of highly successful Innovation System.

Development of these seem to be lacking in India both at the government level as well as University/Government Laboratories. Though in last year or two, the realization of importance of these institutional arrangements have dawned on the government and few initiatives can be noticed from states which have advance infrastructure. e.g. – 'The Biotechnology Policy' released by the Government of Tamil Nadu pledges to create :

- Biotechnology Incubator at Chennai.
- Women's Biotechnology Park at Chennai.
- Medicinal Plants Biotechnology Park near Madurai.
- Marine Biotechnology Park in Rameshwaram.

Even Government of Andhra has now pledged to develop Biotechnology Parks near Hyderabad in its newly framed Biotechnology Policy. A huge Biotechnology Park is to be set up in Noida by Government of India. Though in India there is Biotechnology Consortium of India Ltd. (BCIL) but this does not seem to be as active as it should. Rather it being only of its kind fails to look into the needs of upcoming Biotechnology sector in a vast country like India.

On Site Arrangements : One can observe a lot of Industrial funding to Universities in USA and Europe taking the form of long term strategic alliances. Such coalitions normally are based on a coincidence of interests or mutual affinity between the scientific concerns of the company and the University/National Laboratory. This alliance may take the shape of firm sponsored laboratoriess; applied research institutes; industrial extensions; business development centers; etc.

Such arrangements have failed to come up in India mostly because Biotechnology sector is still in nascent stage; industrial funding is less; Indian Pharma and Biotech industry flourishing in protective environment did not feel need for R&D; financial institution and venture capital funding is less; etc. Even the free mobility of scientific personnel between industry and university / national laboratories, which is so prevalent in West seems to be almost absent in India.

(e.g. – continuing course; sponsored Ph.Ds; short course & distance learning; visiting professors from industry to University; etc.)

R&D Projects and Progammes :-Though this mode seems to be prevalent in India as one can observe sponsored projects to University/ Government Laboratories, small business technology transfer programmes, testing, calibration, etc . But here also (as the data from this study reflects) it is mostly an arrangement of government funding Universities/ National laboratories. Though various reasons have been put forward from time to time for lack of industrial participation, but one of the structural factor contributing to this is lack of intermediary institutional arrangements in universities/national laboratories to help scientists in transfer of technology, patent their technology, deal with industry, etc. Most of the scientists/ professors have a common ruse that their institute does not have any licensing office or technology transfer office – to which all confirm that it is a must to be in place in their respective Institutes' Organizational Structure.

According to one higher official at DBT:

> "Technology transfer units, licensing offices are excellent mode of propagating or publicizing the R & D going in University/ Government labs and at the same time Industry can reflect their needs there. These can act as major facilitators."

Another higher official at DBT strike at the very base of the problem by giving reason for majority of universities/ public sector research institutes licensing office or technology transfer office:

> "It is very difficult to have technology transfer units in every institute as technology transfer is a very complex process and there is dearth of personnel having expertise in the field of technology transfer. (Though, ideally there should be provision for technology transfer units in every Institute)."

5.7 Relevance of 'TRIPLE HELIX' : Some Findings

To briefly recapitulate the concept of triple helix, its important features (which may be considered as 'indicators'), the following may be considered:

a) The existence of partnerships between academia, government and industry segments manifested through joint projects; funding pattern or sharing of research budgets between three sectors; and prevalence of variety of linkages in the joint production, dissemination and marketing of knowledge emerging from interactions between them;

b) Transformation in each of the three segments relating to institutional and organizational factors which will catalyze interaction; and

c) Normative changes taking place among scientists (e.g . – publication vs. patenting; scientists taking up role of entrepreneurs; disposition towards various processes in capitalization of knowledge; etc.)

Within the limitations of time, resources and scope, the empirical research undertaken mainly through questionnaire, interviews and tapping of secondary data and information has thrown some light on the extent of relevance of triple helix in the case of biotechnology sector in the Delhi region.

As the main results from Table 5.2(c) reveal, a predominant source of funding (+ 78%) is accounted by the government in universities and full time research based national laboratories in biotechnology. The industry units (both the government and private sectors) do not come to play a significant part in the financing of research project in our sample of Delhi based institutions. In terms of the source of fund the industry accounts for mere (+) 2.2%. This initial findings lend support to the view that it is rather two way interaction between government and university/ national laboratories; seem to be meaningful. This follows from the funding pattern of the projects, which implicitly and explicitly reveal some form of partnerships (in what ever manner they come to exist). It may be in a limited way said that the partnerships also reflect a two-way partnerships between government and university/national laboratories. The overall 'picture' that emerges from the empirical research reported in the previous sections may be depicted as follows:

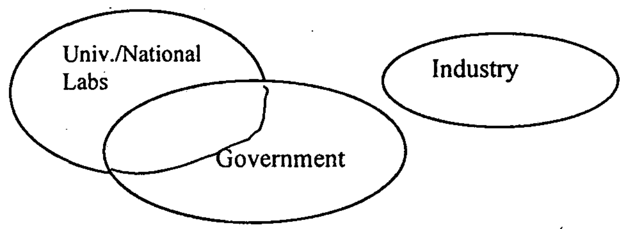


Figure 2

Secondly, the fact that industry as one of the three actors in the triad does not occupy a significant part in the pattern of funding, the design of empirical research (i.e. through questionnaire) contained the question: relating to the extent of importance given to industry or relevance of industry in the scientific research domain (tapped through perceptions and orientations) of scientists in the ongoing research projects. As table 5.3(a) shows, interestingly, only about 36.5% of (in the perception of researchers) research projects reveal academic relevance and about 63.5% of projects have either direct or indirect relevance to industry. Even though industry does not figure in the orientations of universities and national laboratories (as seen through the source of funding of projects) , this is a notable insight which suggests a potentiality of triple helix. According to Table 5.2(b) the percentage of projects being sponsored by government are: Delhi University (76%); IIT (62.5%); CBT (100%); AIIMS (75%); JNU (84.6%); NBPGR (100%); and NII (100%). This data depicts that it is a bilateral kind of relationship i.e. public sector research-government, that is prospering rather than a tripartite relationships.

Thirdly, the extent of industrial relevance and the above point of the existence of a potentiality for triple helix can be further explored through Tables 5.4(a) and 5.4(b) when the scientists and researchers were asked the extent of importance they attached to various facets of research. It is revealed that even though researchers are more oriented towards academic values (adding to systemic knowledge) they are not disoriented to other features of research (solving problem for client, designing of products/kits, etc.) which are highly valued by industry clients.

Fourthly, when it comes to actual commercialization of their knowledge, tables 5.4(c) and 5.5(b) respectively reveal that though 42.9% of scientists claim that their research has led to improvement in products and processes but hardly 14.3% claim that their research has led to the establishment of new firms.

Fifthly, the data reveal that though scientists are now more favorably disposed towards the commercialization of knowledge but they do feel that there is a conflict between patenting (an important component in the process of commercialization of knowledge) and publication. Table 5.5(c) reflects that almost 88.9% of scientists in the sample confer to the above mentioned viewpoint. And an interesting result of table 5.5(d) reflect that 92.6% of them consider publication to be as important or perhaps more than patenting. Our findings indicate that researchers are not yet tuned to the Intellectual Property Regime.

Sixthly , the data (through questionnaire as well as interview) reveal that institutional and organizational changes have not kept pace with the normative changes that have taken place in the scientific community – this has probably also led to confusion among scientists regarding the issue of commercialization of knowledge. Even though the public sector research institutions are institutionalizing organizational changes and some institutional changes (cf . Merton's ethos) are indicated, it can not be said that Delhi based biotechnology institutions reflect the 'Triple Helix' features mentioned earlier.

CHAPTER . 6

Concluding remarks and some S&T policy implications

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6. Concluding remarks and some S&T policy implications

6.1 Concluding remarks

The present case study is undertaken to understand the relevance of Triple Helix in the context of biotechnology in the Delhi region. At an ideal level of understanding , Triple Helix is considered as an important concept because it advocates partnerships between government, industry and university and public research institutions (main actors in the National System of Innovation), but also claims (explicitly or implicitly) to provide strategy of innovation. The analysis of empirical research, which was restricted to orientations of scientists and interviews, shows that in the present context of Delhi region, with respect to biotechnology, bilateral linkages and partnerships – mostly between government and public sector research institutions including universities seem to be more relevant and meaningful than tripartite relationships. In a limited way the empirical research also lends support to the prevalence of university-industry or national laboratories-industry linkages as shown in the perception of researchers. The nature and extent of partnerships between three helices of triple helix in the biotechnology sector of Delhi region is rather non prevalent (Hypothesis). We see that government is the main source of financial supporter of various research projects being carried out in public research institutions including universities. Further it may be said that the government is attempting to facilitate the partnerships between public sector research and the industry in its policy discourse and certain mechanisms. In our sample the industry's component of funding came out as residual component compared to government support. Further in depth study is required to further probe into the issue. This puts biotechnology in Delhi region close to the situation in France, Germany and UK where governments are taking the initiative to forge the partnerships. This is quite unlike the USA, where industry has taken lead or a pro-active role in forging partnerships with the universities or public sector research institutes and government at best providing support to it in this initiative.

Even though the concept of 'Triple Helix' has a universal relevance, the level of its operation or practice varies in different socio-economic and national contexts, which in turn is determined by the structure of linkages between different actors (Hypothesis).

The feature that the Triple Helix varies in different contexts is quite clear in the case of biotechnology in the Delhi region. From the secondary literature which reflects other empirical situation in the Indian context, it may be said that the variation of Triple Helix concept at the level of operation is dependent on the structure and the extent of linkages between different actors. Mapping this in the case of biotechnology in the Delhi region was restricted to the universities/ public research institutes and government as actors. However, the role of industry (as another actor) was examined in the context it was manifested (in terms of funding, linkage, its relevance) in the public sector research laboratories including universities. To a large extent it was found that the bilateral linkages between government and national laboratories and universities determine the partial relevance of Triple Helix in the Delhi context, biotechnology sector. In the limited way it may be also pointed out that the linkages between CSIR and university laboratories are also minimal.

The study in a small way has also been able to address various research questions posed at the beginning like organizational and institutional changes that are being introduced in public sector research institutes and universities as a part of emerging 'Triple Helix' linkages and partnerships and normative value changes taking place among the biotechnology scientists. Even though scientists give considerable importance to industrial relevance in their research, our survey perceptions indicate that the scientists are experiencing some sort of conflict between commercialization of research and academic orientation. The survey of

Delhi based public sector research institutions including universities (with possible exception of IIT, Delhi) shows that these institutions are yet to institutionalize organizational changes (patent related legal units, technology transfer units, etc.) compared to other countries. In any case this is an important issue that deserves much in depth study than the present one.

In 'knowledge economy', tripartite partnerships between public sector research institutions-industry-government is desirable but in Indian scenario it is inevitable to take policy initiatives such that the national goals of universities as provider of higher education, training, skills and basic oriented research is sustained and at the same time making them flexible enough so as to ensure that they could manage multiple demands. Such a view of balancing, in my view, applies to national laboratories like those under CSIR to cater to the socio-economic demands of the people at large. In the case of universities it may be said that triple helix related policies are not suitable to be applied across all universities. Only a limited number of university settings like IIT, JNU, Delhi University may be able to respond to Triple Helix type of partnerships serving industry and at the same time sustaining teaching and research. There is a need to further examine the relevance of Triple Helix in the case of developing countries (wherever possibility exists), imposed on it because of different socio-cultural milieu and economic needs of each country. This is vital in Indian context as India is becoming increasingly entangled in a double bind situation : on the one hand responding to market forces under globalization and on the other hand sustaining research activities directed to the view of 'science as public good'.(Krishna,2001)

6.2. Some S&T policy implications

One of the major concerns of developing countries is to formulate their S&T policies in the context of their national needs and demands keeping in view the fast changing economic situation triggered by globalization. This is important in the present context as future capacity for technological innovation in creating wealth from knowledge which depends on science and technology policies followed currently. It is also to be kept in mind that in order to be effective these policies must be in tandem with the socio-cultural milieu, organizational structure of the national system of innovation, present requirements and other industrial policies of the government. Though the need to formulate a Scientific Policy Resolution dawned on the policy makers of India in the early years after independence in 1958; and a Technology Policy Statement in 1983, the strategies to implement several important features in these policies have fallen short of expectations and objectives. As some researchers have argued, "S&T policies so far have largely concentrated on the 'input side' of R&D spectrum and left the 'diffusion end' to the natural play of different actors" (Krishna 2001).

The way in which the main actors of national systems of innovation (i.e. universities and national laboratories, industries, government agencies, etc.) operate and interact to a large extent depends on the government policies in S&T for development. This is so because a major portion of the total R&D effort is also met by the government. This is clearly evident from the success stories of Japan in the 1970s and 1980s and East Asia in the recent years. In the present scenario of globalization and liberalization, the role of knowledge institutions (i.e. actors in national system of innovation) have become important. This is particularly so for a knowledge intensive industry like biotechnology. The present study which has the broad objective to explore the relevance of triple helix in the Indian context with respect to the case of biotechnology in Delhi region has drawn our attention to some S&T policy implications which are as follows. In a way these can be taken as part and parcel of the conclusions of the study also.

- Steps should be taken by various ministries like finance, trade and commerce, public sector financial Institutions, Banks and venture capital institutions to induce biotechnology industries to target potential projects in the academia and national laboratories to exploit their commercial viability. There are risks but there are also enormous benefits even if a small proportion of projects find their way into production. There are some examples in firms such as M/s Shantha Biotech, Hyderabad; and M/s Ranbaxy which have accumulated experience in this regard. Dr. Inder Verma (Prof. of Genetics at The Salk Institute, USA), while speaking at ASSOCHAM Summit on "Biotechnology – The new World" observed:

  > "In the US, the biotech spent close to $ 10 billion in research and development. In India, though venture capital and angel funded investments in the IT sector have grown from Rs. 70 crore in 1996 to Rs. 3,200 crore in 2000, funding in biotechnology is still negligible due to lack of awareness and understanding in biotechnology and its long term potential by financers". (Hindustan Times, 10th June, 2001)

  However there is some interest being shown by the government to this sector only in recent years. Financial companies like Industrial Credit and Investment Corporation of India (ICICI), Industrial Development Bank of India (IDBI) etc. came forth to support venture companies in biotechnology. Some of the beneficiaries of these activities have been Ajay Biotech Ltd., Pune; Bangalore Genei, Bangalore; Transgene Biotech, Hyderabad; Monozyme, Hyderabad; etc. (Visalakshi,1999). However, given the size India's public sector research base in biotechnology and growing demands in health, chemicals, pharmaceuticals agriculture; and given the low level of investment in research by private biotechnology industry, there is a need for government to assume a pro-active role in promoting venture capital schemes and policies involving public sector research laboratories and universities.

- There are a number of programmes launched by the Department of Science and Technology for technology development and commercialization.

  (a) The Ministry of Science and Technology has launched a novel programme known as "Technopreneur Promotion Programme" (TePP) jointly operated by Department of Science & Industrial Research (DSIR) and Department of Science and Technology (DST).

  (b) Home Grown Technology (HGT) Programme of TIFAC (Technology Information, Forecasting and Assessment Council) assists to reach technologies from a bench scale to pilot or semi-commercial level.

  (c) DSIR under its Plan Scheme Programme aimed at Technological Self Reliance [PATSER] is promoting industry's efforts in the development and demonstration of indigenous technologies, development of capital goods and absorption of imported technologies.

Currently, there is a feeling among researchers these programmes operate in a limited scale and very little information is however disseminated across institutions in the country. There is need to expand these programmes on a wider scale to involve universities and public sector research institutions with industry in a partnership mode rather than the present mode of government programme. Since these above programmes are related to commercialization of research, there is scope here to involve financial institutions and venture capital institutions also.

- Assocham has recommended the formation of the Assocham Council on BT with the objective of bringing biotechnology in the forefront of future business investment, working closely with the government to develop policy framework that encourages such development in the bio-economics in India that have the potential to be converted into business and helping business work with bio-labs and universities. ASSOCHAM has mooted the idea and requested Government to set up dedicated biotechnology patent offices in Mumbai, New Delhi, Kolkata, Chennai, Hyderabad and Bangalore. There is need for Department of Biotechnology to work with Confederation of Indian Industries and ASSOCHAM to evolve appropriate schemes in this biotechnology area.

- It is important for public sector research institutes/ universities that they must have patent units and licensing offices or technology transfer offices. Steps should be taken to build human resource which have deep knowledge and understanding of the process of technology transfer, patent laws and other nitty-gritty of technology transfer processes related to it. Even steps should be taken to sensitize and educate professors and scientists about India's patent laws and various policies that are being framed in biotechnology sector.[1]

- Government should give support to some higher education institutions and National Labs to join together on regional basis to establish technology transfer centers to commercialize technologies emerging from their

[1] Suggested by almost all the scientists interviewed.

laboratories. This has been successfully practiced in European Union especially UK and thus some lessons can be drawn from this.

The above perspective could be widened and steps taken to establish and promote Science Parks jointly by few public sector research institutes/ universities (and even industry can be involved) at a particular location, in the hope of encouraging spin off companies and interaction between Public Sector Research and tenant company researchers. Even 'conservative' universities in UK like Cambridge and Oxford have established large scale Science Parks on their respective campuses. The joint partnerships with the industry now generates a portion of the university budgets in these universities. Indian universities including IITs are lagging behind. There is a talk of DBT initiating some technology incubation units but no full fledged units of this kind comparable to science parks are in full operation on the Indian university campuses so far.

- It is observed that organizational changes needed in the universities to encourage partnerships with the industry, to deal with the patenting regimes, commercialization of research and catalyse spin off companies are either very slow are non existent. There is a need to incorporate new norms and regulations in the university constitution to encourage triple helix based partnerships. For example, professors in the US universities can own companies emerging out of their research and yet retain their faculty positions. In the case of French CNRS scientists, they can have dual positions in their laboratories as well as universities. In India, if scientists move from CSIR to universities or vice versa, they will have to tender resignation and then take up 'new positions'. The same applies to government and industry related cases. This hinders mobility. These implications relate not just to biotechnology but across all fields of science and technology.

- Industry had by and large, inadequate scientific capabilities to absorb and improve upon what it received. R&D capability of the industry is generally low and needs up-gradation. Industry expects turn-key projects and is not interested to carry out the subsequent in-house development work. This situation can change if there is some definite policy which would make obligatory on Industry to spend specific percent of its profit on R&D.[2] Currently, the DST provides certain tax incentives to industry for the money spent on R&D. But as in the case of South Korea, there is no legal or penal support to norms evolved to punish companies which obtain R&D tax incentives but by and large involve in quality control, testing etc. There is a need for a good legally supported monitoring system put in place for dealing with the R&D tax incentives.

All the above strategies are various modes of partnerships and are worth trying in various setups and conditions. Centralized system of management and decision making in educational institutes, universities and national laboratories is also one of the main hurdle in the research carried out by individual scientists. So, there is a need to change management style in public sector research institutes/universities so as it to be in conformity to changes taking place due to commercialization of knowledge. A decentralized management is thus the most suitable for the management of research activities.[3]

[2] Views expressed by higher official at DBT and professor at JNU.
[3] Views expressed by professor at JNU.

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APPENDIX 1

ISSUES RELATED TO PENDING NEW ACTS : ***New Patent Act , Protected Plant Varieties Act (PPV) and the Biological Diversity Act.***

1. New Patent Act : IPR on inventions in biotechnology may become a controversial topic , as such inventions cut across issues related to S&T policies, ethics and economics. India would have to be in conformity with the provisions of WTO on IPR in biotechnology. It is in this regard that new Patent Act is being proposed. Some of the issues, which are of concern to India regarding this, and probable remedies / measures to safeguard them are (See References for detail .) :-

- IPR regimes as enshrined in TRIPS , provide for no sharing of benefits with the public-domain foundation , resulting in claims that have been termed ' bio piracy '.
- TRIPS article 27 compels member countries to protect through patents innovations in all fields including food , health and other biotechnology related fields. It also rods the authority of the governments to demand compulsory licensing in the name of public interest and to regulate their prices. But member countries may, however, in some instances exclude plants, animals and essentially biological processes for reproduction from patenting.
- Indian parliament has amended the Indian patent act 1970, so as to grant EMRs in the field of agro-chemicals and pharmaceutical ; to which many and even opposition members are opposed . But if that is excluded it may cause more harm than good as it would deprive CSIR and Indian entrepreneurs from claiming patents on innovations based on Indian System of medicine, which is quit in demand.
- The modern plant breeders develop varieties that have a very narrow genetic base so that they satisfy the criteria of distinctiveness (D) , stability (S) , and uniformity (U) prescribed for protection under the UPOV (Union for Protection of New varieties)framework , also adopted by our draft on PVP act. However, the folk varieties are unlikely to satisfy these norms and are consequently deprived of protection. Thus, instituting petty patents or a less rigorous plant breeder's rights system might serve to protect atleast some of the folk varieties.
- To step up the pace of granting patents ,without sacrificing social justice, it would be desirable to make the patent scrutiny more broad based involving people from all walks of life. (e.g.-- specialists such as ayurvedic and folk healers, etc.)
- Setting up of Benefit sharing tribunal and People's biodiversity registers.
- TRIPS require protection (patenting) of microorganisms. the present Indian patents Act dos not allow this. It is possible that countries could keep the core issue of defining microorganisms away from the scope of TRIPS in future

discussions of WTO or the definition of microorganisms , which is the purview of national levels , could b formulated according to our requirements. (e.g.-- not to include cell lines of vertebra or other cell lines originating from higher life forms in microorganisms.)

- In order to keep the national patents law more people friendly, decisions should be taken to keep naturally found substance, howsoever isolated or processed, outside the purview of patenting. By this animal or plant obtained materials would be more economically available. (e.g.-- lipids, glyco-proteins, polyneucleotide sequences , all naturally occurring DNAs , etc.)
- India has already enacted the ***Geographical Indications of Goods (Registration and Protection) Act, 1999***. According to this any labeling of the goods determining its location which enhances its value (e.g.- basmati rice; Darjeeling tea etc.) Will have to share the benefit of it with the government.

2. **Plant Variety Protection act (PVP Act)** : In India , the protection of plant Varieties and Farmers' Rights (PPVFR) Bill, 1999 was introduced as Bill No. 123 of 1999 in the Parliament. Th bill is under examination by a select committee of the Parliament. Th Indian PPVFR has substantially incorporated in it the 1978 provisions of the UPOV (which are more beneficial in Indian setting). The varieties that would be developed by incorporating one or few transgenes by standard methods would be considered as essentially derived varieties and these would also be eligible for protection as " essentially derived varieties ". In other words , GM plants shall b protected as essentially derived varieties provided they satisfy DUS criteria. The PPVFR recognizes the rights of researchers as well as farmers similar to what was available in UPOV 1978. The Bill further recognizes the rights of community that contributed to the development of protected variety.

3. **Biodiversity Act** ;- The Convention of Biodiversity (CBD) has advanced beyond the conventional IPR regime to accept the sovereign rights of nations over their Biodiversity resources, and the need thereof to share benefits of commercial applications of traditional knowledge of sustainable use of Biodiversity resources with local communities. It is therefore important for India to benefit from these provisions and create legislations to put it in effect. Biodiversity Act is an attempt in this direction. Some of its important clauses are ;-

- People's knowledge shall be registered at local, state and national levels and protected with the help of *sui generis* system of IPRs (Art. 14). This provision presumably refers to information yet undisclosed.

- Any person applying for IPRs in India or abroad , relating to biological resources occurring in and/or accessed from India , must obtain prior permission and abide by the benefit sharing conditions by the national authority. (Art. 17)
- The national authority if necessary shall oppose worldwide the IPRs granted in relation to biological resources or knowledge derived from India. (Art. 8 iv).
- No foreign agency can access biological resources occurring in India and related knowledge without the prior-informed consent of the national authority.
- In cases where a person or a group of persons exclusively contribute to the resource or knowledge, they shall directly share the royalty resulting from its subsequent commercialization. Otherwise ,such share of benefits will be deposited in a national Biodiversity fund. (Art. 16)

These are indeed Some of the positive provisions. In order to make them more effective it is required to set up guidelines , meticulously avoiding any loopholes . it is also desirable that the proposed Biodiversity Act , New Patent Act and Plant Protection Variety Act are formulated such that thy are complimentary to each other.

It can be said that these three proposed bills are definitely set to define the prospects of 'Biotechnology in India' in new globalized world and are to be taken a major step in further institutionalizing this field .

APPENDIX 2

No.	Research Centre and Address	Projects / Facilities
1	Allahbad University Allahbad - 211002	Improved routes for synthesis of modified oligonucleotides
2	Aligarh Muslim University (UGC) Aligarh - 202002, UP State.	Immunodiagnostics, Peptide and Nucleic acid chemistry, surface proteins study.
3	Alps Industries Ltd., Ghaziabad Ghaziabad, U.P.	Production of fully standardised ecofriendly natural dyes
4	Andhra University (UGC) Visakhapatnam - 530003, Andhra Pradesh.	Enzymology, Bioconversion of agro-industrial wastes for biogas/alcohol/SCP/mushroom. Microbial leaching, Aquaculture.
5	Andhra Pradesh Agricultural University (UGC) Hyderabad - 500030, Andhra Pradesh State.	Plant tissue culture, Immunodiagnostics, ETT
6	Anna University (UGC) Sardar Patel Road, Guindy, Chennai - 600025. Tamil Nadu State.	Biosensors, Bioinsecticides, Bioinformatics, Enzyme immobilisation, Animal Tissue Culture, Immunodiagnostics. Development of biocontrol agent (Bacillus sphericus) for malarial larvae.
7	Annamalai University Centre of Advanced Study in Marine Biology, Parangipettai - 608 502, Tamil Nadu	Rhizobium Biofertilizers technology development
8	All India Institute of Medical Sciences (AIIMS) Ansari Nagar, New Delhi. http://www.aiims.ac.in/ Tel. 91-11-6864851, 6561123, 6560110 Fax. 6862663, 6521041 Department of Biotechnology	(1) Molecular Biology of Malaria Parasite (Group Leader - Prof. Y. D. Sharma) (2) Molecular Biology of Tuberculosis (Group Leader - Dr. Jaya Sivaswami Tyagi) (3) Immunology of Tuberculosis (Group Leader - Dr. H. Krishna Prasad) (4) Immunology of Leprosy (Group Leader - Prof. Indira Nath) (5) Tumour & Molecular Immunology (Group Leader - Dr. Satya N. Das) Iron binding protein and lactotransferrin (antibacterial activity)
9	Agharakar Research Institute Agharakar Road, Pune - 411 004	Biotreatment of mining wastes
10	Assam Agricultueal University (UGC) Jorhat - 785013, Assam State	Plant tissue cultue, enzyme engineering, Bioinformatics, Hydrocarbon degradation, Seed storage protein biosynthesis in rice, Mycorrhiza in Capsicum
11	Avinashilingum Institute for Home Science	Tissue culture, Biopolymers, Biofertilizers, Industrial Microbial and Energy

	(UGC) Coimboatore - 641043, Tamil Nadu	Conservation, hybrid varities by biotechnology.
12	Avra Labs, Hyderabad	Established by the former director at the Hyderabad-based Indian Institute of Chemical Technology (IICT) Multinationals like Searle are the clients. Contract research Molecule Makers Synthesis of biomolecules
13	Banaras Hindu University, School of Biotechnology. Varanasi - 221 005, UP State.	Biosensors, Biological waste treatment, Oil from yeast, Vitamin B12 from Propionibacterium, Detoxification of chromium from industrial wastes.
14	BAIF Development and Research Foundation Wagholi, Pune	-
15	Barkatullah University, Dept. of Microbiology. Bhopal - 462 026	Bioconversion of lignocellulosic wastes
16	Berhampur Univerity (UGC) Berhampur - 760007, Orissa State.	Mushroom Biotechnology.
17	Bhabha Atomic Research Centre, Nuclear Agriculture & Biotechnology Div. Trombay, Mumbai 400085 Website: http://www.barc.ernet.in/	Immobilized enzymes in bioprocess
18	Barkatullah University Golap Bagh, Burdwan - 713 104, West Bengal	Rhizobium Biofertilizers technology development
19	Bhabha Atomic Research Centre Trombay, Mumbai-400085 Website: http://www.barc.ernet.in/	Tissue culture propagation of Oil Palm
20	Bharatiya Agro Industries Foundation (BAIF), Pune Pune, Maharashtra	Biofertilizers project and Know-How Rapid Diagnostic Kits for disease in poultry (IBD) & cattle (Brucella & Newcastle). The technology is licensed to Hoechst Roussel Vet (India) for a period of five years. The company will popularize diagnostic kit to identify the need for vaccination in poultry and cattle farms across the country. The kits are expected to be low priced and farmer friendly.
21	Bharathiar University, Dept. of Biotechnology Coimbatore - 641 046	(1)Lipase from Rhizomucor miehei (2)Extrathermostabilisation of aspartyl protease from *Rhizomucor pusillus*
22	Bharathidasan University (UGC)	Microbial genetics, rDNA technology, plant

	Tiruchirapalli - 620024, Tamil Nadu State.	tissue culture, Biol. Nitrogen fixation by BGA and Azolla, Marine cyanobacteria,
23	Biochemical Engineering research Centre, (BERC) New Delhi.	Project on Applied biocatalysis in cooperation with University of Lund, Sweden. Project on Microbial synthesis of Lipase.
24	Bioinformatics Centre (DIC) University Of Pune, Pune 411 007, Maharashtra, INDIA -	It provides an upto-date and an accurate information in the area of Biotechnology with a stress on Virology, proteins and nucleic acid sequences and structures, Microbial strain data and also an access to the other related areas through networks. Supplying the sequence data, facilities for data analysis.
25	Birla Institute of Technology and Science Pilani - 333031, Rajastan State.	Tissue culture, Peptide and Nucleic acid Chemistry, Bioconversion of lignin from paper mill wastes, Study of proteins of pollen grains.
26	Birsa Agricultural University (UGC) Ranchi- 834007, Bihar State.	Immunodiagnostics, Tissue culture, ETT
27	Cancer Institute, Madras Canal Bank Road, Adyar, Madras-60002	Indigenous ELISA/RIA kits for Tumor markers
28	Centre for protein engineering & Biomedical Research, Madras Voluntary Health Services, Adyar, Madras-600013	Protein stabilization through chemical modification. Project on natural and recombinant proteins as biosensors.
29	Centre for Biochemical Technology (CBT Near Jubilee Hall, Univ. Campus, Mall Road, Delhi - 110007, India. Tel: (+91) 11 7257-578/298/439/310 Fax: (+91) 11 7257471 E-mail: mailto:root@cscbt.ren.nic.in Website: http://www.cmmacs.ernet.in/nal/icast/csir/cbt.html	Conducts research in Immunology, Diagnostics, Reagents. Services offered: Biochemical testing, Training Programmes.
30	Council of Science & Technology B-144, Sector C, Mahanagar, lucknow 226006	Blue green algae technology development
31	Centre for Cellular and Molecular Biology (CCMB) Uppal Road, Hyderabad -500007, AP state.RRL Campus, Uppal Road Hyderabad - 500007, India. Tel: (+91) 40 672241 Fax: (+91) 40 671196 E-mail: root@csccmb.ren.nic.in	Research in multidisciplinary areas and to seek potential applications of this work, Development of biochemical and biological technology in the country, Vaccines for fertility control Conducts research in Biotechnology, Molecular Biology, Instrumental Techniques, Mathematical Modelling.

	Website: http://www.ccmbindia.org/ http://www.cmmacs.ernet.in/nal/icast/csir/ccmb.html	
32	Center for DNA fingerprinting and Diagnostics (CDFD) Laboratory Website: http://www.cdfd.org/ Administration CDFD A & H Bldg., ECIL Road, Nacharam, Hyderabad-500076,INDIA. Tel: + 91 40 7155481 Fax: + 91 40 7155479 admin@www.cdfd.org.in Research CDFD Laboratory, ECIL Road, Nacharam, Hyderabad-500 076, INDIA. Tel : + 91 40 7151344 Fax : + 91 40 7155610 research@www.cdfd.org.in	CDFD, an autonomous institution supported by Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India. It is India's premier Centre providing services in areas of DNA Fingerprinting, Molecular Diagnostics, and Bioinformatics CDFD is now poised to initiate basic research in fields relevant to its objectives. CDFD is also the Bioinformatics national node for the European Molecular Biology network (EMBnet). The node currently provides bioinformatics services in the form of browsing biomolecular sequence databanks, macromolecular structure databank, genomeand other useful databases.
33	Centre for Research in Medical Entomology (ICMR) Post Box No.11, 4-Sarojini Street Chinna, Chokkikulam Madurai-625002. Tel: 91-452-530746 Fax: 91-452-530660 Gram: OIKOS EMail: crmeicmr@satyam.net.in : icmrcrme@ren.nic.in : icmr%bicmku@dbt.ernet.in	Aim is to undertake studies on the behaviour, distribution and control of insects which act as vectors of disease, with particular emphasis on the vectors of viral encephalitides.
34	Central Drug Research Institute (CDRI) Chattar Manzil Palace, P.B. No 173 Lucknow - 226001 Tel: (+91) 522 232411 Fax: (+91) 522 243405 E-mail: root@cscdri.ren.nic.in Website: http://www.cmmacs.ernet.in/nal/icast/csir/cdri.html	Tissue culture and viruses, Embryo transfer technology, Drug development-laboratory animal science, toxicity and teratogenicity, Development of immunodiagnostics for Kala Azar, for malaria, Conducts research in Drugs & Pharmaceuticals, Regulatory Toxicity & Clinical trials, Biological Activity Screening, Fermentation, Reagents. Services provided: Testing/Analysis/Evaluation, Bioevaluation, Experimental Analysis,Information Dissemination, National Facilities, Training Programme.
35	Centre for Research in Medical Entomology (CRME) Madurai	Efficacy of Biocide-S (Bacillus sphericus) against mosquuto larvae
36	Central Jalma Institute for	Analysis of rRNA and rRNA genes of

	Leprosy (ICMR) Agra, UP State	pathogenic mycobacteria (M. Leprae), Expression of M. leprae enzymes, evaluation of leprosy vaccines.
37	(CSIR) Central Institute of Medicinal & Aromatic Plants (CIMAP) Lucknow - 226016	Tissue culture studies in aromatic grasses, Projects on conservation of plant species seed biology and tissue culture, Bioinformatics Centre especially for areas of medicinal and aromatic plants.
38	Central JALMA Institute for Leprosy (ICMR) Post Box No.101Tajganj Agra-282001. Tel: 91-562-331756 Fax: 91-562-331755 Grams: JALMA E-mail: icmrcjil@ren.nic.in	WHO Collaborating Centre for Epidemiology of Leprosy
39	(CSIR) Central Leather Research Institute Dept. of Biotechnology Adyar, Chennai 600 020	Microbial Enzyme technol. for leather industry, synthesis and secretion of connective tissue components in cultured cells, animal tissue culture, hybridoma, cell culture based vaccines, Bioinformatics, immunodiagnostics
40	(CSIR) Central Food Technological Research Institute (CFTRI) Mysore 570 013	Basic molecular biology, microbial genetics, animal feed from wastes, ethanol from starch, production of algae, bioprocess development
41	(CRTRI) Central Food Technological Research Institute. Pesticide Residue Abatement Lab, Food Protectants and Infestation Control Dept. Mysore 570 013	(1) Microbial production of biosurfactants(2) Food safety related to Microbiology - The need through biotechnology. (3) Applied Biocatalysis projectin cooperation with University of lund, Sweden.Project on Standardisation of production parameters for Mushroom. Liposome technology development.
42	Center for Human Genetics Banglore	Institutions being setup for Genome research
43	CDFD Laboratory, ECIL Road, Nacharam, Hyderabad-500 076, INDIA. Tel : + 91 40 7151344 Fax : + 91 40 7155610 EMail: mailto:research@www.cdfd.org.in Tel: + 91 40 7155481 Fax: + 91 40 7155479 EMail: admin@www.cdfd.org.in	Autonomous institution supported by Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India. It is India's premier Centre providing services in areas of DNA Fingerprinting, Molecular Diagnostics, and Bioinformatics. CDFD is also the Bioinformatics national node for the European Molecular Biology network (EMBnet). It provides bioinformatics services in the form of browsing biomolecular sequence databanks, macromolecular structure databank, genome and other useful databases.
44	Centre for Plant Molecular Biology (CPMB) at JNU New Delhi	-
45	Centre for Plant Molecular Biology (CPMB) at Tamil Nadu Agricultural	-

	University (TNAU) Coimbatore, INDIA, 641 003. Tel: (91) 422 432 222 Fax : (91) 422 xxx xxx Email: cpmbtnau@hotmail.com	
46	Centre for Plant Molecular Biology (CPMB) at Madurai Kamaraj University (MKU) Madurai	-
47	Centre for Plant Molecular Biology (CPMB) at Osmania University Hyderabad	-
48	Centre for Biochemical Technology (CSIR) Mall Road, New Delhi - 110 007 Tel: 91-011-7256156,7256157 Fax: 91-011-7257471 Email: root@cbt.res.in	Engaged in various aspects of Biotechnology research. Centre was established with the core competence in preparative biochemistry for isolation of fine biochemicals from natural resources viz., proteins, lipids, enzymes; synthesizing bioorganic compounds like peptides, oligonucleotides and preparing reagents required for recombinant - DNA research. Centre is in the process of transforming from a singular laboratory working in the area of biochemical research to a network laboratory, leading to the formation of a virtual institute of new biology. CBT is now a premier Institute carrying out research leading to generation of new knowledge and development of technologies in various areas of modern biotechnology with a special focus on Genomics and Genome informatics. Control of fertility and allergy
49	Centre for Research in Medical Entomology (CRME) Madurai	Efficacy study of biocontrol agent (Bacillus sphericus) for mosquito larvae.
50	(CSIR) Central Scientific Instruments Organisation CSIR complex, Taramani, Chennai - 600113	Development of application software for bioprocess data acquisition and control systems, design and dev. of industrial transmitters and multiplexers, Microprocessor based fermenter controller, foam level cotrollers.
51	Central Tuber Crops Research Institute, Division of Crop utilization and Biotechnology. (ICAR) Trivandrum - 695 017	Production of virus-free tuber crops, Preservation and maintenance of tuber crops through tissue culture, Waste treatment from starch industries
52	Central Agricultural Research Institute (ICAR) Port Blair - 744101	Rice tissue culture, improvement of rice for salt resistance and insect pest resistance, Improvement of Indian major crops through biotechnology, biotech. for enhanced fish production,
53	Central Institute of Brakishwater	Aquaculture of Brakishwater prawns and fish

	Aquaculture (CIBA) 141, Marshalls Road, Egmore Chennai - 600 008, Tamil Nadu E-Mail: ciba@tn.nic.in Phone: (091)-(044)-8554866, 8554891, Director (Per) 8554851, Fax: 8554851, Gram: MONODON, Telex: 41-6054 CIBA IN (ICAR) Chennai- 600029	for higher production
54	Central Institute of Fisheries Technology (ICAR) Willingdon Island, Matysapuri P.O. Cochin -682029, Kerala State.	Biodegradation of water hyacinth to produce fuel gas, Proteinases and protein chemistry, studies of biofilms on ships and fishing boats, lipase from marine bacteria feed for prawns and fish.
55	Central Institute for Freshwater aquaculture (ICAR) Kausalyaganga, Bhubaneswar - 751002, Orissa State EMail: cifa@x400.nicgw.nic.in	Biotechnology to achieve fish production of 25 tonnes/ha/annum, use of Azolla and blue-green algae for fish production, genetic engineering, Bioinformatics, Immunodiagnostics,
56	Central Marine Fisheries Research Institute (ICAR) Cochin - 682031, Kerala State	Breeding, sed production and sea ranching of fin fishes, pearl oyster, edible oyster, clams & mussels etc.
57	Central Institute for cotton research (ICAR) Nagpur - 440001	Biofertilizer, Tissue culture for increasing crop production, genetic study to identify genes for resistance to bacterial blight.
58	Central Institute of Horticulture for Northern Plains (ICAR) Lucknow - 226016	Tissue culture, development of in vitro techniques for mango and papaya improvement.
59	Central Institute for research on buffaloes (ICAR) Hisar - 125001, Haryana State	Standardisation of ETT, Growth hormone biotechnol., Bioinformatics,
60	Central Institute for research on goats (ICAR) Mathura - 281122, UP State	ETT for goats
61	Central Plantation Crop Research institute (ICAR) Kasaragod-671124, Kerala State.	Clonal propagatin of coconut, oil palm, cacao through plant tissue, cell and anther culture, Bioinformatics
62	Central Potato Research Institute (ICAR) Simla - 171001, Himachal Pradesh	Tissue culture for potato improvement, enzymatic and non-enzymatic probes for detection of viruses.
63	Central Research Institute for Dryland Agriculture (ICAR) Hyderabad - 500659, Andhra pradesh State	Plant tissue culture studies on dryland crops to develop tolerance to abiotic stresses, Micropropagation of dryland fruitcrops like Annona squamosa.

64	Central Research Institute for Jute & Allied fibre Barrackpore - 743101, West Bengal State	Tissue culture for strengthening the jute production
65	Central Rice Research institute (ICAR) Cuttack - 753006, Orissa State	Molecular mapping of rice genome for resistance genes, anther culture for generation of somaclonal variants for selection against desirable traits, Utilization of tissue and anther culture for rice breeding etc.
66	Central Soil Salinity Research Institute Karnal - 132001, Haryana State.	Evaluation and development of plant genetic resources tolerant to salinity, sodicity and waterlogging stress in rice.
67	Central Soil and Water Conservation Research & Training Institute (ICAR) Dehra Dun - 248195, UP State	Tissue culture and viruses
68	Central Sheep and Wool Research Institute (ICAR) Avikanagar - 304501, Rajasthan State	Disease diagnostics, utilization of tannin-rich feed, ETT, Evaluation and linking of sheep productivity model
69	Central Tobacco Research Institute Rajahmundry - 533105, Andhra Pradesh State	Micropropagation, somaclonal variation, tisue culture and biotic stresses
70	Chemical Technology Dept. Calcutta University 92, Archaryya P. C. Road, Calcutta - 700 009.	Biotechnology for Potential Oleochemicals.
71	CSIR Centre for Biochemicals VP Chest Instt. Building, Delhi University Campus, Delhi - 110007	Basic molecular biology & DNA technology, Biosensors Immunodiagnostics, Lectin research, Preparation of restriction enzymes & fine chemicals for genetic engineering, peptide and NA chemistry.
72	Council of Scientific & Industrial Research (CSIR) Complex Palampur (Kangra), Himachal Pradesh State.	Plant Tissue culture, micropropagation of tea, bamboo, selected ornamental plant, virus elimination through plant tissue culture, development of immunodetection kits for tea root pathogens.
73	Dalmia Centre for Biotechnology (DCBT) WebSite: http://www.dalmiaindia.com/	DCBT was established in 1992 The Department of Scientific & Industrial Research (DSIR), Ministry of Science & Technology, Government of India, has recognized DCBT promotion of applied research, plant biotechnology research, micropropagation of neem
74	Delhi University, South campus New Delhi	In vitro propagation of tree species, In vitro conservation of endangered species, Immunodiagnostics, Cellular basis of differentiation, Preparation and standardisation of restriction enzyme, Liposome Technology
75	Delhi University , Dept. of Microbiology.	Microbial lipases

	South Campus, Benito Juarez Road, New Delhi 110 021	
76	Department of Biotechnology CGO Complex, Lodhi Road, New Delhi 110 003 micro@dusc.ernet.in	Microbial lipasesEnterepreneurial opportunities in India
77	Dr. Y. S. Parmar University of Horticulture and Forestry, Department of Post-harvest Technology. Nauni, Solan - 173 230	Micropropagation technique for bamboo, Artocarpus, juniperus, Apple pomace utilization for SSF
78	Dr. Ramaih Medical College Banglore 560 054	S&T project on immunological approaches for fertility control (PhaseI clinical trials for FSH vaccine)
79	Dr. Ram Manohar Lohia Avadh University Department of Microbiology. Faizabad - 224 001	-
80	Dept. of Horticulture (Govt. of Andhra Pradesh) Hyderabad	Oil palm demonstration project
81	Development Corporation of Konkan Ltd. 5th Floor, Warden house, Sir P.M.Road, Mumbai-400001	Oil palm demonstration project
82	Devi Ahilya Vishwavidyalaya Indore, Madhya Pradesh.	Post-graduate training
83	Directorate of Oilseed Research (ICAR) Rajendranagar, Hyderabad - 500030	Biotechnological approach to overcome the crossing barrier between cultivated Castor and Jaltropha
84	Directorate of Pulses Research (ICAR) Kanpur - 208024, UP State	Tissue culture studies in pulses.

No.	Research Centre and Address	Projects / Facilities
82	Entomology Research Institute Llyola College, Madras-600 034	Testing bioinsecticides
83	Foundation for Medical Research 84 A, R.G. Thadani Marg, Sea Face Corner, Worli, Mumbai-400018	Recombinant protein as vaccine for leprosy.
84	Gauhati University (UGC) Gauhati - 781014, Assam State.	Tissue culture in orchids, tea, and crop plants, rDNA technology, Immunodiagnostics
85	G. B. Pant University of Agriculture & Technology,	Bioinoculants, Biological control of Rhizoctonia

	Department of Microbiology, College of Basic Sciences & Humanitics. Pantnagar - 263145	
86	Guru nanak Dev University, Dept. of Microbiology. Amritsar - 143 005	(1)Transformation of Thermomyces lanuginosus with Hygromycin resistance gene by electroporation (2)Diagnosis, prevention and treatment of genetic disorders of Human
87	Goa University (UGC) Goa - 403202	Expression of osmotolerant genes from marine bacteria in E.coli, Biosurfactant production by natural and recombinant bacteria.
88	Govt. Medical College Jammu	S&T project on Immunological approaches to fertility control (phase - I clinical trials on FSH vaccine
89	Gulbarga University (UGC) Gulbarga - 585106, Karnataka State.	Salinity tolerant / Fe efficient lines of sugarcane through cell and tissue culture, Studies in bioproductivity of firewood crops under saline conditions.
90	Gujrat University (UGC) Ahmedabad - 380009, Gujrat State.	Biohydrometallrgical applications of sulfur bacteria
91	Gujrat Agricultural University (UGC) Ahmedabad - 380004, Gujrat State.	Plant tissue culture, ETT, All India coordianted project on Biological control of pests, Biogas production, Biochemicals responsible for drought and disease resistance.
92	Guru Nanak Dev University Amritsar-143005	Diagnosis, prevention and treatment of genetic diseases of human being.
93	HAL) Hindustan Antibiotics Ltd., Research and Development. Pimpri, Pune - 411 018	Projects on (1) Penicillin: Pan-lab. strain absorption and establishment technologyin plant scale, (2) Development of technology for cephalosporin C and 7-ACA, (3) Strain improvement for gentamycin and antifungal Polyene antibiotics, (4) Computer simulation studies in fermentors. (5) Improvement of recovery processes for penicillin.
94	Haryana Agriculture University, Department of Microbiology.(UGC) Hissar - 125 004, Haryana State.	Immunodiagnostics against sheeppox, Tissue culture of woody trees, Biofertilizers, ETT, Ethanol production using thermotolerant / thermophilic yeasts
95	Human Biologicals Institute (HBI), Ooty	Anti-rabies DNA vaccine (First in the world)
96	Indian Council of Medical Research (ICMR) New Delhi - 110029	Cancer epidemiology
97	Indian Drugs and Pharmaceuticals Ltd, (IDPL) Rishikesh. UP State.	Projects on (1) development of rifampicin technology (fermentation and scale up) (2) Development of whle-cell penicillin acylase enzyme and production of 6-APA. (3) Optimisation fermentation parameters and scale up of high yielding strains of tetracycline producers. (4) Strain improvement, development and scale up of griseofulvin technology.
98	(CSIR) Indian Institute of Chemical Technology	Synthetic vaccines, biotechn. applications of oils and fats, Biochemical engineering, proces

	Biochemical and Environmental Engineering Hyderabad 500 007	optimisation and computer modelling, Microbial Fermentations with Immobilised Cells
	Indian Association for Cultivation Of Science (IASC) Website: http://mahendra.iacs.res.in/	
99	Indian Institute of Science, Department of Biochemistry. Banglore 560 12 Website: http://www.iisc.ernet.in/ EMail: v-nadig@mailcity.com	Microbial production of biosurfactants,
100	Indira Gandhi Agricultural University (UGC) Raipur - 492012, MP State.	Rice anther culture, crop improvement in Lathyrus, Brassica, Tomato, forest trees.
101	(CSIR) Institute of Microbial Technology (IMT) Post Box No 1304, Sector 39-A Chandigarh - 160036, India. Tel: (+91) 172 690004, 690025, 690138 Fax: (+91) 172 690585, 690632 E-mail: root@csimt.ren.nic.in Website: http://www.cmmacs.ernet.in/nal/icast/csir/imt.html EMail: rmvohra@excite.com	Rifamycin fermentation, genetic and biochemical approache for improved process development, microbial prospecting of oil and gas, Regulation of immune system, Enzyme engineering, immobilized biocatalysts, site-specific drug delivery systems, Microbial Transformations - Production of D-aminoacids using hydantoinase
102	Indian Institute of Chemical Biology (IICB) 4, Raja S.C. Mullick Road Calcutta - 700032, India. Tel: (+91) 33 4730492, 4733491, 4734503 Fax: (+91) 33 4730284, 4735197, 4735112 E-mail: root@csiicb.ren.nic.in Website: http://www.cmmacs.ernet.in/nal/icast/csir/iicb.html	Conducts research in Molecular Biology, Biochemicals/Chemicals, Enzymology, Drugs and Diagnostics, Neurobiology, Immunology, reproductive Biology, Biotechnology. Services offered: Testing/Analysis/Evaluation.
103	Indian Institute of Chemical Biology (ICCB) 4 Raja S.C.Mullick Road, Jadhavpur, Calcutta - 700 064	Monoclonal antibodies to brain cells and their appli. in diagnosis of brain tumor, Molecular biology of human enteric pathogens,Oral cholera vaccine, PCR-based diagnostic test for Leishmania parasites.
104	(IIT) Indian Institute of Technolgy, Delhi, Dept. of Biochemical Engineering & Biotechnology Hauz Khas, New Delhi - 110 016	Microbial polysaccharides, Engineering analysis of mammalian cell cultures, Technology development for biofertilizers, Process optimisation for restriction enzymes, Applications of enzymes in textile industry, Engineering analysis of microbial, enzymatic, plant and animal culture systems. Project on Applied Bioctalysis in cooperation with University of Lund, Sweden.
105	Indian Institute of Technology, Kharagpur Dept of Chemical Technology Biotechnology Centre Kharagpur - 721	* Continuous ethanol production by using nonconventional raw materials in novel bioreactor. * Hydrogen production through waste recycling.

	302 http://www.iitkgp.ernet.in/~btc/java/homepage.htm	* Industrial enzyme production. * Microbial degradation of dyes and phenolics. * Microbial herbicides production . * Development of biosensor for the analytical purpose. * High frequency mass propagation of plants in liquid media and bioreactors. * Induction of automation in industrial plant cell culture (medicinal & aromatic metabolities). * Metabolic manipulation in cultured plant cells. * Purification and cloning of protease inhibitors * Genetic techniques for improvement of tasar silk. * Characterization of baculovirus for Eukaryotic gene expression. * Molecular modelling of protein / DNA * Lectin based affinity matrix development & diagonistic kit development. * Process development for rapid anticancer alkaloid production/extraction from plants. * Dev. of Immunodiagnostic reagents for Cytoplasmic Polyhedrosis Virus * Dev. of immunotoxins for targeted cell Killing. * Single crystal x-ray crystallography of drug molecules. * Protein x-ray crystallography. * Fibroin gene structure. * Characterization and cloning of feline leukemia virus receptor. * Biotransformation of tannic acid to gallic acid by solid state fermentation
106	(IICT) Indian Institute of Chemical Technology, Division of Organic Chemistry -1. Hyderabad - 500 007	(1) Newer applications of Baker's yeast in organic synthesis (2) Biotechnology of Oleochemicals
107	Indian Institute of Technology, Biotechnology Research Centre. Chennai - 600 036	(1)Cloning of DNA from Pseudomonas with lipase activity. (2)Cellulase activity.
108	Indian Institute of Technology, Centre for Environmental Sciences & Engg. Powai, Mumbai - 400 076	Environmental Management incorporating Biotechnology Developments
109	Biotechnology Centre, Indian Institute of Technology Powai, Mumbai 400 076, INDIA Tel: (91)(-22) 576 7771; Fax : (91)(-22) 578 3480 E.mail : office@helix.btc.iitb.ernet.in Faculty Research http://www.iitb.ernet.in/~btcSee	
110	Indian Institute of Chemical Biology, Biophysics Division.	Recombinant live oral cholera vaccine

	4 Raja S. C. Mullick Road, Calcutta - 700 032	
111	Indian Institute of horticultural Research (ICAR) Banglore - 560080, Karnataka State	Plant tissue culture, bioinsecticides, production of disease free plants, Production of monoclonal antibodies for disease diagnosis.
112	Indian Institute of Sugarcane Research (ICAR) Lucknow - 226002, UP State.	Tissue culture, germaplasm conservation, breeder seed production in sugarcane through tissue culture.
113	Indian Council of Agricultural Research, Krishi Bhavan, New Delhi 110 001, India. Tel: 0091-11-3382306 e-mail:gbsingh@icar.delhi.nic.in	
114	ICAR Research Complex for New Region Barapani, Shillong, Meghalaya State.	Plant tissue culture in rice, bioinsecticides development
115	IIP Deradun.	(MEOR) Microbial Enhanced Oil Recovery
116	(IIT) Indian Institute of Technology Powai, Mumbai - 400 076 EMail - http://www.iitb.ernet.in/~btc	(1)Membrane bound Enzyme sensors for biotechnology & bioengineering (2)Bioconversion of hemicellulose to furfural (3)UASB reactors (4)Molecular recognition and environmental monitoring (5)Vermiculture - Bioconversion of solid residues
117	Indian Institute of Technology Kharagpur-721302	Development of programmable biofreezer using liquid nitrogen
118	Indian Agricultural Research Institute (ICAR) New Delhi - 110 012	Micropropagation of ornamental plants, Bioinformatics, Plant tissue culture and viruses, floriculture, biogas from agricultural wastes, Study on pulses, Improvement of fruitcrops through tissue culture, Biofertilizers in sustainable agriculture
119	Indian Grassland and Fodder Research Institute (ICAR) Gwalior Road, Jhansi - 284003, UP State	Tissue Culture and viruses
120	Indian Veterinary Research Institute Izatnagar-243112	(1)Animal vaccines (2)Application of rDNA technology & Hybridoma technology for development of immunogenes and diagnosis (3)Development of immunodiagnostics against Ranikhet Diseases and infectious bursal diseases using molecular techniques
121	(CSIR) Industrial Toxicology Research Centre P.O Box 80 Mahatma Gandhi Marg Lucknow 226001, India. Tel: (+91) 522 233786, 234118, 236148 Fax: (+91) 522 248227 E-mail: intox@itrc.sirnetd.ernet.in Website: http://www.cmmacs.ernet.in	Conducts research in Toxicology, Material Toxicology, Environment. Services offered: Testing/Analysis/Certification/Surveys/Information Dissemination, training Programme.Genetic engineering of microorganisms for biodegradation of chlorinated pesticides: studies with mammalian biotransformation enzymes, Development of MAB/polyclonal

	/nal/ica st/csir/itrc.html	antibody based immunodiagnostics for alfatoxins, mixed culture technology for COD reduction, methane production from distieery wastes.
122	(ICMR) Institute of immunohematology 13th Floor, New Multistoryed Building KEM Hospital Campus Parel, Mumbai-400012. Tel: 91-22-4138518 Fax: 91-22-4138521 E-mail: dir@icmriih.ren.nic.in : icmriih@ren.nic	Gene mapping for thalasemia, hemophilia, HLA and Ig gene, prenatal diagnosis of thalasemia by globin synthesis, Diagnosis of autoimmune disorders, Immunohematology. The Institute runs training courses in Transfussion Medicine for Blood Bank Medical Officers, Blood Group Serology and Blood Bank Methodology for Blood Bank Technicians and an Advanced course in Haematology and Immunohaematology.
	Institute of Himalayan Bioresource Technology (IHBT) Palampur, Himachal Pradesh.	Plant Tissue Culture
	Institute of Pathology Safdarjang Hospital Campus, Post Box No. 4909 New Delhi-110029. Tel: 91-11-6198403 Fax: 91-11-6198401 Grams: INSTPATH E-mail: icmriop@ren.nic.in	The Institute is one of the premier centres for research in pathology, providing diagnostic and referral services. Areas of special interest in human pathology include pigment cell biology, tumour biology, tropical pathology and pathology of sexually transmitted diseases.
123	Institute for Research in Reproduction (ICMR) Jehangir Merwanji Street Parel, Mumbai-400 012. Tel: 91-22-413 2111, 91-22-413 2112 91-22-413 2116, 91-22-413 2117 Fax: 91-22-4139412 Gram: INSTREP E-mail: libirr@icmrirr.bom.nic.in	Fertility regulation, Immunodiagnostics, Biologically active proteins and peptides, reproductive immunology, in vitro fertilization and embryo transfer.
124	Jadhavpur University Jadhavpur, Calcutta-700032	V. cholerae vaccine development studies Rhizobium biofertilizer development
125	Jawaharlal Nehru University (JNU) New Delhi	Animal tissue culture and hybridoma based vaccines, Immunodiagnostics, Recombinant insulin, Study on Azotobacter, Azospirilum, Biochemical Engineering, Peptide and Nucleic acid chemistry.
126	Jawaharlal Nehru Technological University (UGC) Hyderabad - 500028, Andhra Pradesh State.	Pollution control, ETT, bioinsecticides, Animal tissue culture.
127	Karnataka University (UGC) Dharwad - 580003, Karnataka State.	Biodegradation of pollutants.
128	Karnataka State Sericulture Development Insti. Thalaghttapura, Banglore 560 002	Control of silkworm disease by development of new bed disinfectant
129	Kasturba Medical College, Microbiology Department Udupi-	AIDS Surveillance Centre by the Government of India.

	Manipal http://www.manipalgroup.com/ kmcma nipal/microbio.html	Recognised as a LEAD CENTRE in Clinical Microbiology sponsored by NIB, New Delhi and World Bank. Sentinel Surveillance Centre for Tuberculosis 250 papers in National and International journals and 6 ICMR projects
130	Kerala Agricultural University (UGC) Trichur - 680654, Kerala State.	Plant biotechnology, ETT.
131	KEM Hospital Mumbai	Clinical trials for liposome technology to deliver drugs in human subjects
132	Konkan Krishi Vidyapeeth (UGC) Dapoli - 415712, Maharashtra State.	Tissue culture activity for strengthening horticultural and plantation crops.
133	Madurai Kamaraj University, Department of Genetic Engineering, School of Biotechnology. Madurai - 625 021	Fish biotechnology, Drug design, Bioinformatics, Tissue culture and viruses, Animal tissue culture, ETT, peptide and Nucleic acid chemistry, Trends in Antibiotic research
134	Madurai Kamaraj University, Department of Microbial Technology, School of Biological Sciences. Madurai, 625 021	Microbial genetics, Ethanol Fermentation Technology, Biofertilizers
135	Madras University Madras 600 025	Development of prawn species
136	(MRC) Malaria research Centre New Delhi.	Field trials for biocontrol agent (Bacillus sphericus) developed by Anna University, Chennai.
137	Marine Products Export Dev. Authority M.G.Road, Cochin 682016	Intensive Prawnfarming with application of biotechnology
138	M.S.University , Baroda Baroda 390 002	Use of RFLP in rice research, Rhizobium - Biofertilizer, genetic manipulation of plants and microbes
139	Mahatma Phule Krishi Vidyapeeth College of Agriculture, Pune 411 005	Rhizobium - Biofertilizer development, Blue Green Algae development project
	Malaria Research Centre (ICMR) 22, Sham Nath Marg Delhi-110054. Tel: 91-11-2528455: 91-11-2928805 : 91-11-2233201 Fax: 91-11-2215086 Grams: ANOPHELES E-mail address : sks2000@vsnl.com : sks@ndf.vsnl.net.in : icmrmrc@ren.nic.in web address: http://www.biotechsupportindia.com/www.malaria-tn.org	
140	Meerut University (UGC) Meerut, UP State.	Biodegradation of agricultural material, Immunodiagnostics, cereal cytogenetics and DNA technology.
141	National Bureau of Fish Genetic Resources (ICAR) Allahabad - 211006,	Biochemical genetics of carps, cryopreservation of fish spermatozoa,

	UP State	cytogenetic studies of carp.
142	National Bureau of Plant Genetic Resources (ICAR) Pusa Campus, New delhi - 110012	Tissue culture technology, Isoenzyme analysis for detection of somaclonal variants, RFLPs for genome mapping, DNA kinetics, characterization
143	National Dairy Research Institute (ICAR) Karnal- 132001, Haryana State.	Animal tissue culture, ETT, Bioinformatics, Microbial genetics, Biosensors, Peptide and Nucleic acid chemistry, Development of fermented dairy products etc.
144	National Dairy Development Board Anand, Gujrat	Cattle Head improvement for increased productivity using ETT
145	National Institute of Nutrition Jamai Osmania, Hyderabad	Setting up of National Animal House Facility
146	National Institute of Virology (ICMR) 20-A, Dr. Ambedkar Road, Post Box No.11, Pune-411001. Tel: 91-020-624386 Fax: 91-020-622668 Gram: VIROLOGY, PUNE E-mail: icmrniv@icmrniv.ren.nic.in	MAb against several viruses, Cloning, sequencing of several viral genes, diagnosis of several viral infections using PCR, Development of immunodiagnostics, Animal cell culture, Hybridoma.
147	National Institute of Cholera and Enteric Diseases (ICMR) Calcutta - 700010, West Bengal State.	**Vaccine development, development of immunodiagnostics, DNA probes, hybridoma etc.**
148	(CSIR) National Environmental Engineering Research Institute (NEERI)T Nehru Marg, Nagpur - 440 020 India Tel: (91-712) 526071 to 75 Fax: (91-712) 523893 Telegram: NEERI NAGPUR Telex: 0715-233 NEERI IN Email: root%neeri@sirnetd.ernet.in http://sunsite.sut.ac.jp/asia/india/jitnet/india/csir/neeri.html	(1) Environmental Biotechnology in India - Prospects and Case studies. (2) Bioleaching, ELISA and PCR techniques and DNA probes for detection of enteric pathogens in drinking water, **desulfurisation of fossil fuels**
149	(CSIR) (NCL) National Chemical Laboratory (1) Biochemical Sciences Division, (2) Division of Organic Chemistry Pune 411 008 Tel: 331453, 336451, 336452 Telegram: CHEMISTRY PUNE Telex: 0145-7266, 0145-7586 0145-7633 NCL IN Fax: (91-212) 330233 and 334761 Email: root@ncl.ernet.in	Microbial xylanases for paper industry, Culture Isolates suitable for MEOR, Plant Tissue Culture work in Coconut Palm, Bamboo Appli. of biocatalysts in drug intermediates, identification of novel microbial germaplasms with biotechnological potentials, genetic manipulations of seed storgae proteins. Cell cultures for phytochemicals, genetic modifications of plants through protoplast technology. Project on tree tissue culture in collaboration with Swedish University.
150	National Dairy Research Institute, Dairy Microbiology Division. Karnal 132 001	Microbial enzymes for dairy processing
151	National Institute of Immunology	DNA probes and diagnostic tests, vaccines for

	New Delhi	fertility control,
	National Institute of Cholera and Enteric Diseases (ICMR) P-33, CIT Road Scheme XM, Post Box No.177, Beliaghata, Calcutta-700010. Tel: 91-33-3508493 Fax: 91-33-3505066 Gram: CHOLCENT E-mail: niced@cal2.vsnl.net.in	
152	(CSIR) National Institute of Ocenography Doan Paula- 403004, Goa.	Assessment & development of culture techniques for prawns, mollusks, and seaweeds to generate extra sea food and marine biotechnology.
153	(CSIR) National Phsical Laboraory Dr. K. S. Krishnan Road, New delhi - 110012	Biomolecular electronic devices, Biosensors
154	National Research Centre for Equines (ICAR) Hisar, Haryana State.	Immunodiagnostics, vaccines development, Artificial insemination and ETT.
155	National Research Centre for Groundnut (ICAR) Junagadh - 362015, Gujrat State.	Role of Embryo rescue, tissue culture in interspecific gene transfer in groundnut.
156	National Research Centre for spices (ICAR) Calicut - 673012, Kerala State.	Tissue culture for rapid multiplication of cardmom, In vitro selection of resistance to soft rot and bacterial wilt of ginger, micropropagation of black pepper.
157	North Maharashtra University, Department of Life Science. Jalgaon - 425 001	(1)Microbial Conversion of lignocellulosic wastes into Soil Conditioners (2)Steroid Biotransformations
158	Osmania University, Department of Microbiology. Hyderabad - 500 007	Biconversion of cellulosic biomass to ethanol using Clostridium thermoacellum
159	Osmania University, Department of Microbiology. Hyderabad - 500 007	(1)Solid State Fermentation for the production of thermostable amylase and pullulanase by anaerobic Clostridium thermosulfurogenes (2)SSF for ethanol production by thermotolerent yeast
160	Osmania Medical College Dept. of Gastroenterology, Afzal Gunj, Hyderabad 500 012	Collection, characterization and storage of human foetal and adult hepatocytes.
161	Osmania University Institute of Genetics, Begumpet, Hyderabad 500016	Cost-effective Prenatal diagnosis of sickle cell anemia and thallasemia
162	Post-graduate Institute of Basic Medical Sciences Dept. of Genetics, Taramani, Madras 600013	Prenatal diagnosis and carrier detection, RFLP analysis using DNA probes.

No.	Research Centre and Address	Projects/Facilities
163	Plant Genomics Center, New Delhi	Institutions being setup for Genome research.
164	Poona University, Department of Zoology Ganeshkhind, Pune - 411007	Multifunctional Glucanases from Cellulomonas sp.
165	Pondicherry University, Centre for Biotechnology. Pondicherry - 605 014	Polysaccharide production by marine bacteria, Biogas from aquatic weeds, wastewater treatment with aquatic weeds, Development of hydroponic system for studying germination and early growth of angiosperms, Biosensors, Biochemical engineering, process optimisation, and computer modelling.
166	Post Graduate Institute of Medical Education and Research (PGIMER) Chandigarh	Study on thalassemia (pre-natal diagnosis based on DNA analysis)
167	Punjab Agricultural University (UGC) Ludhiyana - 141004, Punjab State.	Nitrogen fixation studies, Immunodiagnostics, Plant biotechnology and tissue culture centre, rDNA technology.
168	Punjab University, Dept. of Biotechnology Chandigarh	Toxicity profiles of biscarbamates, Characterisation of cells with metastatic potential, Molecular biology of cervix cancer, Purification and Characterization of novel thermostable lipase.
169	Punjabrao Krishi Vidyapeeth (UGC) Akola - 444104, Maharashtra State.	Animal tissue culture, ETT in cows, Poultry and aqaculture biotechnology, Intrspecific hybridization through embryo culture in cotton, micropropagation of banana and sugarcane, Chromosomal abnormalities study in cattle and buffaloes.
	Punjabi University, Patiala - 147002	
170	Rajasthan Agricultural University (UGC) Jobner - 303329, Rajasthan State.	Collection, evaluation and conservation of local germaplasms of fuelwood species of semiarid region, Bioinsecticides, Tissue culture and viruses.
171	Regional Medical Research Centre, Division of Microbiology Chandrasekharpur, Bhubaneswar - 751 016	Lipase from thermophilic bacteria of hot springs in Orissa.
172	Regional Medical Research Centre, N. E. Region (ICMR) Dibrugarh - 786001 Assam State.	Development of Immunodiagnostics, Study on Japaneses Encephalitis
173	Regional Medical Research Centre for tribals (ICMR) Jabalpur - 482003, MP State	Diagnosis of shigellosis, Yaws, filariasis. study of prevalance of sickle cell anemia and G6PD deficiency in tribals.
174	Regional Occupational Health Centre (Eastern) (ICMR) Calcutta - 700016, West Bengal State.	-
175	Regional Research Laboratory, Biotechnology Division. Thiruvananthapuram	Solid state fermentation for production of industrial enzymes
176	Regional Research laboratory, CSIR Division of Biochemistry.	Role of plasmid in Endosulfan degradation

	Jorhat - 785 006	
177	Regional Research Laboratory (CSIR), Bhubaneswar - 751013, Orisa State.	Biotechnology of metals (Bioleaching, Bioprecipitation biobeneficiation, etc.)
178	Regional Research Laboratory (CSIR), Jammu Tawi -180001, J & K State.	Biofertizers, Fermentation technology, Enzyme production, Genetic engineering, rDNA technology, Study of phytochemical compounds.
179	Regional Research Laboratory (CSIR), Jorhat-785006, Assam State.	Micropropagation of oil-bearing plants, Hydrocarbon (prospecting) biotechnology, Microbial Enhanced Oil Recovery (MEOR), Microbial genetics, Microbial Desulfurization of Petroleum.
180	Regional Research Laboratory (CSIR), Biotechnology Division,Biochemical Processing and Wastewater Technology Division Trivandrum - 695 019	Inulinase producing strains,Endoxylanase from Bacillus spp.,Production of cyclodextrins
181	Rajiv Gandhi Centre for Biotechnology Trivendrum - 695 014	Molecular Biology of Hepatitis C virus
182	Research Centre, Hoechst Marion Roussel Limited Mulund (W), Mumbai - 400 080	Antifungal antibiotic
183	Regional Plant Resource Centre Nayapalli, Bhubaneshwar, Orisa	Mass cultivation of Madhuca latifolia, Bambusa vulgaris, Oxytananthera nigrocilists
184	Rohilkhand University (UGC) Bareilly - 243005, UP State.	Enzyme immobilisation, Role of wood-eating fungi from mangove swamps.
185	Sardar Patel University, Post-graduate Department of Biosciences Vallabh Vidyanagar - 388120	Lignolytic enzyme production by SSF by Pleurotus ostreatus and tramates versicolor
186	SPIC Science Foundation Dept. of Biotechnology, 110 Mount Road, Madras 600 032	Improvement of strain efficiency, inoculant quality and mass production technology fro heterotrophic microbial inoculants.
187	Seth .G.S. Medical College Parel, Mumbai 400 012	Clinical Research on Liposomal Medicated drug delivery
188	Shri A.M.M. Murugappa Chettiar Research Centre Photosynthesis and Energy Division, Taramani, Madras 600113	Spirulina algae, Biotechnology for SC/ST women
189	Sri Krishnadevaraya University, Dept. of Microbiology Anantpur - 515003	Cellulolytic activity of fungal cultures.
190	Sri Venkateswara University (UGC) Tirupati - 517502 Andhra Pradesh State.	Production of biochemicals by bioconversion, subunit reccombinant protein as a leprosy vaccine
	M.S. Swaminathan Research Foundation, MS Swaminathan Foundation Institute Third Cross Road, Taramani Institutional Area, CPT Campus, Chennai (Madras) 600 113, INDIA Phone : +91-44-235 1698, 235 0698 Fax : +91-44-235 1319 Website:	To introduce genes that confer salinity tolerance into crop species. Basic work is underway to assess the intra - specific genetic variability of Mangroves, a group that grows well in inter-tidal zones. The work involving identification of the mechanisms for this characteristic, isolation of the associated genes and subsequent introduction into tobacco plants.The registration of genes

	http://www.biotechsupportindia.com/www.mssrf.org Email executivedirector@mssrf.res.in	isolated and characterised from Mangrove and other plant species is an on-going exercise. The use of molecular markers (RADP and RFLP) to determine the phylogeny of species of Rhizophora as well as inter and intra - specific variation in Avicennia. Community Gene Bank project, established with support from an Italian geneticist and conservationist. Land races and traditional cultivars of selected crop species (seeds) are held under conditions that will allow for good germination after a number of years (Temp 4 C and RH at 25%, vacuum sealed bags). In light of the trend to patent biological material, the objective is to ensure equity in respect of ownership of any material that includes genes that have been preserved through selection by traditional farmers. soil microbes from various locations including areas exposed to pesticides and heavy doses of inorganic nutrients. The large - scale micro-propagation of a number of endangered medicinal plants. Studies are also on - going to determine the genetic diversity of these plants from different populations.
191	Tamilnadu Agricultural University (UGC) Coimbatore - 641003, Tamilnadu State.	Bioinformatics, transgenic plants, stress physiology, ETT, anther culture, embryo culture in rice and grain legumes, tissue culture for cotton, rice, cereal crops, microbial genetics.
192	Tamilnadu Veterinary and animal sciences university (UGC) Chennai - 600035, Tamilnadu State.	Immunodiagnostics, animal vaccines, MAB for Rinderpest virus, ETT in bovines and goats, karyology studies of various species of animals, DNA analysis and charactrization of various microbes and animals.
193	Tata Institute of Fundamental Research (TIFR) Mumbai Website: http://www.tifr.res.in/	Microbial genetics, Malarial vaccine, Immunodiagnostics, Animal tissue culture based vaccines, rDNA technology. Basic molecular biology, Protein engineering.
194	Tata Energy Research Institute (TERI) New Delhi WebSite: http://www.teriin.org/	Research in various areas like - Genome analysis of Brassica, Populus app., Biobleaching by xylanase for paper pulp, bioremediation of oil-spilled area, Tissue culture for various plant spewcies, Tissue culture of Bamboo, Developed Mycorrhizae based biofertilizer. (will be commercialised and marketed by Cadilla Pharmaceuticals Ltd.), Work om Microbial Enhanced Oil Recovery (MEOR).
195	Thapar Corporate R & D Centre, Biotechnology Division. Patiala - 147 001	(1)Microbial Conversion of lignocellulosic wastes into Soil Conditioners. (2)Degradation of xenobiotic compounds - by Phanerochaete chrysosporium (3)Biopulping (4) Thermostable alkaline alfa amylase for starch, textile and paper industry. Also work on papain and other enymes.
196	Tamil nadu Agricultural University Fermentation Laboratory, Department of Environmental Sciences, Coimbatore	(Biogas Production Technology, Anaerobes in tannery effluent recycling.

	641 003 ensciens@mds.vsnl.net.in	
197	Tamil Nadu Agricultural University, Department of Microbiology. Coimbatore - 641 003	Biofertilizers for rice production
198	Tripura university (UGC) Agartala - 799004, Tripura State.	Mass culture of biocontrol agents
	Tuberculosis Research Centre Mayor V.R. Ramanathan Road (Spurtank Road) Chetput, Chennai-600031. Tel: 91-44-8265403 Fax: 91-44-8262137 Telegram: CHEMOCURE, Chennai E-mail: modeldots@vsnl.com director@trc-chennai.org Web address: http://www.trc-chennai.org/	The Centre undertakes research in the area of immunology and molecular biology of tuberculosis.
199	University of Agricultural Sci. (UGC) Banglore - 560065, Karnataka State.	Animal tissue culture based vacciens, microbial genetics, in vitro development of stress resistant sunflower, in vitro propagation of tropical fruits, immunodiagnostics.
200	University Department of Chemical Technology (UDCT) Matunga Road - 400019, Mumbai, Maharashtra State. http://www.udct.org/	Downstream processing programme M. Sc. (Technology), Mushroom cultivation, microbial polysaccharides, microbial enzymes, immobilisation, antibiotics and other fermentation studies.
201	University of Delhi, Department of Microbiology South Campus, Benito Juarez Road, New Delhi - 110 021	(1)Production and applications of xylanases for paper pulp bleaching. (2)Thermostable amylopullulanase from thermophilic bacteria.
202	University of Calcutta, Calcutta	Development of improved strains of methane producing bacteria through genetic engineering.
203	University of Hyderabad (UGC) Hyderabad - 500134, Andhra Pradesh State.	Animal tissue culture based vaccines, bioactive compounds, biosensors, peptide and nucleic acid chemistry, basic plant genetics, plant tissue culture.
204	University of Jabalpur (UGC) jabalpur - 482001, MP State.	Biopesticides, Industrial enzymes, Plant tissue culture
205	University of Jodhpur Jodhpur 342001	In vitro manipulation of prosopis cineraria
206	University of Kalyani Dept. of Biochemistry & Biophysics, Faculty of Science, Kalyani 741235	Techniques to improve bioleaching by use of cell surface dependent cell sorter and modelling
207	University of Karriavattom Dept. Of Biochemistry, Kariavattom, Trivandrum 695581, Kerala	Filarial parasites
208	University of Health Sciences (UGC) Vijaywada, Andhra Pradesh State.	Hypothyroidism, Immunology and immunodiagnostics
209	University of Manipur (UGC) Canchipur, Imphal - 795003, Manipur State.	Sericulture, cytogenetics of silkworms, fishery, study of fermented foods of Manipur, Plant tissue

		culture, Microbial genetics.
210	University of Mumbai	-
211	University of Mysore Mysore 570006	Proposal to establish Drosophila Resource Centre
212	University of Poona (UGC) Pune 411007, Maharashtra State.	Dairy technology, membrane biology, ETT, Bioinformatics, rDNA technology, Biochemical engineering, process optimisation and computer modelling.
213		Nitrogen fixing gene of Rhizobia, immunodiagnostics, peptide and nucleic acid chemistry, biomolecular interactions with drugs, study of cell membranes and surface proteins of plants, Study of palnt enzymes, microbial genetics.
214	UPASI Tea Research Institute	Studies on usage of pectinase to improve the quality of black tea.
215		Plant tissue culture studies, mass propagation of sal through tissue culture.
216	Vector Control Research Centre (ICMR) Medical Complex, Indira Nagar Pondicherry-605006 Tel: 91-413-72784 Fax: 91-413-72422 Grams: MOSQUITO E-mail:mosquito@md5.vsnl.net.in icmrvcrc@ren.nic.in	Study on Malaria, filariasis, immunodiagnostics, medical entomology
217	Vikram university (UGC) Ujjain - 456010, MP State.	DNA methylation of brain during ageing, Hormonal regulation of structure and function of chromatin during ageing.
218	Visva Bharati, Shantiniketan, Molecular Laboratory, Department of Botany, Santiniketan - 731 235	Molecular cloning of a plasmid coding for Streptococcin production in Streptococcus sp.
219	Vittal Mallya Scientific Research Foundation, Banglore, P B # 406, K R Road, Bangalore 560004, India Tel: 91-80-661 3223, 661 1664; Fax: 91-80-661 2806)	Recombinant DNA work - cloning and expression of human insulin in yeast, biopesticide from neem, energy efficient alcohol production, hydrocitric acid from fruits etc.
220	Vivekananda Institute of Biotechnology Sri Ramkrishna Ashram, South 24 Paraganas, Nimpith Ashram 743338	Blue Green Algae - Biofertilizer technology development
221	Vivekananda Parvatiya Krishi Anusandhan Shala (ICAR) Almora - 263601, UP State.	Cellular physiology and tissue culture in crop plants.

Source: www.biotechsupportindia.com

APPENDIX 3

Current Consumption and Anticipated Future Demand of Biotech Products in India

Biotech business in India (1997) sales of $ 500m.

- Biotech business in India (1997) sales of $1 billion.
  Human health-biotech accounts for 60% of sales.
  agbiotech and veterinary-biotech together account for 15% of the total revenue.
  medical devices, contract R&D and reagents and supplies constitute the remainder.
- The Indian government has granted marketing licenses for about 25 recombinant protein therapeutics. Recombinant insulin, human growth hormone, interferon and hepatitis B vaccine are the products with a larger market share. Medical proteins such as relaxin, rennin, the interleukins and Tumor Necrosis Factor also offer market opportunities.
- The total seed market has been estimated at $500 million, with expected sales of $1.5 billion by 2001. The genetically engineered seed market has an estimated value of $250 million. There are about 50 Indian private seed companies About 400 organizations are doing commercial research on agriculture: 200 research labs, 150 companies and 50 service firms.
- In 1998, (Department of Biotechnology of Ministry of Science and Technology) DBT'S budget was over $30 million.
- DBT has launched a 5 year $20 million Indian Genome Initiative (IGI) to study the genetic variation of the diverse Indian population.
- Human Healthcare - The vaccine market in India is currently approximately $100 million growing at the rate of more than 20% per year.
- India's diagnostic market totals approximately $50 million. Monoclonal and polyclonal antibodies for disease immunodiagnosis, tissue typing, clinical assays and research constitute a huge portion of the market.
- The animal health biotech market is yet another expanding field. It is expected to reach $200 million by 2001, with increasing demand for veterinary vaccines, diagnostics, therapeutics and protein feed.
- The global market for genetically modified (GM) crops may soar to $25 billion by 2010 from an estimated $3 billion in 1999 year, according to a non-profit organization tracking developments on biotechnology in agriculture.
- Biotechnology industry will grow to $35 billion by year 2004 from the current (1999) sales of around $ 7 billion.
- The Indian biotech industry employs about 10,000 people, which is expected to grow to 20,000 (research 50%, technical/services 35%, and management 15%) by 2001.
- Since development of indigenous know how by developing state of the art R&D facilities will be of

immense importance in the biotech sector, the 1999 financial budget has given proper weightage to it, and all biotechnology research over the next five years has been given 125 percent exemption over R&D spending.

- The total market-size for seeds in India is estimated at approximately Rs.5,000 crores - comprising of seed retained by the farmer (Rs.3,500 crores), public bred seeds (Rs. 1,300 crores) and research hybrids (Rs.200 crores).

- Flowers of late have become a money-spinning activity with the Indian Floriculture Industry earning forex to the tune of $ 5 million (approx. Rs. 18 crores). While world floriculture market is $ 25 billion worth.

- Demand for biotech products in human & animal healthcare in India was Rs.352 crores in the year 2000 and is expected to be Rs.574 crores by 2005.

- There are around 800 companies operating in all sectors of biotechnology. Only about 25 of them are working in modern biotech.

- India's presently employed biotech workforce of 10,000 is expected to double this year. Half of the increase will be in research, 35% in the technical and services sector; and 15% in management.

- Small and medium enterprises in plant tissue culture and aquaculture can enter the biotech industry, especially in contract research. About 23,000 such companies will soon serve international companies.

- The global bio-informatics industry clocked an estimated turnover of $US2 billion last year and this figure is expected to grow to $US60 billion by 2005. If industry and government work together, it is possible for India to achieve a 5% global market share by 2005.

- By 2010 the market is estimated to reach $4.5 billion.
  The immuno-diagnostic market is expected to increase four to five times by 2005. Diagnostics for malaria is expected to increase by more than 50 per cent.

- The World Bank has funded up to US$240 millions to the ICAR towards the National Agricultural Technology Project (NATP), a 5-year project to focus on plant and agriculture biotechnology research and private sector development.

- A study by Rabo India Finance indicated that the investments in bio-informatics have increased from Rs 3.85 crore in 1997-98 to Rs 6 crore in 1999-00.

- Biotechnology R&D in India has been largely dominated by Government-funded institutions that have absorbed nearly Rs 1,900 crore during the last five years. The total expenditure in 1999-00 have been to the tune of Rs 459 crore.

In India, the vaccines market is estimated to be around Rs 2.7 bn, growing at a rate of more than 35%.

Source: www.biotechsupportindia.com

Appendix 4

No.	PROJECTS	Institute
1	Molecular biology of virus of rice.	DU
2	Technique to develop multiplication of rice viruses.	DU
3	Development of disease-resistant rice against virus by transgene technology.	DU
4	Study on viruses of cassava.	DU
5	Development of eggplant transgenic plants to abioticstresses by metabolic engineering of polymine biosynthesis.	DU
6	Genetic manipulation of polymine and carbohydrate metabolism for osmotic stress tolerance in rice and eggplant.	DU
7	Genetic engineering of eggplant for disease resistance.	DU
8	Development of efficient plant regeneration protocols in different genotypes of indica rice.	DU
9	Genetic transformation of Taxus baccatta.	DU
10	Production of valuable breeding material of eggplant (solanum melongena L.) resistant to fungal bacterial witts, and root knot nematodes by using protoplast fusion.	DU
11	Manupulation of ril. Gene	DU
12	Bioremedration of HCH	DU
13	In virto morphogenic studies in jojo ba. Mass-propogation and somatic embryogenesis.	DU
14	Salt-stress induced sttraction in Rabiso activity.	DU
15	Transgenic Brasica junesa with enhanced potential to withstand salt & drought.	DU
16	Transformation of chickpea.	DU
17	Metal Accumulation by Bacteria and its Application.	DU
18	Metal Removal by Fungi - An Environmental Perspective.	DU
19	Development of phage display based protein engineering systems for diagnostics, prophylactics and therapeutics.	DU
20	Technology perfection and transfer of agglutination based detection of HIV - 1/2 antibodies in human blood.	DU
21	Strengthing of DNA sequencing facility at UDSC.	DU
22	Phage display technology for functional genomics.	DU
23	Identification of specific immunodominant epitopes using phage display fragmented genome library of M. tuberculosis.	DU
24	Phage display based structure - function analysis of human immunodeficiency virus-1 capsid protein p24.	DU
25	Assistance for carrying out work on limited improvement of the reagent being used in the kit.	DU
26	Production of urokinase using perfusion bioreactor.	IIT
27	Production of feed enzymes.	IIT
28	Production of animal feed.	IIT
29	Microbial production & Application of Enzymes in Fruit Juice Processing,	IIT
30	Production by Phytase for Poultry Feed.	IIT
31	Setting up of a biogas plant for treatment of domestic biodegradable waste.	IIT
32	Construction of expression vectors for coryneform bacteria.	IIT

33	Development of Biocatalytic process for desulphurization of Diesel.	IIT
34	TQ in Oral cancer.	AIIMS
35	Flocytonestry in Oral ca.	AIIMS
36	Immunology of Breast cancer.	AIIMS
37	Immune response in Breast ca.	AIIMS
38	ACE gene polymophism in relation to high attitude disorders.	CBT
39	Endothelial nitric oxide synthase gene polymorphism in relation to high attitude disorders (Bloodpressure/ hypertension).	CBT
40	Development of monodonal antibodies against human cardiac troposain T for an issunoarray.	CBT
41	Treatment of PalmOrlMnl Effluent	CBT
42	Enzymatic treatment of oil-seeds.	CBT
43	Tuberculosis.	CBT
44	Protein Toxin	CBT
45	Development of injutable system releasing erythromycin.	CBT
46	Development of liposomes containing mute allergen.	CBT
47	Development of Databases for diabetics.	CBT
48	Edible vaccine against Anthrax.	JNU
49	Generation of Non-toxic productive antigen for developing recombinant vaccine against anthrax.	JNU
50	Production of thermostable antigen against anthrax.	JNU
51	Laser Immunoassay for detection of AIDS in Blood serum.	JNU
52	Laser Immunoassay for Malaria.	JNU
53	Thermostablisation of Ban H2 restriction enzyme.	JNU
54	Transgenic Facility	JNU
55	Pentanucleotide defect Polymorphism & Atherosclerosis.	JNU
56	Anti-Pol. II antibody & multiple connective tissue disease.	JNU
57	Bovine immunodeficiency virus ...	JNU
58	Transformation of legumes.	JNU
59	Transformation of Cajanus Cajan.	JNU
60	Isolation of glyphosate tolerant cell lines of Aractus. H.	JNU
61	DNA fingerprinting of pulses, oilseeds & fibre crops.	NBPGR
62	Developing of molecular marker for ananlysis genetic diversity in sesame.	NBPGR
63	Validation of core collection of sesame using molecular markers.	NBPGR
64	Technology development for DNA fingerprinting of horticultural.	NBPGR
65	Technology development for DNA fingerprinting of selected medicinal plants.	NBPGR
66	Molecular assisted gene tagging in chickpea.	NBPGR
67	National containment facility for testing transgenic planting material.	NBPGR
68	Technology developemtn DNA fingerprinting of cereals & millets.	NBPGR
69	Ribozymes against HIV - I genes.	NII
70	HIV - I co-receptors	NII
71	Scavenger receptor mediated delivery of antisense oligonucleotides to macro phages.	NII
72	Site specific in-corporation of alpha amino iso-butyric acid (Aib) in sickle haemoglobin.	NII
73	Developing an immuno-sensor Anthrax.	NII
74	Impedance based immuno-sensor.	NII

APPENDIX 5

CENTRE FOR BIOCHEMICAL TECHNOLOGY

Mission Statement : -

" To translate concepts developed in basic biological research to commercially viable technologies for health care ."

Areas of Research :-

- Allergy , Immunology and Immunogenetics
- Immuno-diagonstics , DNA-diagnostics and Biosensors
- Nucleic Acids and peptide chemistry design and synthesis
- Recombinant DNA Technology
- Genomics ands Molecular medicine
- Genome Informartics
- Environmental Biotechnology
- Product and process development for Biologicals
- National Facility for Biochemicals and genomic resources

\+ **Concultancy and technical services**
\+ **Teaching and Training students , clinicals and technicians**

NATIONAL INSTITUTE OF IMMUNOLOGY

The National Institute of immunology is amongst India's foremost research institutions that conduct fundamental research in the area of human and veterinary health . Registered as an autonomous society receiving core funding from Department of Biotechnology , Govt. Of India . The institute primarily conducts research in the realm of immunology and molecular biology . The core areas in which research is conducted in this Institute can be broadly categorized as follows :-

- Reproduction and development
- Immunity and infection
- Molecular design
- Genetic Regulation

NII has over 20 labs investigating associated sub-disciplines . The Institute also runs a residential Doctoral programme with degrees being granted by Jawahar Lal Nehru University with which academic affiliation have been established .Some other facilities at the Institute are :

- Reagent Bank
- Small Animal Facility
- Primate Research Centre

NATIONAL BUREAU OF PLANT GENETIC RESOURCES (NBPGR)

NBPGR was established by the ICAR in 1976 with its main campus at New Delhi . it is the nodal organization in India with the national mandate to plan , conduct , promote and coordinate all activities concerning plant exploration and collections and also for safe conservation and distribution of both indigenous and introduced genetic variability in crop plants and their variability in crop plants and their wild relatives . The bureau is also vested with the authority to issue Import permit and Phytosanitary certificate and conduct Quarantine checks on all seed materials and plant propagules introduced from abroad or exported for research purposes . It has following main divisions :-

1. Division of plant Exploration and Collection
2. Division of Germplasm Evaluation
3. Division of Germplasm Conservation
4. Division of plant Quarantine
5. Germplasm Exchange Unit
6. Plant Genetic Resource Policy Planning Unit
7. Tissue Culture and Cryopreservation Unit
8. NRC on DNA Fingerprinting

Since , we are concerned with Biotechnology sector in this research We must look into the areas being covered in this Institute under this . Main Division carrying research in this front here is Nation Centre for Research on DNA Fingerprinting.

Mandate for NRC on DNA Fingerprinting :-

- Development of molecular marker systems for DNA profiling of economically important plants.
- Standardisation of experimental protocols , sample size and statistical methods for application of molecular techniques in variety identification , DUS testing and essential derivation.
- DNA fingerprinting of released / notified crop varieties , parental lines of hybrid and elite strains / genetic stocks of potential value in agri-horticultural crops (in collaboration with respective crop institutes).
- Molecular genetic mapping and gene tagging of some selected crop taxa (in collaboration with respective crop institutes).
- Training of manpower and human resources development in molecular market techniques.
- Co-ordination and interlinking of plant , animal and fish DNA fingerprinting programmes through technical consultation meetings.

INDIAN INSTITUTE OF TECHNOLOGY , DELHI

·DEPARTMENT OF BIOCHEMICAL ENGINEERING AND BIOTECHNOLOGY

This department was created in 1976 . The objectives of the department are :-

- Training and developing expertise in biochemical engineering and biotechnology at the post-graduate and Ph.D levels.
- R&D of various microbial and enzyme systems—understanding of biological/biochemical phenomenon underlying analysis and optimal design.
- Transfer of knowledge through seminars , symposia and short term courses at national and international levels.
- Carry out industrial consultancy jobs to solve the specific problems of bioprocess industries.

Major Research Activities :-

- Bioprocess and Enzyme engineering : Bioprocess engineering involves the translation of new products from shake flasks to large scale industrial production. Enzyme engineering is concerned with the development of enzymes which have specific functions or applications. Another aspect of this field is in creating novel techniques whereby enzymes give a significantly high turnover of a desired product.
- Bioseparation and Downstream Processing : The department is actively engaged in various unit operations which have a potential application in downstream processing . This is an area of concern to most bioprocess industries since downstream processing significantly adds to the cost of the final product.
- Environmental Biotechnology
- Animal and Plant Cell Culture
- Biosensors and bioprocess automation : Process instrumentation and control is significant component of modern bioprocess industries. Since the products of these industries have clinical applications , stringent quality control must be ensured. Also, high productivity and reproducibility of a process is for industry to be competitive in the market . Consequently , implementation of new control strategies and measuring devices has become an indispensable part of the growth of a bioprocess industry.
- Metabolic regulation, molecular biology and r-DNA Technology

CENTRE FOR BIO-MECDICAL ENGINEERING :-

The area of research and development of the center include :

- Biomechanics
- Biomaterials
- Rehabilitation Engineering
- Bioengineering in Reproductive Medicine
- Prevention and control of Injuries
- Biomedical instrumentation

DELHI UNIVERSITY

Department of Biochemistry :

The department is well equipped and offers research opportunities in the following areas :

- Liposomes as model membrane , as a vehicle for drug and enzyme delivery and in immunomyco diagnostics
- Molecular biology of myco bacteria and strategies for prevention and control of tuberculosis
- Expression and cloning of human antibodies using genetic engineering methods
- Phase display based protein engineering of protein A , human CD4 and anticancer antibodies
- Mechanism of translocation of polypeptide toxins from plants such as ricin, gelonin and diptheria toxin
- Role of various enveloped animal viruses and fusogenic liposomes (virosomes) in site specific delivery of biologically active molecules.

Department of biophysics :

The main research emphasis of the department is in the area of theoretical biology, membrane biophysics , in particular membrane channels . The department is equipped with electrophysiological set up which are most sensitive tools to study such channels. It has started research programme on Neural Network and perception . other areas of active reaearch in the Department are : enzymatic modulation of enzyme channels , biological spectroscopy , developmental biology and biosensors.

Department of Genetics :

The research interests of the department are in the area of heavy metal resistance in soil bacteria , fungi and higher plants , biochemical genetics of fungi , plant transformation , somatic hybridization , development of transgenic rice and vegetables resistant to diseases pests and environmental stresses , genetic engineering of polyamine and carbohydrate metabolism for stress tolerance and for studying plant development in vitro , plant tissue culture : molecular biology and functional significance of repetitive DNA , molecular genetics of human inherited diseases , fragile X syndrome , Schizophrenia and Breast and ovary cancer.

Department of Microbiology :

The research areas available are microbial differentiation, food and industrial microbiology , agricultural microbiology , medical microbiology and immunology.

Department of Plant Molecular Biology :

The areas of research activity include gene expression , photobiology and signal transduction mechanisms in plants , tissue culture and genetic transformation and stress molecular biology.

Other departments which are doing significant work in Biotechnology are :

Department of Botany
Department of Zoology
Department of Environmental Biology

(For details of areas of research being carried in these se 75th Annual Report , university of Delhi , 1997-1998)

JAWAHAR LAL NEHRU UNIVERSITY

School of Life Sciences :

The School of Life Sciences was established on the basis of report prepared by a working group headed by Prof. M.S. Swaminathan in the year 1970. This school has made pioneering effort since then to integrate physical sciences with biological sciences. The school has been recognized as the Centre for Excellence under UGC-COSIST and DSA Special Assistance Programmes.

Some facilities available in the School are :

- The Central instrumentation Facility : This facility houses some hundred odd sophisticated specialized equipment for research works of students and faculty.
- The Photographic Facility : Specialized services available in the photographic include both colour and black and white photography , preparation of slides , preparation of scientific artwork . The unit has facilities for taking of photographs of a variety of biological and scientific material , all types of electrophoresis gels, and autoradiograms.
- The Glass blowing Unit : This unit serves the need of designing small apparatus , glass joints and chromatography etc.
- The Animal House
- The Experimental Botanical Garden
- School's Library

The School has facility to carry out research in almost all frontiers of research in Life Sciences. The idea of this could be had from modules taught :-

- Biochemistry
- Microbiology
- Cell Biology
- Genetics

- Molecular biology
- Immunology
- Biophysics and structural biology
- Animal Physiology
- Plant/microbial Physiology
- Developmental Biology
- Bioinformatics
- Biostatistics
- Molecular genetics and genetic engineering
- Radiation biology
- Cancer biology
- Photobiology
- Neurophysiology
- Virology
- Molecular parasitology
- Hormone action and metabolic disorder
- Plant cell culture
- Free Radicals in Biology
- Membrane Biology
- **Etc.**

Centre for Biotechnology :

The special Centre for Biotechnology was established in the year 1985 under joint sponsorship of the UGC and the Department of Biotechnology , Govt. of India .Its aim is to generate manpower in different areas of biotechnology which would not only feed the Biotechnology related industries but would also provide trained and motivated persons required by other institutions.

Thrust areas of research :

- Protein engineering
- Eukaryotic gene expression
- Molecular biology of Infectious diseases
- Immunology
- Protein stability, conformation and folding
- Over expression of recombinant proteins
- Transcription of Eukaryotic genes
- Transgenic systems
- Molecular genetics of inherited diseases

(The center does not offer programme in Plant Biotechnology)

ALL INDIA INSTITUTE OF MEDICAL SCIENCES (AIIMS)

Research which falls under the category of Biotechnology related to Health and Medicine is carried out in this institute as this is the most premier institute of India dedicated to Training and research in Medical Sciences. (For detail see Annual Report , AIIMS)

Appendix 6

Information about FITT (Foundation for Innovation and technology Transfer), IIT Delhi.

- Steps taken to protect Intellectual Property Rights :

In a world where intellectual property is expanding the bounds of science and technology , the IIT- Delhi , has kept abreast of the latest developments in the IPR regime.

Recently IITD has launched a 'patent Clinic' where faculty members can solve their IPR problems . The clinic has been started in association with the patent facilitation cell of the TIFAC , a registered society under DST. IITD also offers a course on IPRs at its Department of Management Studies.

During the last few years , The FITT has taken a number of initiatives to promote IPR culture among the faculty members and students. This has obviously yielded results. In the last four years , more than 100 applications have been filed for patents, registration of designs and copyrights for software and publication by IITD students and faculty members. Compared to this only 15 IPR applications had been filed by the IITD faculty members in the previous 20 years.

FITT, which is the proactive industry interface of IITD , plays the role of facilitator since safeguarding of IPRs is the key to technology transfer. The mantra at IITD , infact, is ' Patent before you publish'. The earlier academic obsession of publish or perish is now being replaced by the 3P slogan of ' Patent, Publish and Prosper'.

The IITD standing IPR committee also looks into the possibility of simultaneously filing under the Patent Cooperation Treaty (PCT) route for safeguarding the rights of the investors in the international market.

According to Mr.Naveen Chak, executive consultant, Technology Transfer and Business Development at FITT :

" However, enquiries from bio-medical and bio-material areas have increased substantially in recent times".

- **N-WISE** (NISSAT's Window to Information Services for Entrepreneurs)

  An information support service unit had been set up in FITT since its inception in 1992 in order to keep abreast the industry with the technological developments , research activities and faculty and expertise of IITD and also to help IITD faculty to access details on industry as well as technology development information worldwide. In this endeavor a cell has been set up in FITT known as N-WISE by National Information system for Science and Technology (NISSAT) of DSIR inviting the industry /industry associations/R&D organizations and financial institutions to become corporate members of FITT at a nominal annual fees.

- Technology Business Incubation Unit

  The Technology and Business Incubation Unit is a place where technology entrepreneur starts converting his or her new idea/concept /service or product into a commercially viable business in technological association with members of the faculty and students of IITD. While the start up business incubates, the firm may continuously develop and bring its products to market. Eventually, the technology firm matures to the point where it can graduate from the Incubator and continue its growth as a viable Enterprise.

  Objective :

  ✓ To provide limited space for a limited period of time in the campus to new entrepreneurs , start-up companies and technology based organization to facilitate Research and Technology operation in areas of interest to the faculty of the institute .

  ✓ To incubate novel technology or business concept into viable commercial product or service.

  ✓ To encourage , nurture and support students and faculty with potential to convert innovative ideas and concepts into sound commercial venture.