THE MEDICAL BIOTECHNOLOGY INDUSTRY IN INDIA: A PRELIMINARY REVIEW

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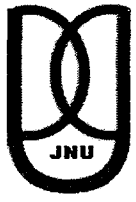
RAFI. P



CENTRE OF SOCIAL MEDICINE & COMMUNITY HEALTH
SCHOOL OF SOCIAL SCIENCES
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI-110067
INDIA

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CENTRE OF SOCIAL MEDICINE & COMMUNITY HEALTH
SCHOOL OF SOCIAL SCIENCES
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI - 110 067

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CERTIFICATE

This dissertation entitled "THE MEDICAL BIOTECHNOLOGY INDUSTRY IN INDIA: A PRELIMINARY REVIEW" is submitted in partial fulfillment of six credits for the award of the Degree of **MASTER OF PHILOSOPHY (M. Phil.)** of this University. This dissertation has not been submitted for the award of any other degree of this university or any other university and is my original work.

(Rafi. P)

We recommend that this dissertation be placed before the examiners for evaluation.

Prof. Mohan Rao

(Supervisor and Chairperson)

Chairperson
Centre of Social Medicine &
Community Health, SSS
Jawaharlal Nehru University
New Delhi-110067

Tel : (011) 26704420, 26717676, 26717557 Gram: JAYENU Fax : 91 (011) 26717586, 26704420

When introducing change for development, ask how the poorest of the poor will benefit from it

Mahatma Gandhi

Dedicated to my grand mom
(1911- 29th June 2008)

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Introduction

Introduction

The world has witnessed extraordinary advances in science over the last few decades. One such truly amazing development has been the discovery of double helix structure of DNA in 1953 which is considered as a major break through in biology. Since then, the world has entered a new era where, basic science powered with nanotechnology and information technology seems to be revolutionizing the future of medicine. The French Philosopher and social critic Jacques Ellul describes technology as an autonomous and uncontrollable force, which pervades social, economic and political life (Ellul 1990).[1]

Biotechnology is one such area which has been showing tremendous growth over a period of time and has impacted social and economic life. Many breakthroughs have already been achieved from this enormous sector in the field of health care, agriculture, food and environmental productions. It is one of the most important scientific and technological revolutions of the last century and has benefited various aspects of human life. Tracing the paths which the biotechnology industry has travelled over the years, it seems that the industry is poised to play a significant role in shaping the future of the global economy. The existence of a medicinal biotech revolution have been widely accepted and promoted by academics, consultants, industry and governments. Healthcare biotechnology, shares the major part of the biotechnology market and revenue through out the world. The increased involvement of the private players as the health service providers and their interest in the utilization of the modern technique had opened a new room for increased involvement of the technology in the health services sector.

Today the use of biotechnology in the field of medicine and biological research has become very important. It is increasingly playing a commendable role in the conventional drug discovery as well as opening up new possibilities to prevent, treat and cure diseases using novel methods of treatment test and diagnosis. It is important to state here that these new advances offer both potential benefits as well as risks.

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[1] Ellul, Jacques, (1990), "*The Technological Cliff*", Eerdmans, London.

The biotechnology revolution is gaining momentum all over the world and India is no exception. The importance of India's role in the field of biotechnology has been manifold since the inception of this industry in India. India is one of the leading biotech players among the developing countries in the world. Being nurtured as one of the most potential sectors by the Government of India (GOI) for the last three decades, the biotechnology industry in India is getting ready to surpass the ripple created by the IT industry in the 1990's. The impetus started with an initiative from the GOI in the mid eighties with the setting up a separate department- the Department of Biotechnology. Today the biotechnology sector in India has grown to a position where it is widely accredited and acknowledged though out the world. The international biotechnology companies are finding India as an irresistible attraction for their research and development for different reasons.

While the major advances in the biotechnology over the last thirty years have transformed the face of medicine in the industrialised countries, its innovations are yet to reach the world's poorest countries, where more than three billion people live on less than two dollars a day (Human Development Report 2007/08).[2] At the same time, whether biotechnology can address all the health issues of the developing world is a question that needs to be debated over, because health issues of these countries have links with major structural issues of the society like poverty. A close look into many of the disease prevention and treatment technologies shows that it has wholly or partially neglected the epidemiological aspects of diseases (Emanuelle 2005).[3]

This study is a preliminary review of medical biotechnology industry in India, which traces the growth of the biotechnology industry in India, in general and the medical biotechnology specifically. The study is based on the review of Five Year Plans of GOI, annual reports and publications of the Department of Biotechnology, books related to the topic, various articles published in journals, e-journals, various studies and reports by the Confederation of Indian industries, and other reports and market

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[2] Human Development Report 2007/08, URL: http://hdrstats.undp.org/indicators/24.html, Accessed online on 15th March 2008.

[3] Em. anuelle, Anne (2005), "Gates's Grandest Challenge: Transcending Technology as Public Health Ideology", URL: http:// image.thelancet.com/extras/04art6429web.pdf, Accessed online on 25th July 2008.

research published by the Bio Industry Organizations of India and U S, Europe and several other publications.

This study intends to look at,

a) The evolution and growth of Medical biotech industry in India.
b) What the global biotech scenario's influence is on the growth of the industry in India.
c) Why India is seen as a favorite destination for this sector.
d) The role of Private/Venture Capitals/Corporates in this sector.

Definition: Conventional and Modern Biotechnology

The word "biotechnology" was coined in 1919 by Karl Ereky, a Hungarian engineer, to refer to the methods and techniques that allow the production of substances from raw materials with the aid of living organisms (Sanson 2005).[4] A standard definition of biotechnology was reached in the Convention on Biological Diversity (1992)[5], it defines biotechnology as– "any technological application that uses biological systems, living organisms or derivatives thereof, to make or modify products and processes for specific use". This was later agreed by the 168 member nations, and also accepted by the Food Agriculture Organisation of the United Nations (FAO) and the World Health Organisation. So Biotechnology is a collection of techniques or processes using living organisms when applied on industrial and commercial scales, which in turns develops to added value products and services which give rise to bio-industries. The conventional biotechnology includes plant and animal breeding and the use of the micro organisms and enzymes in fermentation process and the preparation and preservation of the products.

Apart from the conventional definitions there are certain other definitions for the biotechnology. The broadest definition can be given as "the application of all natural sciences and engineering in the direct or indirect use of living organisms or parts of

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[4]Sanson, Albert, (2005), *"Medical Biotechnology: Achievements, Prospects and perceptions"*, United Nations University Press, New York.

[5] Convention on biotechnology (1992), URL: http://www.nssd.net/pdf/BIO-CONV.pdf, Accessed online on 23rd March 2007.

organisms, in their natural or modified forms, in an innovative manner in the production of goods and services and/or to improve existing industrial process (Ernst & Young 2001).[6] Thus it is the application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge and biotechnology products and services. Another definition refers biotechnology as "the application of molecular and cellular processes to solve problems, conduct research, and create goods and services" (OCED 2001).[7] So it includes a diverse collection of technologies that manipulate cellular, sub-cellular, or molecular components in living things to make products or discover new knowledge about the molecular and genetic basis of life, or to modify plants, animals and micro-organisms to carry desired traits. Modern biotechnology is a cluster of in vitro nucleic acid techniques, including recombinant deoxyribonucleic acid (r-DNA) and monoclonal antibody that use living organisms, or their derivatives, to make products or processes which involve the genetic transformation of living matter (Mugabe 2003). [8] So biotechnology is a broad term that applies to all practical uses of living organisms—anything from micro-organisms used in the fermentation of beer to the most sophisticated application of gene therapy.

U.S. government publications have defined biotechnology as "techniques that use organisms or their cellular, sub cellular, or molecular components to make products or modify plants, animals, and micro-organisms to carry desired traits" (Paugh & Lafrance 1997: 21).[9] This broad definition includes methods of treating disease developed from recent research in molecular biology and other fields, as well as the centuries-old practices of animal and plant breeding and the use of micro organisms to make leavened bread and fermented beverages. Therefore biotechnology is not defined by the products, but by the technologies or a set of enabling technologies used

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[6]Ernst & Young, 2001, Convergence , the biotechnology industry report , URL: goliath.ecnext.com/coms2/gi_0199-348451/Ernst-Young-Global-Biotechnology-Reports.html, Accessed online on 23rd March 2007.

[7] Organization for Economic Co-operation and Development (OCED), 2001, "Biotechnology Statistics: United States", URL: http://www.oecd.org/document/36/0,3343,en_2649_34537_2674020_1_1_1_37437,00.html, Accessed online on 23rd March 2008.

[8] Mugabe, John (2003), "*International Trend in Modern Biotechnology: Entry by and Implications for African Countries*", African Technology Policy Studies Network (ATPS), Kenya.

[9] Paugh, jon & Lafrance, John (1997), "*Meeting the Challenge: U.S. Industry Facts the 21st century; The U.S Biotechnology Industry*", Office of the technology of the U.S. Department of Commerce, New York, pp 21.

by a broad array of companies/institutions in their research and development and manufacturing activities to make the products.

Biotechnology is generally divided into three sub fields – the red, the white and the green biotechnology. 'Red biotechnology' deals with genetically altered micro-organisms that are used for producing products like insulin and vaccine for medical use. 'White biotechnology' involves the creation of useful chemicals for the industrial sector through organisms like moulds or yeast. This form of biotechnology is also referred to as grey biotechnology. 'Green biotechnology', also known as agricultural biotechnology, deals with applications related to agriculture.

Biotechnology and human health:

There is a wide spread belief that biotechnology is seeking new and better ways to enhance the quality of life through improvements in human health. It is argued that biotechnology offers a unique opportunity to create tools for prevention and treatment of disease (GOI 2007).[10] Medical biotechnology is intended to improve human health by developing new techniques for preventing diseases, curing ailments, producing products for transplants and improving the genetic makeup of individuals (Chase *et al* 2002).[11] The areas where biotechnology relates to human health includes Pharmaceuticals and diagnostics, treatment and tests. This is the main focus area of modern biotechnology. It is a fact that the contribution of biotechnology in the field of the discovery of medicines and vaccines which are used to fight diseases is centuries old. Medicines for the Diseases like *Cancer, Heart disease, Stroke, Diabetes, Arthritis, Obesity, Alzheimer's* and *AIDS* are some of the examples of this technology which helps us to understand the role of the laboratory techniques during the last half of the twentieth century which are significant. The role of the diagnostic methods helped us in understating the underlying causes of diseases.

Advances in biotechnology-driven diagnostic methods not only help the patients, but it is also a quick aid to the doctors too. Since Edward Jenner's systematic demonstration of using cow-pox to control the spread of small pox, biotechnology has

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[10]Government of India, Ministry of Science and Technology, Department of biotechnology India, URL: dbtindia.nic.in/index.asp, Accessed online on 23rd March 2007.
[11] Chase *et al* (2002), *op cit.*

provided more than 15 Vaccines. There is immense research going on in the field of designing new methods of immunization using the tools of the biotechnology.

One of the biggest leaps of biotechnology is the research on gene and gene therapy. This technology helped scientists to study an organism's gene by sequencing its deoxyribonucleic acid (DNA). The recently concluded Global Genome project and its out come are going to change the face of health care scenario. Apart from all these biotechnology is applied in the areas like Organ replacement Therapy, Stem cell research, Tissue Engineering etc.

Biotech industry

Biotechnology is not to be seen as an industry confined to the era of modern technology. In ancient times as well micro organisms were used for fermentation, domesticating animals for livestock, alcohol in the form of wine and beer, herbal remedies and plant balms for treatment of wounds and ailments etc. These can be sited as examples of ancient biotechnology. Looking back to the time prior to the 20th century we could find that attempts were made for the acceleration of scientific thoughts. Microscopes, first cork cell, protozoa, smallpox vaccine, Darwin's theory of evolution are some of the famous discoveries relating to this very field. The significant developments in the immunology, genetics, penicillin, computers, and the discovery of DNA as the genetic basis in the 20th century had paced the growth of modern biotechnology.

Modern biotech industry has developed rapidly over the last three decades. It is the one which deals with the application of biological knowledge and techniques pertaining to molecular cellular, genetic process to develop products and services. It is important to understand that the biotech industry now has almost captured every sphere of human life as its industry segment is very vast. Biotechnology therefore comprises a collection of techniques or processes using living organisms or their units to develop added-value products and services. When applied on industrial and commercial scales, biotechnologies give rise to bio-industries (Sasson 2005).[12]

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[12] Sansons (2005), *op cit.*

The study is organized into three chapters. The first chapter looks at the global biotechnology industry. Here we trace the evolution and growth of global biotech industry, its current status and its relevance in developing nations. The second chapter is a discussion on the medical biotechnology industry in India which focuses on the major development that has taken place in the sector and tracks the changes that happened to the biotech sector in India, i.e. the shift from the role of the government to an increased growth of private players in it. In third chapter, taking the case of hepatitis B vaccination as an example we will examine how far biotechnology based solutions can play to address a particular disease problem from a public health point of view. This will be followed by a discussion.

Chapter 1

Chapter 1

Global Biotechnology Industry

Benefits for human development are just beginning: Breakthrough applications in medicine and agriculture have huge potential for accelerating human development. But this potential will be truly tapped only if biotechnology is used to address the key health and agriculture challenges of poor countries - tropical diseases and the crops and livestock of the marginal ecological zones left behind by the green revolution. And only if this is done with a systematic approach to assessing and managing risks of harm to human health, environment and social equity.

-UNDP 2001[13].

1.1 Introduction:

Claims were made towards the end of the 20th century that the era of biotechnology was near at hand. Vishalakshi (2005)[14] states that the series of important scientific discoveries from 1980's onwards in the biotechnology sector have created a range of products which offer new hopes in the areas of global health and pharmaceuticals. The term biotechnology first appeared in 1920 in a bulletin of the Bureau of Biotechnology that was published from Yorkshire (Purohit & Mohan 1996).[15] In 1919 Karl Erekly, a Hungarian engineer, defined the term biotechnology as that field of work, which with the aid of living organisms produce products from raw materials. Erkely envisaged a biochemical age similar to the Iron Age (Murphy & Perrella 1993).[16]

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[13]UNDP (2001), "United Nations Development Report on Making new technologies work for human development", Oxford University Press, New York, pp 47. Also available at URL: http://hdr.undp.org/en/media/completenew1.pdf, Accessed online on 12th August 2007.

[14] Visalakshi, S, (2005) "Transferring biotechnology in India: Experiences and Lessons", National Institute of Science and technology and Development Studies, New Delhi. Working paper.

[15] Purohit S.S & Mohan S.K, (1996), "Biotechnology fundamental and applications", Agro Botanical publishers, India. URL : http//www.biotechnology /BT210/introl.html, Accessed online on 12th August 2007.

[16]Murphy,Ann and Perrella, Judy (1993), "*A Further Look at Biotechnology*" Woodrow Wilson Foundation Biology Institute. Princeton, NJ, URL: http://www.accessexcellence.org/RC/AB/BC/Overview_and_Brief_History.php. Accessed online on 12th August 2007.

The modern biotechnology industry which we see today has emerged over a period of time. Health-care innovation has transformed the practice of medicine over the course of the last century. It was in 1953 that Watson and Crick discovered the double helix structure of DNA which was considered as an important breakthrough in biology. Over the last fifty four years the world has witnessed some amazing developments in the biotechnology sector. We are now at the threshold of a new age where the unprecedented growth of science, with the support of nanotechnology and information technology, is revolutionizing the future of medicine. This chapter intends to look at the evolution and the current status of the global biotechnology industry.

In the first section of this chapter we will trace the evolution of biotechnology. We then look into the major scientific advancements that have led biotechnology to its present form. Universities played a significant role in the growth of the biotechnology industry; the next section of the chapter deals with this. We then look into the current status of the global biotechnology industry followed by a discussion on the funding patterns and about the agencies which are involved in funding the research and developments. The chapter concludes with a discussion on biotechnology and patenting.

1.2 Evolution of biotechnology

The process and evolution of ancient biotechnology to modern biotechnology industry is of great historical importance. The history of biotechnology began when human beings domesticated plants and animals, when they gathered and processed herbs as medicine, created fermented food products including yogurt, cheese and vaccines to immunize themselves against diseases (Wallman 1997).[17] Examples of such process go as far back as 5000 to 10000 BC (IRS).[18]

The development of modern biotechnology from its ancient form to the present one became possible as a result of better understanding and adapting of biological

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[17] Wallman, Sonia (1997), A short history of biotechnology, URL: http://www.biotech.nhctc.edu/BT220/Section_1_0_0.html - 7k, Accessed online on 12th August 2007.

[18] Internal Revenue Service (IRS), USA Department of Treasury, "Biotech industry overview-history of industry", URL: http://www.irs.gov/businesses/article/0,,id=169544,00.html, Accessed online on 27th August 2007.

sciences. Some of the major discoveries in this field of research include the isolation of DNA by Frederick Miescher in 1860s, the discovery of penicillin by Alexander Fleming in 1928, the discovery of the structure of DNA by James Watson in 1953, translation of the genetic code by Rosalind Franklin and Francis Crick in 1961, the first recombinant DNA experiment in 1973, creation of the first hybridomas in 1975 and so on. Other important advancements of this period were the start of the first successful biotechnology company called Gentech in 1976, successful gene splicing, the production of first monoclonal antibodies for digestion in 1982 and the manufacturing of first human therapeutic protein (Humulin) in 1982, etc. Various drug discoveries, cloning, the unprecedented growth of pharmaceutical industries, the sequencing of human genome and so on also were the results of wide ranging research in biotechnology. It is only by going through a prolonged period of evolution, starting from ancient biotechnology techniques to the modern period, that the biotechnology industry of today has reached a stage in which successful use of recombinant DNA is being done to produce recombinant protein. To obtain a better understanding, it is conveniently divided in to three phases.

1.3 Three phases of development of biotechnology

1.3.1 The First Phase:

From the point of view of its development, the history of biotechnology can be divided into three phases: the first phase is of ancient biotechnology, which involves biotechnologies prevalent in the ancient India and Egypt and other societies. Since prehistoric times, this phase of biotechnology has been flourishing in one way or another. When human beings first understood that they could grow their own crops and breed animals of their choice, they learned to use biotechnology (Brock 1961).[19] This involved the discovery that fruit juices could be fermented into wine, milk could be converted in to cheese or yogurt, beer could be made by fermenting solutions of malt and whey to make soft spongy bread, and so on (IRS 2007).[20] Simultaneously, animal breeders realized that there can be exaggeration or muting of selected traits by

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[19] Brock, Thomas D. (1961), "*Milestones in Microbiology*". Science Tech Publishers. Madison, Wisconsin. pp 273.

[20] Internal Revenue Service (IRS), Department of Treasury, USA, "Biotech industry overview-history of industry", URL: http://www.irs.gov/businesses/article/0,,id=169544,00.html, Accessed online on 27th August 2007.

appropriate mating of animals. They too engaged in the manipulations of biochemical or genetic characteristics of the organism.

This phase roughly lasted until the discovery of antibiotics in 1928. Biotechnology techniques used during this phase were mainly related to utilization of fermentation, together with trial and error techniques used for growing hybrid crops as well as animal vaccines. One important aspect to be noted here is that the ancient knowledge that brought about the exchange of genetic materials between different crop varieties or animal breeds were based on the experimental choice of the farmer or the owner of the animal herd, but they were not scientific (Hellemans & Bunch 1988).[21] But this fact in no way lessens the importance of those trials. Selection and trial had given a general idea about the characteristics of the resultant hybrid crop or animal variety. There was no scientific support to get the exact desired result and it was more learning by doing. For generations seeds were produced and selectively preserved for future use.

1.3.2 The Second Phase:

The second phase roughly started with the advent of penicillin, the first antibiotic product, developed by Alexander Fleming in 1928. This phase was characterized by the involvement of biotechnology utilizing micro organisms for medical purposes. The basic area of scientific involvement of this phase was of the microbiology (Microbiology, is that area of biological science which studies nature and characteristics of various microorganisms). The search for antibiotics began in the early twentieth century following the acceptance of germ theory, which propounded that various micro organisms are responsible for causing certain diseases in human and animals. The progress of scientific discovery during this period later found that not all organisms were harmful. Certain micro organisms could be utilized in counteracting the disease causing behaviour of other microorganisms without causing any harm. This concept led to the development of antibiotic and vaccines (Michigan

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[21] Hellemans, Alexander, and Bunch, Bryan. (1988), *"The Timetables of Science"*, Simon & Schuster. New York, pp. 660.

State University 2007).[22] Large scale production of these antibiotics came much later in 1940's. The German scientist Gerald Domagk investigated the effects of different chemical drugs and bacterial infections and found the drug "prontosil' cured the disease caused by streptococcus. This result started a search for synthetic antibiotics. This period lasted from 1920-1975 (Hellemans &Bunch 1988: 660).[23]

In the 1950's and 60's, pharmaceutical companies turned towards finding new sources for drug production as the existing processes were more time consuming and costly. Another important turning point in this industry was its ability to transfer genes from one microorganism to another in 1970's. In other words, the development of gene manipulation had cleared the roads for a novel and productive source for drug production. In this way, hormones such as human insulin and growth hormone were released in the market (National Health Museum 2007).[24] Another major milestone in the 1980's was the ability to produce any protein by recombinant methods in any amount needed.

1.3.3 The Third Phase:

The third phase of modern biotechnology started with the discovery of the recombinant DNA technique and polymerase chain reaction technique. These two proved to be the landmarks in the history of biotechnology. This technique brought the manipulation of natural genetic information under control within the laboratory. The exchange and utilization of genetic information between two naturally inter-breeding species could be realized with the help of various techniques developed later. This phase is still continuing with the development of more advanced techniques and is utilizing the information coded in the genetic expression of living beings (humans, plants, animals and microorganisms) for various purposes in the field of medical science, agriculture, enzymes, food and manufacturing industry.

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[22] Michigan State university, The history of biotechnology, URL: http://www.agriscience.msu.edu/specialprojects/biotechnology/biotechpart3.htm, Accessed online on 2nd November 2007

[23] Hellemans, Alexander, and Bunch, Bryan (1988) "*The Timetables of Science*", Simon & Schuster. New York, pp 660.

[24] National Health Museum, USA 1900 - 1953 - Converging on DNA, URL: http://www.accessexcellence.org/RC/AB/BC/1953-1976.php, Accessed online on 27th august 2007

Thus, three points of difference could be seen between ancient and modern biotechnology. First, the crossing of species was different from genetic engineering. The former allowed crossing only between natural interface species unlike the latter, which involves exchange and expressing of genetic information between non-interbreeding species. Second, the speed of expression was much slower in ancient biotechnology and took years to show up. Thirdly, the ancient biotechnology included a smaller number of plant and animal species and negligible knowledge about the utilization of microorganisms. In the next section of this chapter we will discuss the important landmarks of scientific advancement which has lead to the rise of modern biotechnology industry.

1.4 Chronology of scientific advancement in biotechnology field:

There has been a continuity in the content and form of biotechnology experienced by different generations. A common misconception is the thought that biotechnology includes only DNA and genetic engineering. However, biotechnology is not a new field of research. It is a well acknowledged fact that human beings have been handling living things to improve his way of life for millennia. We would now classify certain practices as biotechnology applications that have been in use since man's earliest days (IRS 2007).[25] We describes below the chronological timeline of biotechnology from the historic period till now.

It is recorded that in 6000 BC, yeast was used to make beer by Sumerians and Babylonians (National Health Museum USA)[26]; by 4000 BC the Egyptians discovered how to bake leavened bread using yeast. Socrates, the Greek philosopher, speculated (around 420 BC) on why children do not always resemble their parents. Hippocrates proposed that it is heredity, which is passed on to offspring from parents and sometimes skips expressions in the immediate generations. Around 1660-1675 AD Marcello Malpighi (1628-1694) used the microscope to study the circulation of blood

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[25] Internal Revenue Service, USA Department of Treasury, "Biotech industry overview-history of industry", URL: http://www.irs.gov/businesses/article/0,,id=169544,00.html, Accessed online on 27th August 2007.

[26] National Health Museum, USA "6000 BC - 1700 AD: Early Applications and Speculation", URL: http://www.accessexcellence.org/RC/AB/BC/6000BC-1700AD.php Accessed online on 27th August 2007..

in the capillaries and explained the nervous system as bundles of fibers linked to the brain by the spinal cord (National Health Museum 2007).[27]

Anton van Leeuwenhoek (1632-1723) was the first scientist to describe protozoa and bacteria to recognize that such microorganisms might play a role in fermentation (Hellemans & Bunch 1993).[28] In the early 18th century (1701) inoculation was practiced by intentionally generating small pox in children to prevent a serious case in later life. The late 18th century and the beginning of the nineteenth century witnessed the arrival of vaccination. During the 19th century Lewis Pasteur (1822-1895) proved that fermentation is the result of the action of yeast and bacteria, and invented the process of pasteurization. Germ theory was established during this time and Pasteur developed rabies vaccine in 1884, which underwent first human trials in the following year (Hellemans & Bunch 1988).[29]

In 1897, Edward Butcher demonstrated that fermentation can occur with the extract of yeast in the absence of its cells and this was a crucial moment in the history of both biotechnology and enzymology (National Health Museum 2007).[30] Later Friedrich Loeffler and P Frosch explained that the pathogen carried in food and mouth disease of cattle is so small that it can easily pass through the filters which trap the smallest of the bacteria. Later on these pathogens were called as the 'filterable viruses'. Ronald Ross discovered plasmodium, the protozoan that leads to malaria, in the anopheles mosquito and showed that the mosquito transmits the disease from one person to another. In 1900 Walter Reed established that mosquitoes transmit yellow fever, which was the first human disease known to be caused by viruses. Charles Darwin gave the theory of natural selection and Gregor Mendel proposed the laws of heredity in the 19th century. Walter Stanborough Sutton suggested that Mendel's factors are located on chromosomes and chromosomes are paired. After observing chromosomal movements during the meiosis process Sutton developed the chromosomal theory of

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[27] *Ibid*

[28] Bunch, Bryan and Hellemans, Alexander (1993), *The Timetables of Technology*, Simon & Schuster. New York, pp. 490.

[29] Hellemans, Alexander, and Bunch, Bryan. (1988), *"The Timetables of Science"*, Simon & Schuster. New York, pp 660.

[30] National Health Museum ,1700 - 1900: The Miracle of Life and Death Appears Smaller . . . and Smaller, URL: http://www.accessexcellence.org/RC/AB/BC/1750-1900.php, Accessed online on 27th august 2007.

heredity. In 1902 Thomas Hut Morgan proved that genes are carried as chromosomes, which established the basis of modern genetics. William Bateson demonstrated in 1904 that certain characters are not independently inherited. He introduced the concept of 'gene linkage' which led to the need for genetic maps describing the sequence of linked genes (Michigan State University 2007).[31]

In 1905, it was Nellie Stevens and Edmund Wilson who came up with the idea that the separate X and Y chromosomes determine sex. They demonstrated that one Y chromosome determines maleness and two copies of the X chromosome decide femaleness. William Bateson and Reginald Crudell Punnett during 1905-1908, with others expressed that certain genes can modify the action of other genes. This was the first recognition of the role for genetic factor in biochemistry. In 1909, Wilhelm Johannsen coined the terms 'gene' to refer the carrier of heredity; 'genotype' to explain the genetic formation of an organism; and 'phenotype' to describe the actual organism, which forms as a result of the combination of genotypes and of various other environmental factors. The basis of the modern genetics can be referred to the period of 1910 where Thomas Hunt Morgan proved that genes are carried by chromosomes, which established the basis of modern genetics (National Health Museum 2007)[32]. By 1920 Evans and Long discovered the human growth hormone. Later in 1927 Muller established that X-rays can cause mutation. One of the biggest breakthroughs in the history of scientific research happened in 1928 when Alexander Fleming discovered the first antibiotic named penicillin (Bud 1989) [33].

In 1937 Fredric Charles Bandon discovered that tobacco mosaic virus contains RNA. By 1949 Linus Pauling established that sickle cell anemia is a molecular disease caused due to mutation. The discovery of the of double helix structure of DNA by James Watson and Francis Crick in 1963 resulted in an explosion of research in molecular biology and genetics, paving the way for the modern biotechnology evolution. After Watson and Crick described the DNA structure in 1953, Crick and

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[31] Michigan State university, The history of biotechnology, URL: http://www.agriscience.msu.edu/specialprojects/biotechnology/biotechpart3.htm, Accessed online on 2nd November 2007.

[32] National Health Museum, USA 1900 - 1953 - Converging on DNA, URL: http://www.accessexcellence.org/RC/AB/BC/1900-1953.php, Accessed online on 27th august

[33] Bud, Robert, (1989),"Janus-faced Biotechnology - An Historical Perspective", *Trends in Biotechnology*, Vol. 7, pp. 230-33.

George Gamer established the central dogma of molecular biology and suggested that genetic information usually flows only in one direction from DNA to messenger RNA and from messenger RNA to ribosome to produce a protein. Nirenberg, Heinrich Mathaei, and Severo Ochoa in 1966 cracked the genetic code by demonstrating that a sequence of three nucleotide bases (a codon) determines each of 20 amino acids. Paul Berg in 1972 constructed the first recombinant DNA molecule by systematically joining two different strands of DNA in the lab from different species. Later Kholer and Milsten fused cell together to produce monoclonal antibodies (National Health Museum).[34]

In 1977, genetic engineering became a reality for the first time when a human protein in a bacterium was manufactured using a man-made gene. Genentech Inc., the first biotech company established in Berkeley California, reported in 1971 the production of the first "human protein manufactured in a bacteria: somatostatin", which is a human growth hormone-releasing inhibitory factor. In 1978, at the laboratory of Herbert Boyer at the University of California at San Francisco, a human insulin gene was constructed as a synthetic version and inserted in to the bacterium *Escheria coli'* (National Health Museum 2007)[35] and since then the pace of biotechnology development picked up considerably. It became more and more accepted in the field of diagnostics and therapeutic tools, with the advent of the quicker and powerful DNA sequencing and cloning techniques. Many consider this development as the arrival of the Age of Biotechnology. It became another milestone in the advancement of biotechnology when Genentech, Inc. and The City of Hope National Medical Center in 1978 announced the successful laboratory production of human insulin using recombinant DNA technology (National Health Museum 2007).[36]

In 1980, Key Mulli and others in Cetus Corporation in Berkeley, California brought out a technique for multiplying DNA sequence in vitro by the Polymerase Chain

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[34] National Health Museum (2008), *Op cit*
[35] *Ibid*
[36] National Health Museum, USA 1977-1999 the dawn of biotechnology, URL: http://www.accessexcellence.org/RC/AB/BC/1977-Present.php, Accessed online on 28th August 2008

Reaction[37]. One cannot forget the historic ruling of the U.S. Supreme Court of 1980, (The Bayh-Dole Act[38] , otherwise known as the University and Small Business Patent Procedure Act) which says that genetically altered life-forms can be patented. This catalyzed the growth of the biotechnology industry. In 1986, Ortho Biotech's Orthoclone OKT3, used to fight kidney transplant rejection, got approval as the first monoclonal antibody treatment. In the same year FDA approved the first biotech-derived interferon drugs for the treatment of cancer, Biogen's Intron A and Genentech's Roferon A. It was in 1988, that the first genetically engineered human vaccine, Chiron's Recombivax HB, got approved for the prevention of hepatitis B. In 1990, the world witnessed another leap in biotechnology history when the $13 billion project of the international effort to map all the genes in the human body was announced under the project name, 'The Human Genome Project'.

In 1996 a new inexpensive diagnostic biosensor test, which helps in the detection of the toxic 'strain of *E. coli strain 0157:H7* was discovered. This bacteria is responsible for several food poisoning outbreaks. The same year also witnessed the discovery of a gene associated with Parkinson disease which provided an important new path for research into the cause and possible treatment of the debilitating neurological ailment (National Health Museum USA).[39] Researchers at Scotland's Roslin Institute reported in 1997 that they had cloned a sheep —Dolly— from the cell of an adult ewe. In 1998, two research teams succeeded in growing embryonic stem cells, the long sought grail of molecular biology. By the end of 1999 a working draft of human genome map was produced showing the locations of more than 30,000 genes. And by 2001 the sequence of the human genome got published so as to make possible for researchers all over the world to begin developing treatments. The recent completion of human genome sequencing provides new hope in the field of diagnosis and treatment. Thus,

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[37]Polymerase Chain Reaction is developed by Kary Mullis in 1983 for which he got the Nobel Prize. It is used in medical and biological research for variety of applications, which includes the DNA cloning, the diagnosis of hereditary disease, identification of finger print (which is used in forensics tests), detection and diagnosis of infectious disease etc.

[38] The Bayh-Dole Act or University and Small Business Patent Procedures Act of 1980 of United States Legislation, allows the transfer of exclusive control over many government funded inventions to universities and businesses operating with federal contracts for the purpose of further development and commercialization, this is discussed in detail in the later part (university industry relationship) of this chapter.

[39] National Health Museum, USA, 1977-1999 the dawn of biotechnology, URL: http://www.accessexcellence.org/RC/AB/BC/1977-Present.php, Accessed online on 28th August 2007.

the transformation of biotechnology as an industry was preceded by both scientific and applied research.

Universities have always been at the center for the research and development that had taken place through these years. Similarly in the case of development of biotechnology the universities have played a crucial role which we discuss in the next section.

1.5 The university-industry relationship:

Technology transfer from university to industry has been a significant component in biotechnology innovation. In this section with universities in U.S as examples, we discuss how the bond between university and industry has developed over a period of time. Krimsky (2003)[40] argues that for the past several decades, the goals, values and practices of American research universities have been transformed in ways that have brought them in greater alignment with industrial interests. It is a fact that in most industrialized countries, the government has played a role in the development of university-industry relationships. Till 1940 the majority of the American universities and industries carried out their research on parallel tracks, interacting only in minor ways (Roger 1993).[41] Prior to this, researchers usually did some kind of consultation with the industries and corporation, but there were no substantial investments made except in some special cases of applied research during the 1920s (Krimsky 2003). [42]

If it was $3.1 million funds available in 1940 for scientific research in the U.S, after forty years the figures has surpassed $3 billion. University research before the World War II was done primarily through privately funded research system; public support however came to dwarf foundations and other sources of private financial support after the War. It was after the World War II that the federal funding started to increase steeply. In the 1960s the universities received between 6 to 8 per centof their basic and applied research funding from industry (Krimsky 2003).[43]

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[40] Krimsky, Sheldon ,(2003), *"Science in the private interest; has the lure of profits corrupted biomedical research?"*, Rowman and Littefield Publishers Inc, New York.
[41] Rojer L.Geiger's, (1993), *"Research and relevant knowledge"* , Oxford University Press, Oxford
[42] Krimsky, Sheldon, (2003), *"Science in the private interest; has the lure of profits corrupted biomedical research?"*, Rowman and Littefield Publishers Inc, New York..
[43] *Ibid.*

By the mid 1960s and the early 1970s the support from the industry for biotechnology research began to drop sharply, coming down to a mere 2 per cent. This was the period when the share of U.S. federal funding in the University Scientific Research programmes increased considerably, making corporate and industry funding less attractive. This situation however changed by late 1970s and early 1980s, when research funding from federal agencies dropped again, and the universities had to look for corporate and industry finance. A series of federal and state policies in 1980 established incentives for private companies to invest more heavily in university research. This provided the opportunity for universities to benefit directly from the discoveries made by their researchers and faculty members (Krimsky 2003).[44]

In 1970s, competitive forces in the U.S. provided an impetus for legislation aimed at stimulating the collaborative efforts for research and development between the public and private sectors. One such step was the Bayh-Dole Act of 1980, which allowed universities to claim the intellectual property rights on the products developed from federally funded research. Moreover, the Federal Technology Transfer Act of 1986, which created Cooperative Research and Development Agreements (CRADAs), allowed private companies to work with government agencies on a project. It resulted in a biotechnology revolution that developed new and commercially relevant DNA technologies. This move had also sparked and strengthened the industry-academia relationship (Blumenthal, 2003)[45].

The historic ruling of the U.S. Supreme Court in the case of *Diamond Vs Chakrobarty* in 1980, where the court ruled that genetically modified bacteria were patentable in-and-of themselves, apart from the process in which they are used, stimulated the aggressive growth of university-industry relationship. This decision helped scientists who had sequenced genes to claim intellectual property rights over their discoveries. Many scientists licensed it to private enterprises, and many of them even floated their own companies . The Bayh-Dole Act, otherwise known as the University and Small

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[44] *Ibid.*

[45] Blumenthal, D, (2003). "Academic-Industrial Relationships in the Life Sciences", *New England Journal of Medicine*, 349, pp 2452-2459.

Business Patent Procedure Act of 1980[46] helped in the evolution of the university-industry relationship in the U.S. As apart of these developments, private companies established research centers at the universities to foster cooperation between academia and industry.

There are different types of financial relationships between industry, academia, and the government. In certain cases direct assistance is given to the research projects of the university by the companies. A survey report in 1996 revealed that out of 210 life science firms surveyed in 1994, about 90 per cent of the firms had some relationships with academia. Of those, 59 per cent offered research support, while 38 per cent, through grants and fellowship, supported the education of students and their fellows (Blumenthal, *et al* 2003).[47] A study done by the same author in 1996 reported that about 25 per cent of the biomedical research faculty at top U.S. universities had received direct research support from industry in the previous year. The National Science Board of the U.S. says that Industrial R & D support to academic institutions has grown more rapidly than support from all other sources during the past three decades (National Science Board 2004).[48] Even though this support remains a small share compared to the support from federal agencies, it is estimated that the industry provided around $2.3 billion to the research and development for academic purposes in 2001.

Another means through which this relationship has grown is through technology transfer to industry and university spin-off companies. Since 1980, about 4,081 new companies that have acquired license from academic institutions have been established. The medium of consultancy and advisory board membership is yet

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[46] The Bayh-Dole Act or University and Small Business Patent Procedures Act of United States Legislation Act formed in December 12, 1980, allowing the universities intellectual property control over the inventions resulted from the federal research funding. This Act was formed as a part of the initiative took by two senators, Birch Bayh of Indianan and Bob Dole of Kansas. It is considered as a significant piece of legislation in the filed of intellectual property rights in United States. It also permits the Universities, small business or non profit institution to pursue ownership of their invention before the government.

[47] Blumenthal D, Causino N, Campbell EG, Louis KS, (1996), "Relationships Between Academic Institutions And Industry In The Life Sciences—An Industry Survey", *New England Journal of Medicine*, 334, pp 368-373.

[48] National Science Board (NSB), (2004), "*Science and Engineering Indicators*", Washington, DC: U.S. Government Printing Office, URL: http://www.nsf.gov/sbe/srs/seind04/start.htm, Accessed online on 15th December 2007.

another mode of knowledge transfer through which academic investigators pass on their knowledge to industry. A 1994 company survey of life science showed that of about 90 per cent of biotechnology researchers had a relationship with industries. Among them 88 per cent were working both as faculty and consultants, the most prevalent relationship (Blumenthal *et al* 2003).[49] A study published in the year 2000 says that 50 per cent research faculty at top U.S. universities had consulted for the industry in 1995 (Boyd & Bero 2000).[50] Apart from the research contracts there were cases reported of industry providing research-related gifts and materials. More than half of the academic researchers at reputed research universities surveyed in 1994 and 1995 had received research-related gifts for three years in a row in the form of research equipments, biomaterials, discretionary funds, student support, or travel funds (Boyd & Bero 2000).[51] 64 per cent of the scientists who received gifts reported that they were significant to the progress of their research (Campbell *et al* 1998)[52]

Another form of support is through equity relationships, where equity is used as an important mechanism for small companies to provide compensation for services. There is a dearth of complete and comprehensive data publicly available regarding the personal financial benefits for individual scientists (NSB 1998).[53] However, disclosures from a single institution (UCSF) found that 7.6 per cent of researchers had financial ties with industrial sponsors and 14 per cent held equity (Boyd & Bero 2000)[54]. Even though there is less evidence of the engagement of government researchers with the industry, certain studies show the existence of such relationships (Campbell *et al* 1998).[55]

[49] Blumenthal *et al (2003), Op cit.*

[50] Boyd E and Bero L (2000), "assessing faculty financial relationships with industry: a case study", *Journal of American Medical Association*, 284(17): 2209-2214.

[51] *Ibid.*

[52] Campbell EG, Blumenthal D, Louis KS, (1998), "Looking a gift horse in the mouth: Corporate gifts that support life science research". *Journal of American Medical Assocaition*, 279(13):995-99.

[53] National Science Board (NSB) (1998), "Task Force on Industry Reliance on Publicly Funding Science", *Industry Trends in Research Support and Links to Public Research*. NSB 98-99. Arlington, VA: National Science Foundation, URL: http://www.nsf.gov/pubs/1998/nsb9899/nsb9899.htm, Accessed on 12th February 2008

[54] Boyd E and Bero L (2000), "Assessing faculty financial relationships with industry: A case study", *Journal of American Medical Association*, 284(17): 2209-2214.

[55] Campbell EG, Koski, G and Blumenthal D, (2004), "The triple helix: University, government, and industry relationships in the life sciences", AEI-Brookings Joint Center for Regulatory Studies Working Paper 04-12, http://aei-brookings.org/admin/authorpdfs/page.php?id=1000, Accessed online on 16th February.

Throughout the last thirty years, the growth of university-industry relationship has been unprecedented; a fact that is evident in biotechnology, where company-sponsored university based research was 20 per cent higher than the overall average for other industrial sectors. It is estimated that nearly 50 per cent of biotechnology firms are supporting research in universities (Krimsky 2003).[56] By 1984, the industrial support for biotechnology in universities totaled $120 million, which was about 42 per cent of the overall industry-supported research.

However, this relationship has faced serious challenges over time, including financial conflicts of interest Certain members of the U.S. Congress have started to express reservations about the industry-university research agenda, in addition to the criticizing the promotion of this new collaborative arrangement. Objections were raised to the use of public money for industry research agenda. According to Slaughter and Leslie, "the United States is the only country in which universities hold title of the intellectual property developed by the faculty with federal grants." (Slaughter & Leslie 1997 :223).[57]

There were also questions raised by the U.S. policy makers on this unholy relationship during a series of hearings that took place in between 1981 and 1990. Doug Walgern, a co-chair of the U.S. Congress in the 1990s asked, "can universities successfully preserve the free exchange of ideas between students and faculty while meeting the obligations of industrial arrangements?" (Krimsky 2003).[58] Later in the continued hearings of 1991, cases started to come up exposing the down side of the industry-university collaborations. It was revealed that the companies are promoting gifts and travel grants to the physicians so as to shape a positive attitude towards their company and products. Later on it was reveled that academic scientists have been involved in the ethically questionable entrepreneurial ventures.

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[56] Krimsky, Sheldon , (2003), "*Science in the private interest; has the lure of profits corrupted biomedical research?*", Rowman and Littefield Publishers Inc, New York, pp 73.
[57] Slaughter, Sheila & Leslie, Larry.L., (1997), *Academic Capitalism*, The John Hopkins University Press, Baltimore, p.223.
[58] Krimsky (2003), *Op cit.*

One such case illustrates the kind of problems in the new partnership between the university (University of Minnesota) and industry. In 1970, the Food and Drug Administration granted investigative new drug status to the University of Minnesota for the experimental drug Antilymphocyte Globulin (ALG). Made from horse tissue, the product was used in organ transplants to prevent the new host's rejection of the foreign organ. Human cells were injected into horses, and afterwards the animals were bled and their serum was extracted. The drug showed considerable promise in suppressing the body's immune system to reduce the risk of organ rejection. ALG was developed by members of the Department of Surgery, the University of Minnesota Medical School, and it was used for two decades. However, the drug carried only experimental status and was never approved by the FDA for general use. According to officials of the University of Minnesota, ALG was manufactured by the university for nearly twenty-two years and was applied in the treatment of more than one hundred thousand transplant patients in over hundred medical centers and hospitals (Krimsky 2003).[59]

In a later investigation it was revealed that the University Medical School had violated norms and ethics in the ALG programme. In the early 1990s, two journalists Joe Rigert and Maura Lerner of the Star Tribune closely followed this case and wrote that in the ALG case, the University was operating like a small drug company of its own, and even built one research facility of $12.5million from the fund of ALG sales (Rigert and Lerner, 1992)[60]. Along with these, it is revealed that the faculty of the Minnesota University Medical School had set up a nonprofit corporation which had brought in more than $84 million since the mid 1980s. Even though the development, marketing and sales of drugs are not part of the university charter, this incident brought a dark shadow over the institution. There were several unethical cases of different kinds reported from the various leading universities of the United States as a consequence of the university-industry collaboration.

Literature in this field informs us that advanced economies are giving attention to direct contributions from universities to advance industrial competitiveness. As an

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[59] Krimsky (2003), *Op cit*

[60] Rigert, Joe and Lerner, Maura, (1992) "Audits say 'U' knew of ALG problems", *Star Tribunes*, August 23, 1B, 3B.

important follow up of this trend in various countries around the world, inspired by the Bayh-Dole Act of 1980, have been giving their universities a more active role in taking out patents emerging from academic research and in pursuing their commercialisation. While more countries are adopting the Bayh Dole policies and developing the administration for their implementation, an increasing body of research is beginning to question the consequences of the added thrust on 'university property rights' (Cohen 2004).[61]

The presence of the medicinal biotech revolution is a widely accepted and established factor which is encouraged by academicians, consultants, industries and governments. This acceptance has created a hope about an improvement in the drug discovery and economic development process. This has also greatly influenced policy making in biotechnology. The worldwide biotechnology industry has largely originated from the university-industry collaboration, and has today become one of the major and fastest growing industries of the world. In the next part of this chapter, we look into the current status of the global medical biotechnology industry.

1.6 The Current status of Biotechnology Industry:

The biotechnology industry is one of the most research and development- oriented and capital intensive industries in the world. Orginating in the 1970s based largely on the recombinant DNA technology, this industry has created a number of vaccines and therapies till now which aimed at treating several diseases. It is estimated that there are more than 400 biotech derived drugs and vaccines under clinical trials targeting about 200 diseases including *AIDS, Heart Disease, Alzheimer's, Diabetes* (Bio Industries Organization 2008).[62] The strength and opportunities in the biotechnology sector is now discussed worldwide, as it has created a revolution in the fields of medicine, pharmacy, material science, forensic science, food preparation, agriculture, fuel production, industry, information technology, forestry, military, etc., with a Compounded Annual Growth Rate (CAGR) of 17.51 per cent in the last 10 years. This is one of the fastest growing industries in the world. The revolutionary change,

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[61] Cohen, W.M. (2004), "Patents and Appropriation: concerns and evidence", *The Journal of Techonology Transfer*, 30 (1-2), 57-71.

[62] Biotechnology Industry Organisation (BIO), Biotechnology Industry facts, URL: http://www.bio.org/speeches/pubs/er/statistics.asp, Accessed online on 12th January 2008.

made by this innovative technology, has opened the gateway to a new information economic era. The table below represents the current status of the global biotech industries.

Table: 1

Global Biotechnology at a Glance in 2006					
	Global	USA	Europe	Canada	Asia-Pacific
Public company data					
Revenues (US$m)	73,478	55,458	11,489	3,242	3,289
R&D expense (US$m)	27,782	22,865	3,631	885	401
Net loss (US$m)	5,446	3,466	1,125	524	331
Number of employees	190,500	130,600	39,740	7,190	12,970
Number of companies					
Public companies	710	336	156	82	136
Public and private companies	4,275	1,452	1,621	465	737

Source: Ernst & Young
Numbers may appear inconsistent because of rounding
Employment totals rounded to the nearest hundred in the U.S., and to the nearest 10 in other regions

The international biotechnology market, which started 37 years ago with a few U.S. start-ups to manufacture protein drugs, is now one of the fastest growing industries in the world and an emerging global industry with more than 4275 companies in the U.S., Canada, Europe and the Asia-Pacific region. The industry emerged in the U.S. as a result of the easy availability of venture funding sources, and it has a share of more than half of the world biotechnology market. As per the Ernst and Young Report of 2007, the total turnover of the industry worldwide is $73.5 billion, led by the U.S. biotech industry and followed by Europe, Canada and the Asia Pacific region. Compared to the U.S. and Europe, the biotech sector in Asia Pacific region is very small, with a revenue of a mere $3 billion . The industry directly employs about 1,91,000 people world wide, of which sixty one per cent are in the U.S., twenty one per cent are in Europe, four per cent in Canada and the remaining six per cent in Asia Pacific region. While this number seems to be low, compared to other industries, conservatively speaking the biotech industry generates three to five jobs for each direct job in the subsidiary industries (Ernst & Young, 2007). Out of the 4275 global companies, 710 are owned by the public sector. Even though the majority of the market share is owned by the U.S. biotech companies, the number of biotech

companies is more in Europe. A majority of these companies in the European countries are newly established firms. In the case of revenue earned from biotech products the U.S. biotech companies are in a leading position. Hoever, they also have more losses reported compared to the other regions of the globe.

In the last few years the story of the global biotechnology industry has been perceived as one of remarkable successes. After a period of two years, which witnessed a high degree of retrenchments in the wake of the genomics bubble, the biotechnology industry after 2003 has emerged with newfound focus and strength. As reported by Ernst & Young in 2007, companies reinvented themselves using creative strategies to accelerate their product development efforts (Ernst & Young).[63] The year 2006 witnessed a strong financial improvement along with the return of investors to the sector. A robust pipeline for products approval was in place in the U.S., the global leader in the biotechnology sector. According to the Ernst and Young[64] Report of 2007, the signs of the success stories of the U.S. are now being repeated in other parts of the world, with the maturing of products development pipelines, record breaking financial results, and so on.

The table below represents the details of the percentage of biotech competitiveness indicator for different nations in the year 2006:

Table: 2 Biotech Scientific Competitiveness Indicators, 2006

Country	Scientific Paper Citations	Rank	Share of Global Biotechnology Patents (%)	Rank
U.S.	**37,822**	**1**	**43.3%**	**1**
U.K.	7,565	2	5.3%	4
Germany	7,497	3	9.6%	3
Japan	6,298	4	14.1%	2
France	5,172	5	3.6%	5

[63] Ernst and Young (2007), "Beyond Borders: the Global Biotechnology Report", URL:www.ey.com/beyond borders, Accessed online on January 12th 2008.

[64] Ernst & Young, a global leader in professional services, is a professional services firm in the financial reporting with 114,000 people in 140 countries. The Ernst & Young's Global Biotechnology Center is the hub of the Ernst & Young network of professionals serving the global biotechnology market and connects people around the globe, sharing information and experience on current and emerging industry issues.

Country	Scientific Paper Citations	Rank	Share of Global Biotechnology Patents (%)	Rank
Canada	4,194	6	2.7%	6
Italy	3,363	7	1.0%	15
Netherlands	2,665	8	1.7%	9
Australia	2,273	9	2.1%	7
Switzerland	2,168	10	1.4%	12
Spain	2,042	11	0.8%	16
Sweden	1,960	12	1.2%	13
China	1,481	13	1.7%	9
Belgium	1,206	14	1.1%	14
Denmark	1,052	15	1.8%	8
Israel	1,039	16	1.6%	11
Russia	1,019	17	0.2%	19
Finland	893	18	0.5%	18
Korea	841	19	-	-
India	789	20	0.8%	16

Source: Ernst & Young: "Beyond Borders: the Global Biotechnology Report 2007"

The above table shows that the U.S. is leading other countries in terms of scientific competitions, i.e. scientific paper citations and the share of global biotechnology patents. However, if the European countries are taken together, its indicators are almost equal to that of the U.S. In the Asia Pacific region Japan, is the leading country followed by China. India trails in the last position in terms of scientific paper citations, and has sixteenth rank in the share of global patenting among the first twenty countries. Interestingly, even though the U.S. still leads the other regions in the biotech industry, the European biotech sector sustained their recovery which had begun in 2005. The overall profit for the period 2006 was 13 per cent which is more than twice the growth rate of 6 per cent in 2005, i.e. €13.3 billion (US$16.6 billion) for both public and private companies. 2006 also marked a four-year turn around from its 12 per cent revenue decline recorded in 2003. Financing increased by a robust 45 per cent to reach €4.7 billion (US$5.9 billion). Venture capitalist financings touched a

high point of €1.5 billion (US$1.9 billion). The pipelines of publicly traded companies showed an impressive growth of 30 per cent, bringing the overall pipeline to roughly 700 compounds, along with 27 compounds in registration and awaiting approval from the regulatory authority. Apart from these the Europe's privately owned biotech companies have nearly 800 compounds in their pipelines, and 12 compounds waiting for registration.

The interim report of the recently concluded Biotech Industries Organization's conference 2008, at San Diego in U.S commented that the revenue of biotech industries is poised to reach $100 billion by 2010 from the present turnover of $85 billion. The revenue during the 2007 financial year had reported an increase of 16 per cent (i.e to $85 billion) from its pervious year ($73.5 billion) (Bio Industries Organization, 2008). The table below represents the data on the revenue and the net income of the world's 25 top biotech companies in the financial year 2007.

Table: 3 Leading Biotech Companies 2007 - by Revenue and net Income

Company/Country	2007 Revenue (billions)	% Growth	2007 net Income (billions)	% Growth
1. **Amgen (U.S.)**	$14.8	+4%	$3.2	+7%
2. Genentech (U.S.)	$11.7	+26%	$2.8	+31%
3. UCB (Belgium)	$5.0	+42%	$.2	(56%)
4. Gilead Sciences (U.S.)	$4.2	+40%	$1.6	>999%
5. Genzyme (U.S.)	$3.8	+20%	$.5	>999%
6. Biogen Idec (U.S.)	$3.2	+18%	$.6	+193%
7. CSL (Australia)	$2.8	+14%	$.5	+359%
8. Cephalon (U.S.)	$1.8	+1%	($.2)	(>999%)
9. Celgene (U.S.)	$1.4	+56%	$.2	+128%
10.Actelion	$1.1	+39%	$.1	(49%)

Company/Country	2007 Revenue (billions)	% Growth	2007 net Income (billions)	% Growth
(Switzerland)				
11. Amylin Pharmaceuticals (U.S.)	$.8	+53%	($.2)	+3%
12. Elan (Ireland)	$.8	+36%	($.4)	(65%)
13. ImClone Systems (U.S.)	$.6	(13%)	>$.1	(>999%)
14. Millenium Pharmaceuticals (U.S.)	$.5	+9%	>$.1	NA
15. OSI Pharmaceuticals (U.S.)	$.3	+41%	$.1	>999%
16. Abraxis Bioscience (U.S.)	$.3	+84%	(>$.1)	NA
17. Cubist Pharmaceuticals (U.S.)	$.3	+51%	$.1	>999%
18. Crucell (Netherlands)	$.3	+55%	($.1)	100% [1]
19. Nektar Therapeutics (U.S.)	$.3	+25%	($.1)	NA
20. Biocon (India)	$.3	+10%	$.1	+25%
21. PDL BioPharma (USA)	$.3	+4%	-	NA
22. Alkermes (U.S.)	$.2	+44%	-	+125%
23. United Therapeutics (U.S.)	$.2	+32%	-	(73%)
24. ViroPharma	$.2	+28%	$.1	+42%

Company/Country	2007 Revenue (billions)	% Growth	2007 net Income (billions)	% Growth
(U.S.)				
25. Vertex Pharmaceuticals (U.S.)	$.2	(8%)	($.4)	(100%) [2]
Top 25	$52.5	+13%	$8.7	+129%

Source: (Rosen 2008)[65]

Of the top 25 biotech companies nineteen are based in U.S, while six companies hail from Europe to India to Australia. The top twenty five companies represent sixty two per cent of all biotech sales. Out of the first ten leading companies seven are from U.S and the rest from the Europe. Among the developing nations for the first time India as made its presence with Biocon, a Bangalore based biotech company coming at the twentieth rank. The company had made an increase of 10 per cent ($3 billion) in revenue and a soaring 25 per cent ($1 billion) net profit compared to the previous financial year. Biocon is the only company listed in the list from the Asia Pacific region.

Even though the United States still dominates the biotechnology industry, the governments around the world are trying their best to attract the huge revenue potential of this industry by adopting new policies and providing attractive incentives. The biotechnology firms in Asia Pacific and other regions of the world are also slowly making their presence felt in the global biotechnology industry. Even though presently concentrated largely in the U.S. and Europe, the biotechnology industry has started to make ripples during the last decade in the developing countries too. India, China, Cuba, Brazil, South Korea, South Africa etc are some of the developing countries where biotech industry has successfully emerged and made their presence

[65] Rosen, Michael, (2008), "Biotech heading for $100 billion annual business by 2010", URL: http://wistechnology.com/articles/4878/, Accessed online 15th July 2008.

felt. In the next section of the chapter, we will discuss briefly the growth of biotechnology industry in developing countries, citing a few examples.

1.7 Biotechnology in the developing nations:

Traditionally the U.S has been viewed as the world-leader in the area of biotechnology innovations. Yet as globalization becomes more prominent and technology spreads worldwide, other developing nations also have come to the forefront of the biotech arena. Developing countries have slowly started to respond to the public health needs with comprehensive research regarding the local health concerns. For example, even though Sub-Saharan Africa has only 10 per cent of the world population, it is home to more than 60 per cent of the HIV affected population in the world (SAAVI 2005).[66] As a result of these, extensive research and development efforts are going on in Africa to develop a vaccine for HIV. South Africa is the only nation on the continent that is conducting clinical trials for HIV-candidate vaccines. This effort has been coordinated formally since 1999 by a joint government and private-sector initiative known as the South African AIDS Vaccine Initiative (SAAVI, 2005)[67]. This phenomena is being replicated throughout the developing countries, such as the insulin-related research in Egypt. Egypt was facing acute shortage of insulin and was dependant on overseas imports of insulin. A rapid research and development programme sponsored by the Egyptian government has now helped the country to produce 90 per cent of the insulin domestically and thereby saved millions of dollars. Other developing countries also have had similar experiences (Abdelgafar, *et al*, 2004).[68]

Government's involvement as a policy maker, architect as well as a funding partner is cited as the reason for the development of biotech sectors in developing countries. Governments of certain developing nations took an interest in biotechnology in the early 1980s itself. The best example of this is the initiative of the Government of

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[66] SAAVI (South African AIDS Vaccine Initiative), "Background and establishment of SAAVI", URL: «http://www.saavi.org.za/index.htm», Accessed online on 14th January 2008.
[67] *Ibid*
[68] Abdelgafar B, Thorsteinsdóttir H, Quach U, et al, (2004), "The emergence of Egyptian biotechnology from generics." *Nature Biotechnology*. Supplement, December pp 25 to 30 .

India. India stressed the importance of developing its pharmaceutical and biotech sectors as early as in 1980 in its sixth 5-Year Plan. It also created a Department of Biotechnology and invited international experts to serve on its oversight committee in an effort to maximize the use of government funds.

Another reason for the development of biotechnology in the developing countries is the decision of the respective governments to leverage their natural and traditional resources as well as industrial competencies to establish unique biotech sector. Similar were the decision of the Brazilian government to use the vast and rich Amazon forest, or the decision of the Cuban government to use their scientific experience with sugar cane —a major cash crop-to create pharmaceutical agents from the plant, most notably PPG, a cholesterol-lowering agent that is exported to many developing nations (Carr 1999).[69] In the meantime the Indian government highlighted its highly educated population and its large pool of well-trained, English-speaking science and technical experts for bringing FDI into the biotechnology sector, and to keep its highly skilled workers at home (Jayaraman 2004).[70] Similarly, other developing nations also adopted several policies to support the growth of the biotech sector. These are a few examples of the effective policy decisions from the governments in the developing countries to promote their domestic biotechnology industry.

Even though the government funding has been viewed as the primary source of capital for biotechnology research and development, the role played by the private sectors in the development of biotech sector in developing countries cannot be ignored. The globalization wave that came about in the 1990s and the liberalization policies adopted by the developing countries as a result of the influence from the World Bank economic policies has helped the private players to enter and invest in the new economic industries of the developing nations. Biotech industry was one among them. This later resulted in the technology-transfer between the industry and the research universities in public sectors in the name of commercialisation of the

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[69] Carr, K, (1999), "Cuban biotechnology treads a lonely path", *Nature* ,Vol. 398, Issue 6726, Apr Suppl, pp A22-23.

[70] Jayaraman K S , (2004), "Among the best", *Nature,* ;436:492–495, URL: «http://www.nature.com/nature/ journal/v436/n7050/full/436492a. html». Accessed online on 14th January 2008.

product developed by the public institutions. Meanwhile, in response to the global biotech wave, the governments in the developing nations also acted as facilitators by providing infrastructure, incentives and relaxing regulations to promote the biotech sector. The multinational enterprises of developed nations had already made their presence heavily felt in the biotech sector of the developing nations in the form setting up their own units as well as outsourcing their research and development activities. Many developed nations and their multinational companies around the world have now shifted their lab activities including clinical trials, stem cell research and vaccine/drug development, to the developing nations in order to take advantage of the vast resources, potentials and cost efficiency. All these inroads made by the private sector highlight the growing control and powerful role of the private and multinational players in the biotech sector of developing nations. Thus, over a period of time the governments of the developing nations have been relegated from a leading position to a subsidiary position, allowing the private players to dictate their domestic biotech industries.

Research and development in biotechnology field is capital intensive, as it involves a financing of inputs for several years without outputs. For established firms this is not at all an issue as they have there own resources in the form of capital, liquidity and banking. As the world witnesses the phenomenal growth of biotechnology more and more financial institutions are coming up over a period of time to support new firms and also existing ones for research and establishment. Venture capital is one such source which has strongly supported biotechnology initiatives. The next part of this chapter discusses the role of venture capital, the main source of funds for biotech research and development.

1.8 Venture Capital funding in biotechnology

The venture capital industry plays an important role in overall economic landscape in developing countries (National Venture Capital Association)[71] and this is true both in the case of biotechnology and information technology. It is a fact that most of the biotechnology companies would not exist without the financing option of venture

[71] National Venture capital Association , economic impact of the venture capital industry on the U.S economy 2001, URL: venture capital industry on the U.S economy, NVCA 2001, Accessed online on 12th January 2008)

capital. This is because developing a successful drug require a longer timeframe, at times even a decade or more. The factors governing research in the biotechnology sector are quite different from other sectors financed by the venture capitals which run on shorter time frames. If we examine the issue historically, we find that the biotechnology companies have been successful in attracting significant funding in the private and public equity markets without substantial revenue streams and with potential revenue lag times of five or more years. One primary reason for such high rate of funding is that the economic failure rate of biotechnology companies has been much lower in comparison to any other industrial sector over the last one decade (Lee & Dibner 2008).[72]

Biotechnology-based businesses have historically looked to venture capitalists for funding. Hugh initial investments are required to set up biotechnology companies. Unlike 'real' business, they do not have products or services to sell at the beginning. Usually venture capitalists build up their resources from investors such as banks, insurance companies, corporations, pension funds, etc. and to a lesser extent, private individuals. The venture capital fund categories include the following (Lee & Dibner 2008).[73]

Fundraising: Venture capital is set up by raising funds from investors, including qualified individuals, companies, pension funds, and others.

Currently investing: In this stage, the fundraising has typically closed, or certain minimum amounts have been met and the fund may be raising the final additional funds.

Fully invested: At this stage the venture capital fund will not invest in additional companies. Some funds may still be available which are meant for the follow-on or bridging the financial needs of the existing investments.

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[72] Lee DP& Dibner MD (2008),
"The rise of venture capital and biotechnology in the US and Europe", URL:http://npg.nature.com/nbt/journal/v23/n6/full/nbt0605-672.html Accessed online on 5th January 2008

[73] Lee DP& Dibner MD (2008),
"The rise of venture capital and biotechnology in the US and Europe", URL:http://npg.nature.com/nbt/journal/v23/n6/full/nbt0605-672.html Accessed online on 5th January 2008

Liquidating: Here the venture capital fund returns the investment in the form of equity and profit to various investors as per the original partnership agreement. Once liquidated, the fund no longer exists.

Usually the venture capital funding range starts from $20 million to billions of dollars. As a return to the investments in the young and high risk entrepreneurs/companies venture capital firms get hold of a high portion of equity to take advantage of the fact that these companies have a large potential of returning the investment when it begins to trade the shares markets. There is no guarantee for the success of a biotechnology company backed by venture capital in its Initial Public Offering (IPO). The positive side of venture capital funding is that the funding firms can easily reap a profit ranging from five to ten times their investment if the company does well by going public. There is also the chance for losing the investment made by the venture capital firm if the technology of the biotech company fails, or if the company experiences a bitter response from the IPO offering or when the company faces a downturn experience from the markets (Lee & Dibner 2008)[74]. The table below explains how venture capital funds the biotech firms at different stages.

Table: 4 Pattern of Venture capital Funding

Seed stage.	A small initial financing round, typically under $1 million, to validate a concept, get a company formed and complete the initial business plan. The terms of this financing round can be in the form of a straight equity investment, convertible preferred equity, convertible debt or a combination of all three. Warrants to purchase additional shares of stock at a later time and under certain conditions will usually be included. Investors can be individual qualified investors (angels), organized groups of angels or venture capitalists. At this stage, angel investors are involved far more frequently than venture capitalists.
Series A/B Stage	One or two early rounds of approximately $1–5 million (Series A) and $6–10 million (Series B). These rounds are typically VC financed, but

[74] Ibid

	the capital can also come from private investors or other investors such as pension funds. With the first (Series A) round, the founders' shares are typically diluted out by about half. Often, VC funds join together to fund these rounds, with each putting in a piece of this round and one VC fund acting as the lead investor. Often the lead investor negotiates the terms of the round and is afforded a seat on the board of directors (or can designate a seat). Each subsequent round generally requires at least one new bona fide investor to lead the round and value the enterprise. One or more representatives of the lead investor group in each round will be placed on the board of directors.
Series C/D.	Possible financing rounds, generally of $15–50 million, intended to take a company through product development and through an IPO. Often, at this stage, smaller funds cannot participate because larger amounts of capital are required
Mezzanine financing Stage	Typically the last financing round, the size of which is dependent upon the needs of a company before IPO or acquisition. This financing round generally occurs after some validation of the technology or drug, such as initiation of collaboration or advancement in clinical trial. Mezzanine financing also serves to help justify IPO valuation and give another benchmark to the share price before the IPO.
Bridge financing stage	An infusion of cash from either an angel investor or a VC firm to a company before completion of another round of financing or before an IPO. Investors generally do not desire bridge financing after previous rounds as this short-term financing can be very costly in terms of debt and equity
Buyout Stage	The purchase of a company by a VC firm or investor group, after which the incumbent and/or incoming management will be given or acquire a large stake in the business

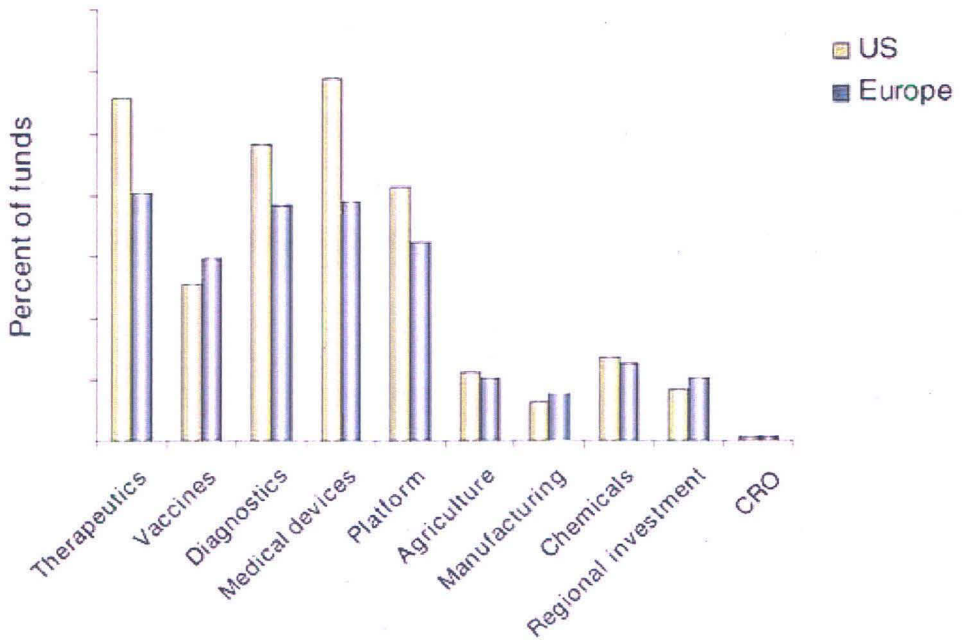
Source (Lee & Dibner 2008)[75]

Data from BioAbility (Burril 2004),[76] a firm specializing in Market Research and Strategic Information for the Life Sciences shows that venture capital funds are

[75] Lee and Dibner (2008), *Op cit.*

heavily diversified into areas which are known to have established market potential and steady growth. This includes companies focusing on their research and development related to diagnostics, therapeutics, medical devices, and other platform development. If we look at the biotech venture capital investment in the United States and Europe there is a lesser extent of investment in the companies researching on agriculture and chemical manufacturing, whereas there is a steady increase in the investment towards the Contract Research Organizations (CROs). The figure below represents the area-wise investment made by the venture capitalists of the U.S. and Europe in the biotech sector.

Figure: 1 Biotechnology investment area by Venture Capital funds in Europe and the United States.



Source: Lee & Dibner (2008)[77]

It is clear from the above data that the venture capital firms are mostly interested in investing in the healthcare sector compared to other biotech sectors including the agriculture.

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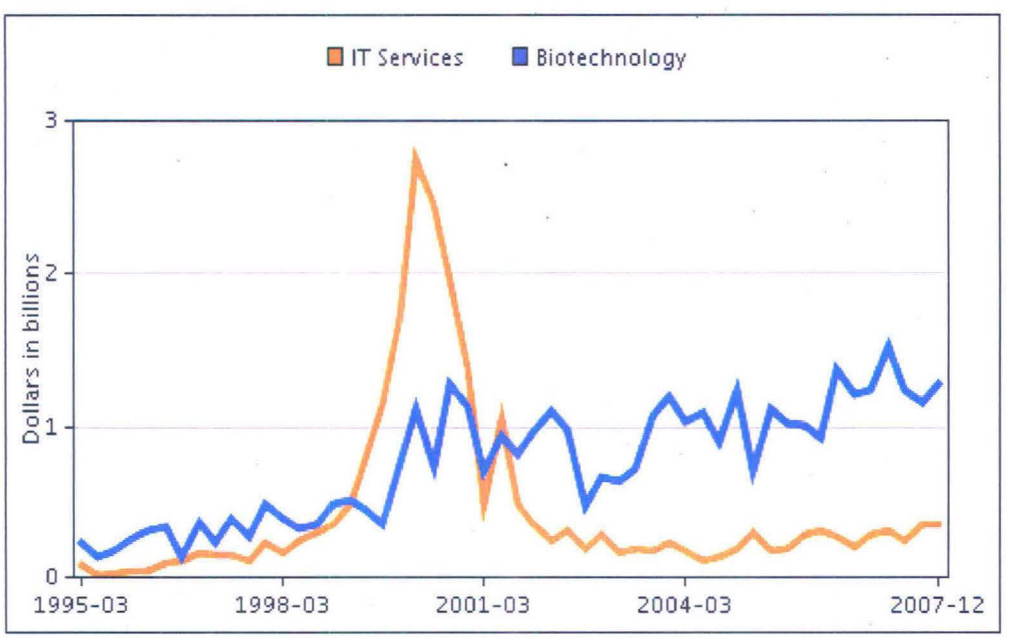
[76] Burrill, G.S (2004), "*Biotech 2004 Life Sciences: Back on Track, 18th Annual Report on the Industry*", Burrill & Company LCC, San Francisco, CA, USA.

[77] Lee DP& Dibner MD (2008),
"The rise of venture capital and biotechnology in the US and Europe", URL:http://npg.nature.com/nbt/journal/v23/n6/full/nbt0605-672.html Accessed online on 5th January 2008.

The 2007 report form Ernst and Young states that apart from the big pharmaceutical companies others have also invested in biotech's future. Public and private equity investors had invested substantially in the year 2006, which led to a total capital of US$28 billion, a massive 42 per cent increase over the year 2005. This is the second highest venture capital raised after 2000, when the industry was at the height of the genomics bubble. The venture capital crossed US$5.4 billion for the first time, an all-time record. The Ernst and Young Report states that even though the greatest increase in the venture capital came from the 'follow on' and 'other' categories, it reflects an underlying truth that much of the year's impressive capital formation was driven by large, established companies. The figure below compares the venture capital investments in biotech companies with the investment of the same in the Information Technology (IT) for the last 12 years.

Figure: 2 Venture Capital Investments



Source: (Federal Reserve Bank San Francisco, 2006)[78]:

The above graph which shows the nature of investments made by venture capital for the last 12 years in biotechnology sector clearly indicates the position of the industry in the global scenario. It is to be noted that this trend of increased investment by the

[78] Venture Capital Investments by Sector, URL : http://www.frbsf.org/csip/data/charts/chart23b.cfm. Accessed online on 18th January 2008.

venture capitals in the biotech sector is still continuing. The first quarter report from the National Venture Capital Association 2008 (NVCA represents approximately 480 venture capital and private equity firms) remarks that despite the decline in the over all venture capital investment for the period, biotechnology had came out with a strong quarter. The biotechnology industry had narrowly edged out software as the number one industrial sector for the quarter with $1.27 billion going in to 126 deals. According to Irving Levin Associates,[79] venture capital funding has significantly increased in the healthcare industry. The report says that in 2007 health care companies announced 481 deals totaling $9.7 billion in venture capital last year, achieving an almost 13 per cent increase in funding compared with 2006.

Along with the increasing global competition among the biotech companies, the cost of drug development and research also started soaring. At the same time venture capital is increasing its grip in the biotechnology industry through funding for Research and Development purposes. This is despite the fact that biotechnology research pursuits are expensive, time-consuming, and with a relatively low success rate. But the venture capitalists trust the growth potential of the technology which they think will revolutionize the medicine markets and would meet growing needs of the world market. This consideration continues to lure venture capitals to invest in this booming industry.

Biotechnology and genetics research have been the subject of extensive investment by both public and private sectors, with the resulting product and process making a significant and increasing contribution to human health. These innovations in the field of advancement of human health have been subject to intellectual property rights for many years. Over the last decades, the number of such innovations has increased and their impact on healthcare has grown substantially. In the next section we will discuss the patenting aspects of biotechnology.

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[79] Irving Levin Associates, Inc. has been the leading source of information and investment research on mergers and acquisitions in the Behavioral Health Care, Biotech, e-Health, Home Health Care, Hospitals, Laboratories, MRI and Dialysis, Long Term Care, Managed Care, Medical Devices, Pharmaceuticals, Physician Medical Group.

1.9 Patenting and biotechnology

Strong intellectual property rights (IPRS) in biotechnology are of critical importance for the continuous growth of this industry (Bhattacharya 2007).[80] In recent times, governments and healthcare providers around the world have shown concern for the licensing of these biologically engineered products. This is to protect them from exploitation, particularly in the healthcare field (Spranger 2003).[81] The U.S. Supreme Court ruling on Diamond vs. Chakrabarty case of 1980 changed the direction of patent laws in that country by holding claim to a bacterium valid. (In essence, Chakrabarty developed a genetically engineered bacterium capable of breaking down multiple components of crude oil). Significant investment has been attributed to this first official patenting system which allowed patents for living matter like microorganism. Since then biotechnology has emerged as one of the most important domains in the patenting system.

Some of the important patented biotechnological domains are genetic engineering process, method of producing organisms, method of isolation of microorganisms from culture medium, method of mutation, biologically pure cultures, mixed cultures, Eukaryotic cells, tissue or organ cultures, mutants, transformants, plasmids, process for making monoclonal antibodies and cell lines for making monoclonal antibodies (Bhattacharya 2007).[82] Patenting has always been prone to controversies, debates and disputes. For example, the transgenic research mouse designed as a laboratory model for cancer studies at Harvard University under National Institute of Health funding was patented and licensed to DuPont, which further sought strong controls over it and other forms of modified mice. In another example, concentrated stem cells, which are undifferentiated or partially differentiated, and can be developed into a number of other cell types, have been patented in the U.S. (Bhattacharya 2007)[83].

Article 27(2) of the Trade Related Intellectual Property Rights (TRIPS) Agreement has excluded certain inventions from patentability on the ground of morality. These

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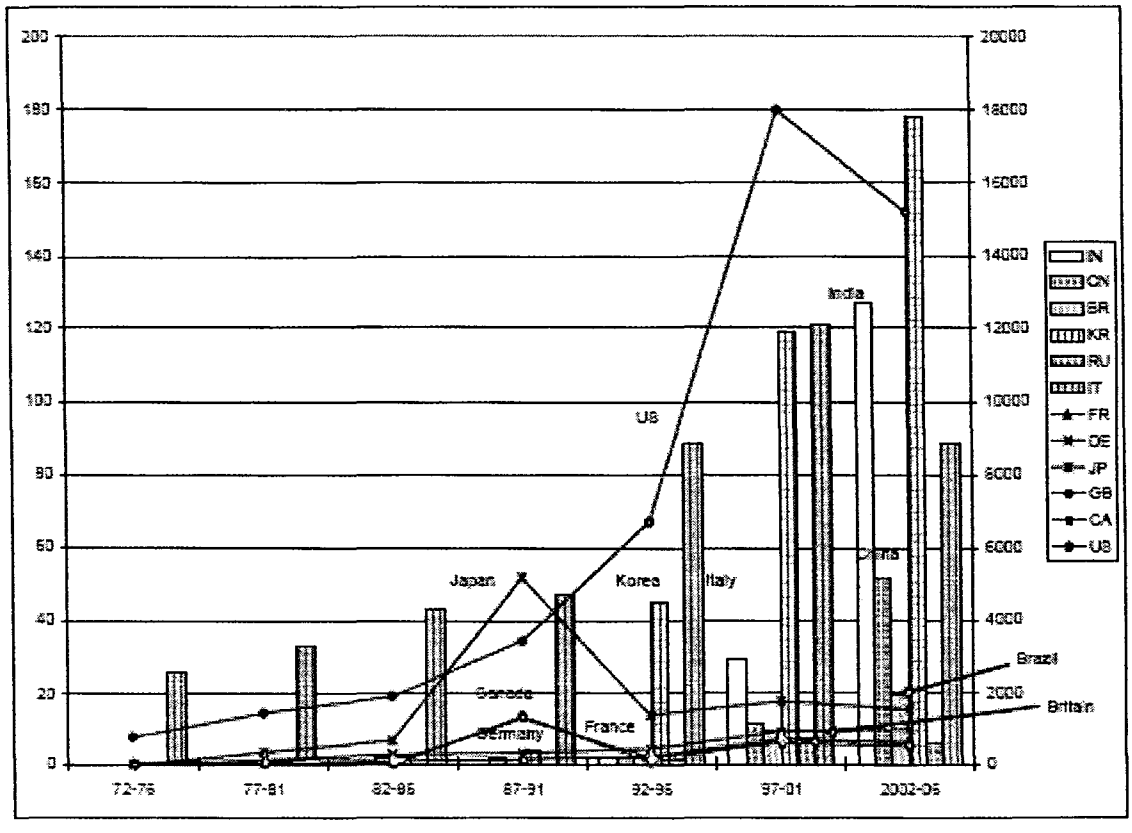
[80] Bhattacharya, Sujith, (2007), "Patenting in Biotechnology",*DESIDOC Bulletin of Information Technology,* Vol. 27, No. 6, November 2007, pp. 31-39.
[81] Spranger TM (2003). Patent protection for stem cell procedures under the law of the European Union. Med Etika Bioet. 10(1-2): 4-8.
[82] Bhattacharya (2007), *Op cit.*
[83] *Ibid*

include protection to human, animal or plant life or health or to avoid serious prejudice to the environment, provided that such exclusion is not made merely because exploitation is prohibited by domestic laws. Provisions of Article 27(3) of the TRIPS Agreement further allows members to exclude diagnostic, therapeutic, and surgical methods for the treatment of human or animals, plants, and essential biological processes for the production of plants and animals from patentability. However, members must provide opportunity for patenting of microorganism and non-biological and microbiological processes. Therefore, microorganisms are patentable with respect to the processes of their production and use (Bhattacharya, 2007)[84].

Figure: 3 Patenting trends in biotechnology by different countries in the USPTO during 1972-2006



The three major patent offices where the international firms file patents are in the U.S., Japan and the European Patent Office. However, in the context of biotechnological inventions, the United States Patent and Trademark Office (USPTO) has a long tradition of firms filing their patents in large numbers. This is because of

[84] Bhattacharya, Sujith, (2007), "Patenting in Biotechnology", *DESIDOC Bulletin of Information Technology*, Vol. 27, No. 6, November 2007, pp. 31-39.

the favourable factors such as the emergence of firms from universities, venture capital investments, and landmark rulings in the U.S. The graph below represents the patenting patterns of different nations over a period of time.

The above figure (Bhattacharya 2007)[85] clearly depicts the U.S. dominance in patenting in biotechnology. Japan is the second most prolific country to be granted patents in this area by the USPTO. It is noted that among the emerging economies India shows significant patenting from 2002 onwards.

1.10 Conclusion:

Biotechnology at the beginning of the twentieth century brought about a tie up between industry and agriculture. During 1930s the industrial requirements were mainly met by the surplus agricultural products. During World War I, fermentation processes were developed which helped in producing acetone from starch and paint solvents for a rapidly growing automobile industry (Murphy & Parrella 1993).[86] Penicillin was manufactured during the period of Second World War and the biomedical focus started slowly moving to pharmaceuticals arena. The Cold War years were mostly dominated by works related to micro-organisms for biological warfare, along with the preparation of antibiotics and fermentation processes.

Today, biotechnology has grown to a level where it has roots in chemistry, physics and biology, and has its applications in diverse areas. The remarkable advancement in our understanding of living organisms and their cell products grants us the ability to control many functions of various cells and organisms. The advent of new biotechnological techniques has created inroads for scientists so as to manipulate desired traits. The development of these techniques has resulted in the advancement of three key branches of biotechnology, viz, genetic engineering, diagnostic technique and cell/tissue culture/ stem cell technique.

The present decade is witnessing unprecedented progress in biotechnology, beyond the improvements that recombinant technologies have initially brought to the medical

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[85] Ibid

[86] Murphy,Ann and Perrell Judy (1993), "A Further Look at Biotechnology." Woodrow Wilson Foundation Biology Institute. Princeton, NJ, URL: http://www.accessexcellence.org/RC/AB/BC/Overview_and_Brief_History.php. Accessed online on 12th August 2007.

understanding of diseases. The robust growth that the industry is experiencing today, along with the interest of venture capitals for the last few years to invest heavily in this sector, reminds us of the same growth experienced by the Information Technology industry in the last decade. The world has witnessed remarkable progress made by the biotechnology industry ever since its early gene splicing experiments. The worldwide phenomenon of industries collaborating with the universities/research institutes (which started in US in the late 1960s) for research and development had created a new platform for drug discovery and major technological breakthroughs. These collaborations also at times resulted in the violation of basic ethical practices leading to controversies. A majority of today's biotech companies are born as a part of this tie-up, with many of the university professors themselves floating private biotech companies. The discovery of new drugs and vaccines along with an enhanced and accelerated process of drug discovery, improved diagnostic capacities and other such advanced uses of medical technology indicates the phenomenal growth of the industry in recent times. The breakthroughs in molecular biology have allowed the scientists and researchers to interpret with improved sophistication of the lives and languages of the cells, resulting in the discovery of new medical technologies.

These remarkable improvements in the medical biotechnology research and development have been considered by scientists as only a beginning. They are of the opinion that the era is near when the improvement of targeted therapies which aim to understand the biological groundwork of diseases will dramatically improve the safety of drugs and its efficacy. It is believed that the development of predictive technologies will lead to a new stage in disease prevention, particularly in some of the world's rapidly developing economies. The progress made in the field of identifying the character of genes which decides the behaviour of a specific cell has provided a better understanding of the diseases and had made promises in controlling certain fundamental cellular processes.

The enduring progress and hope in the field of research and development with the substantial technological advancements in the biomedical sector, along with an aggressive medical market, has created a new outlook in the character and investment in the healthcare sector. The enormous growth of investments from venture capital is one of its indicators. The U.S. has been the leading player in the worldwide

biotechnology industry both in terms of market-reach and number of companies from its inception. Even though the phase of globalization and liberalization has opened up the opportunity for developing countries to enter the arena of biotechnology, it is notable that the leading biotech firms in developing countries too are fully or partially owned by multinational corporations. As a result of this there are very few successful domestic biotech enterprises. There are also concerns over the risks and ethics involved in outsourcing research from the developed countries to the developing ones.

Observers believe that even though the biotechnology industry is going ahead with its unprecedented growth, there are still lots of questions and concerns regarding ethical practice which are still to be answered. Such questions revolve primarily around the application of new technologies, use of advanced diagnosis, new treatments especially in the stem cell research, in clinical trials, the use of genetic information, and so on. But despite these questions and controversies, biotechnology is going to remain one of the fastest growing industries in the world in the days to come.

Chapter 2

Chapter II

The Medical biotechnology industry in India:

2.1 Introduction:

India is considered as one of the major players in the global biotechnology industry. This is partly due to the initiatives of the Government of India in the 1980's to encourage the development of biotechnology. Today India's health biotechnology firms are emerging as leading global players, promising with growing means and expertise, to produce innovative vaccines and generic drugs at relatively small cost compared to those of giant Western firms (Collins 2007).[87]

The decision of the Government of India in 1982 to constitute an agency, viz the National Biotechnology Board (NBTB) under the Ministry of Science and Technology was a landmark in the history of biotechnology in India. The Board was created as an apex coordinating body, to identify priorities, to oversee and plan for required manpower, to integrate industrial developments, for large scale use of biotechnology products and processes (Chaturvedi 2002).[88] The objectives, structure and organization of this Board was formulated through the discussion with all existing Science and Technology organizations and allied agencies along with financial contribution to its core funding (GOI 2007)[89]. The Board also had extensive interaction with the Scientific Advisory Committee of the USA in 1983 so as to identify the needs and priorities of biotechnology in India (Rao 2002).[90] Various programmes including manpower development, establishment of essential

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[87]Collins, Terry, (2007), India's biotech industry emerging as aworld innovator, collaborator, competitor, URL: http://www.eurekalert.org/pub_releases/2007-04/pols-ibi040107.php, Accessed online on 27th August 2007.

[88] Chaturvedi, Sachin, (2002), "Status and Development of Biotechnology in India: An Analytical Overview", Research and Information System for the Non-Aligned and other Developing Countries, New Delhi, working paper.

[89] Government of India, Ministry of Science and Technology, Department of Biotechnology, 1985-86 to 2001-2002, Annual Reports, New Delhi, URL: http://dbtindia.nic.in/publication/publicmain.html Accessed online on 27th August 2007.

[90] Rao, S.R, (2002) "Indian Biotechnology Developments in Public and Private Sectors - Status and Opportunities", *Asian Biotechnology and Development Review*, Vol.5, No.1, URL: http://www.ris.org.in/abdr_nov1.pdf, Online accessed on 27th August 2007.

infrastructure facilities, strengthening of existing laboratories, training of young scientists abroad, introducing biotechnology in curriculum etc, were initiated by the Board so as to promote the growth of biotechnology in the country (Rao 2002).[91] Later, in 1983 April, the National Biotechnology Board (NBTB) issued the Long Term Plan for Biotechnology in India which spelt out the priorities for biotechnology in the country taking into consideration the national objectives. These include self sufficiency in food, clothing and housing, adequate health and hygiene, provision of adequate energy and transportation, protection of environment, gainful employment, industrial growth and balance in international trade (Chaturvedi 2002).[92] The main objective of NBTB was to coordinate the biotechnology research efforts in various research centers across the country. The Ministry of Science and Technology policy statement of 1983 of the government stated that

'Special attention will be given to promotion and strengthening of technologies based in newly emerging and frontier areas such as information, material science and electronics and biotechnology' (DST 2007).[93]

In this chapter we will trace the evolution and growth of the medical biotechnology industry in India. The first section of this chapter looks into the role of the Government of India in establishing a special department for biotechnology, the Department of Biotechnology (DBT). The next section looks in to the DBT, its institutional set-up, major functions, etc. We then briefly examine Five Year Plans where we attempt to present the composition of the budgetary allocation for the DBT since 1986. Biotechnology industry as such and medical biotechnology industry in India and its current status are discussed in the next section. The role/growth of private/corporate players, the venture capitals, and the increasing role of Public Private Partnership in biotechnology sector is discussed in the next section followed by a brief summary of the chapter.

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[91] Ibid .
[92] Chaturvedi (2002), *Op cit.*
[93] Department of Science and Technology, Technology policy statement 1983, URL: [Online: web], Accessed on 17th August 2007, URL: http://dst.gov.in/stsysindia/sps1983.htm, Accessed online on 17th August 2007.

2.2 The Department of Biotechnology:

A new impetus to the development of modern biology and biotechnology in India occurred in 1986 when the National Biotechnology Board (NBTB) graduated to a full-fledged department called the Department of Biotechnology (DBT) under the Ministry of Science and Technology. For the last two decades of its existence, the department has initiated and accelerated the growth and development of biotechnology in the country which includes several research and development projects, demonstrations and creation of infrastructural facilities, different policy initiatives etc. As a result of these initiatives, India has made remarkable achievements in the development and application of biotechnology in the wide areas of health care, agriculture, environment, animal sciences, and industry (GOI 2007) [94]. Several doctoral thesis have been published by the department on various issues relating to the field. The department has been in close interaction with the various state governments particularly through the State Science & Technology Councils for developing biotechnology application projects, demonstration of proven technologies, and the training of human power (GOI 2007)[95].

Apart from supporting biotechnology research, this department was also given the responsibility of development of biotechnology products under the Industries (Development and Regulation) Act of 1951. Research on biotechnology has also been supported by publicly funded institutions like the Indian Council for Agricultural Research (ICAR), the Indian Council for Medical Research (ICMR), Department of Scientific and Industrial Research (DISR), the Council for Scientific and Industrial Research (CSIR) and so on. As the DBT notes

> "The Department of Biotechnology is organized on modern lines of management, viz. reducing vertical hierarchy and promoting horizontal interaction amongst the scientific groups and officers. The Department is being advised by two apex level committees viz. the Scientific Advisory Committee (SAC-DBT) and Standing Advisory Committee (overseas) SAC-O. These committees review the ongoing programmes and suggest new and emerging areas that could be supported. Apart from these several expert task forcers comprising eminent

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[94] Government of India, Ministry of Science and Technology, Department of Biotechnology, URL: http://dbtindia.nic.in/publication/publicmain.html, Accessed online on 17th August 2007.
[95] *Ibid*

scientists, provide useful advice to the department in the pursuit of its goals to promote R&D activities in the country" (GOI 2007)[96].

Presently there are six major agencies in India responsible for financing and supporting research in the area of biotechnology apart from other sciences. They are the Department of Science and Technology (DST), the Department of Biotechnology (DBT), the Council of Scientific and Industrial Research (CSIR), the Indian Council of Medical Research (ICMR), the Indian Council of Agriculture Research (ICAR), the University Grants Commission (UGC) and the Department of Scientific and Industrial Research (DSIR). DST, DBT and DSIR are part of Ministry of Science and Technology while ICMR is with the Ministry of Health, the ICAR with Ministry of Agriculture and UGC with Ministry of Human Resource and Development. The DSIR is the funding agency for CSIR and both of them independently fund biotechnology related research programmes (Chaturvedi 2002).[97] The following table provides the budget allocation of the major biotechnology funding agencies in India.

[96] Government of India, Ministry of Science and Technology, Department of Biotechnology, URL: http://dbtindia.nic.in/organisation/org.html, Accessed online on 17th August 2007.
[97] Chaturvedi (2002), *Op cit...*

Table: 5 Budget allocation for major biotechnology funding agencies

***Millions of USD**

	1990/91	2000/01	2002/03	2003/04	2004/05
Indian Council of Agricultural Research (ICAR)	667	1647	1667	1615	1934
University Grants Commission (UGC)	720	1656	1774	1749	1832
Department of Scientific and Industrial Research (DSIR)	511	1142	1180	1219	1439
Department of Science and Technology (DST)	533	918	1150	1262	1420
Council of Scientific and Industrial Research (CSIR)	484	1073	1145	1184	1399
Department of Biotechnology	135	160	267	293	358
Indian Council of Medical Research (ICMR)	82	173	185	179	197
Total	3133	6768	7368	7501	8579

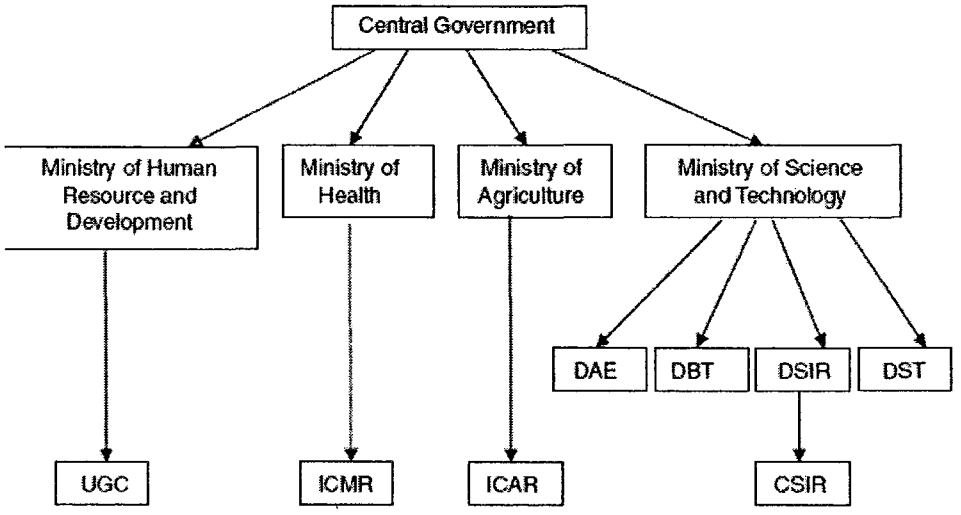
Source:: (Chaturvedi, 2007)[98]

From the table it is clear that the budgetary allocation of these agencies have considerably gone up in the last decade. Another important factor is that among all these agencies the only agency which is completely devoted to research and development is DBT (Chaturvedi 2007).[99] The following figure gives us the administrative structure of the organizations involved in the field of biotechnology in India.

[98] Chaturvedi, Sachin (2007), "Indian innovative systems and Emergence of Biopharmecutical Sector; Issues and Prospects, Research and Information System for the Non-Aligned and other Developing Countries, New Delhi.

[99] *Ibid*

Figure: 4 Administrative structure of organisations involved in biotechnology sector.



Administrative organisation of the government agencies involved in the funding of public research

Source: (GOI 2007)

A vision document giving a ten-year perspective for research, demonstration, commercialization and application of biotechnology in India was declared in the year 2001. According to the strategy presented in the document, the current emphasis is on the consolidation and utilizing the existing infrastructure for promoting all aspects of biotech research and application. It also acknowledges the development of human resource in the fields of genomics, molecular biology, computational and structural biology, immunology and genetics as an important area (GOI 2001).[100]

In 2001-02, the DBT took certain steps towards the promotion of the biotechnology industry. The DBT proposed a single window application-processing cell as part of a new regulatory system for the domestic biotechnology sector. The move formed part of the recent recommendations on biotechnology sector made by the Confederation of Indian Industry (CII). Besides recommending setting up of a single window application-processing cell at DBT, the CII had also suggested a fixed time frame of

[100] Government of India, Ministry of Science and Technology, Department of Biotechnology, URL: http://dbtindia.nic.in/publication/publicmain.html, Accessed online on 17th August 2007.

150 days for clearing new biotech proposals (GOI 2007).[101] In this regard, CII had recommended a process whereby a new application would be sent by the single window agency to the Review Committee on Genetic Manipulation (RCGM), which in turn would be required to submit a scientific evaluation report within 60 days of receiving the applications. This report will be submitted to the relevant approval committee, identified by the end product category. For example, for agricultural products, it would go to the Genetic Engineering Approval Committee (GEAC), in the case of pharmaceutical products to the Drugs & Pharma Approval Committee (DPAC), and in the case of food products to the Biotech Foods Approval Committee (BFAC). The GEAC/ DPAC/ BFAC would be required to accord approval or rejection within 90 days of receiving the evaluation report from RCGM. In case of rejection of the application, the applicants will also have the right to appeal to the concerned approval committee. The CII had also suggested that any additional information required by RCGM for completion of the application form would have to be called for within 30 days of receipt of the application. Apart from DBT, the CII had also submitted the recommendations to 14 other agencies, including seven ministries. DBT have accepted almost all the recommendations submitted by CII.

On its website, the Confederation of Indian Industries identifies biotechnology as one of the areas for cooperation. The reasons which they site for this are the large pool of scientific talent, a world class information technology industry and a lively pharmaceutical sector. And more importantly, the site refers to the billion population and its huge market for products and services along with the presence of various species of mammals (7.6 per cent), birds (12.6 per cent), fishes (11.7 per cent) and plants (6 per cent) in the world accords for a better cooperation in the sector with other countries(CII, 2007).[102]

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[101] Government of India, Ministry of Science and Technology, Department of Biotechnology, Annual reports 2001, URL: http://dbtindia.nic.in/publication/publicmain.html, Accessed online on 17th August 2007. .

[102] Confederation of Indian Industries (CII), "Trade and Investment Relations with India", URL: http://cii.in/menu_content.php?menu_id=1133. [Online, Accessed online on 24th August 2007.

2.3 Organizational structure of Department of Biotechnology

Under the Ministry of Science and Technology, Government of India, the DBT functions with the advice of the Scientific Advisory Committee (SAC-DBT) and Standing Advisory Committee Overseas (SAC-O). This committee reviews the ongoing research programmes, identifies new research areas and monitors the development of inter-institutional and inter-disciplinary projects. A Biotechnology Research Promotional Committee (BRPC) and 16 task forces are also established to recommend and provide networking for new research proposals. These committees meet twice or thrice a year. A National Bioethics Committee, consisting of scientists and representations of various governmental organizations, is also constituted to oversee the ongoing activities on human genome, genetic research and services, including the programme of gene therapy (GOI 2007).[103]

2.4 Major Functions of the Department of Biotechnology:

The DBT supports a variety of activities related to biotechnology. These include, research and development, biotechnology process and product development, human resource development, setting up of biotechnology reposition and facilities and supporting various programmes. The DBT also facilitates the commercialization of indigenously developed biotechnology and products through institutions like the National Research and Development Corporation and the Biotechnology Consortium of India Limited.

2.4.1 Human Resource Development:

Trained humanpower and expertise in India belong to classical and modern biology/biotechnology (Rao 2002).[104] While in many developed countries it has become difficult to find a young generation of classical biologists to supplement the inter-disciplinary modern biotechnology research, India has still adequate expertise in fields like biochemistry, organic chemistry, taxonomy, pharmacology and traditional

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[103] Government of India, Ministry of Science and Technology, Department of Biotechnology, URL: http://www.dbtindia.nic.in/, Accessed online on 17th August 2007.

[104] Rao, S.R, (2002) "Indian Biotechnology Developments in Public and Private Sectors - Status and Opportunities", *Asian Biotechnology and Development Review*, Vol.5, No.1, URL: http://www.ris.org.in/abdr_nov1.pdf, Online accessed on 27th August 2007.

systems of medicine (Rao 2002).[105] Most of the present day biologists have long or short-term training in the laboratories of the USA and Europe.

The National Biotechnology Board had launched an integrated short-term training programme way back in 1984, to cope with growing demand for highly trained humanpower (Chaturvedi 2002).[106] The department is implementing an integrated programme of Human Resource Development in Biotechnology to generate adequate and appropriate human power required for overall development of biotechnology in the country. Under this programme the department is implementing a number of individual components/schemes which include, teachers training programmes in view of long term requirement of trained personnel in any emerging area and supporting various areas of biotechnology at selected universities and research and development institutions in the country. Seventeen universities/research and development institutions have been provided with one-time financial support under non recurring grant for strengthening their ongoing courses under this initiative (GOI 2007).[107] This includes the junior research fellowship, post doctoral fellowship, biotech industrial training programme, biotechnology overseas associateship and visiting scientist from abroad programme. Apart from this, the department provides scholarships and awards in various fields related to biotechnology.

The University Grants Commission has come out with a scheme to promote higher centres of learning at one place and assist them as much as possible. In this regard, Delhi based Jawaharlal Nehru University (JNU) has been identified by the UGC as a centre for excellence in the areas of genomics, genetics and biotechnology (*Indian Express* 2002).[108] The All India Institute of Medical Sciences (AIIMS), IIT Delhi, Kharagpur, Post Graduate Institute of Medical Education and Research, Chandigarh and Sanjay Gandhi Post Graduate Institute of Medical Education and Research,

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[105] *Ibid.*

[106] Chaturvedi, Sachin, (2002), "Status and Development of Biotechnology in India: An Analytical Overview", Research and Information System for the Non-Aligned and other Developing Countries, New Delhi. Working paper.

[107] Government of India, Ministry of Science and Technology, Department of Biotechnology, Annual reports 200-06, URL: http://dbtindia.nic.in/publication/publicmain.html, Accessed online on 17th August 2007.

[108] Indian Express , January 9,2002

Lucknow etc are the other institutions which are prominent in this area (GOI 2007).[109] The 11th Five Year plan provides Rs750 crore for human resource development which aims fulfil the policy goal for the next decade so as to facilitate the availability of high quality scientific and technical human resource in all disciplines relevant to the life science and biotechnology sector (GOI 2007).[110]

2.4.2 Development of infrastructure

Since 1986, concerted efforts have been made by the Government of India towards capacity building, both in terms of human resource and sophisticated infrastructure for R&D (Rao 2002).[111] Until the emergence of globalisation, privatisation and liberalisation policies of GOI in 1990's, biotechnology research in India was mainly a state promoted activity, which consisted of setting up of biotech repositories, research centres, providing equipment and facilities and support to various biotechnology programmes.

The Working Group on 11th Five Year Plan states that while the Indian industry is strong in product development and marketing for commercial benefits, biotechnology in India still lacks the infrastructure for R&D in molecular modeling, protein engineering, drug designing, immunological studies, pre-clinical studies, clinical trials, etc. The Plan (2007-2012) also refers to the need to shape the development of India's concept of contract research organizations (CROs), contract manufacturing organizations (CMOs), contract packagers, lab services providers etc and it adds that this must be strongly encouraged as it is impractical for companies to do all this by themselves (GOI 2007).[112] The Draft also sees the need to encourage private parties to set up infrastructure development including water supply and effluent treatment when building biotech clusters, service 86 facilities like genome sequencing, large animal facility for clinical trial etc. The Plan states "Access to cutting edge research

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[109] Government of India, Ministry of Science and Technology, Department of Biotechnology,URL:, http://www.dbtindia.nic.in/, Accessed online on 17th August 2007.
[110] Government of India, Ministry of Science and Technology, Department of Biotechnology (2007). Report of the Working Group for the Eleventh Five Year Plan (2007–2012), URL:http://planningcommission.nic.in/aboutus/committee/wrkgrp11/wg11_subdbt.pdf, Accessed online on 24th November 2007.
[111] *Op cit.*
[112] Government of India, Ministry of Science and Technology, Department of Biotechnology (2006). Report of the Working Group for the Eleventh Five Year Plan (2007–2012) pp 99.

facilities is critical to the success of product development programmes. This requires large investments. The Model best suited for this is the setting up of an Interagency Capital Fund with involvement of all stake holders including private sector" (GOI 2006).[113]

In the mean time, the government is also investing heavily in the infrastructure development of biotechnology sector. There is a substantial increase towards the allocation of infrastructure in the Eleventh Five Year Plan. If the allocation for the financial year 2005-06 was Rs70 crore and Rs77 crore for 2006-07 (GOI 2007)[114] , the total allocation for the Eleventh FY Plan (2007-2012) is Rs750 crores (GOI, 2006).[115] One can read easily from the new Five Year plan that the infrastructure development has been given a major thrust keeping in view the requirement of teaching facilities, R&D and upscaling of already developed products and processes. As substantial strength in institutional capacity in basic biology has been created, the policy focus is now on institutional strengthening with technology

2.4.3 Research and Development:

Since it is a knowledge based industry, the quality behind the research and development of biotechnology is very important. Nagaratnam (2001),[116] states that the progress in the research and development area of biotechnology that we witness today is the result of the deep involvement of the Indian scientists on the basic research aspect of biotechnology for the last five decades. The DBT has recognized certain priority areas to develop indigenous capabilities to generate new knowledge and to provide a base required for understanding of the basic applied research in the field of biotechnology. The research and development section of the Eleventh Five Year Draft Plan, for example, notes, "A healthy population is essential for economic development. Important contributors to the total disease burden are infections like

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[113] *Ibid*

[114] Government of India, Ministry of Finance, Budget Documents, URL: http://www.indiastat.com/india/ShowDataSec.asp?secid=393451&ptid=391226, Accessed online on 24th August 2007.

[115] Government of India, Ministry of Science and Technology, Department of Biotechnology (2006). Report of the Working Group for the Eleventh Five Year Plan (2007–2012) pp 183.

[116] Nagaratnam, A (2001), "Biotechnology in India: Current Science", *Defense Science Journal*. Vol. 51. No. 4. October 2001, pp. 401-408.

HIV-AIDS, tuberculosis, malaria, respiratory infections and chronic diseases affecting the heart and blood vessels, neuro-psychiatric disorders, diabetes and cancer. It is important to synchronize the technology and products with the local needs of the health system and to facilitate technology diffusion into health practice. This requires developing innovative, cheaper and user friendly technologies" (GOI 2006: 134).[117] The Eleventh Five Year plan proposes Rs3000 crore for the purpose of research and development in contrast to Rs164 and 193 crore during the financial year 2005-06 and 2006-07 (GOI 2007).[118]

The Plan also refers to establishing Centres for Translational Health Science Research (CTHSR)[119] and development of novel strategies for identification of diagnostic antigens for various infections and development of simple syndrome and DNA based diagnostic tests (GOI 2006:121).[120] The plan emphasises the necessity of targeted approach so as to harness the skills of experts and the infrastructure for research. It adds that a similar approach is needed for anti viral drug development for hepatitis 'E', influenza, dengue, JE and so.

2.4.4 Biotechnology product and process development and technology transfer:

The main emphasis of product and process development and technology transfer project is to develop novel products and process so as to evolve certain strategies for utilization of such products and process by various biotech industries (GOI 2006)[121]. Through the Biotechnology Patent Pattern Facility (BPFC), the DBT is also currently creating awareness about patent related issues among scientists. The department also gives due care to put indigenously developed technologies into services in order to

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[117] Government of India, Ministry of Science and Technology, Department of Biotechnology (2006). Report of the Working Group for the Eleventh Five Year Plan (2007–2012) pp 134.

[118] Government of India, Ministry of Finance, Budget Documents, URL: http://www.indiastat.com/india/ShowDataSec.asp?secid=393451&ptid=391226, Accessed online on 24th August 2007.

[119] Translational research means taking medical discoveries from the laboratory into the clinic and out into the community. The Institute of Translational Health Sciences (ITHS) is a multi- and inter-disciplinary "collaboratory" funded by the National Institutes of Health to advance translational research.

[120] Government of India, Ministry of Science and Technology, Department of Biotechnology (2006). Report of the Working Group for the Eleventh Five Year Plan (2007–2012) pp 121.

[121] Government of India, Ministry of Science and Technology, Department of Biotechnology, Annual reports 2005-06, URL: http://dbtindia.nic.in/publication/publicmain.html, Accessed online on 17th August 2007.

commercialize them. For this the DBT is working with an autonomous body, the Biotech Consortium India Limited (BICL). Till 2005 about 60 technologies have been transferred to the private companies from the public funded research and development as per this agreement with BICL (Visalakshi 2005).[122] Among the transferred technologies a large number are related to the technologies addressing health needs compared to the other segments of biotechnology viz, agriculture, industrial and environment. A brief discussion on the transfer of these technologies to private companies and its outcome is discussed in the section for Public Private Partnerships. The list of the products and the companies who owned these are listed as appendix.1

2.5 Bioinformatics:

Information technology has been playing an important role in the development of the biotechnology industry. Access to comprehensive biological information is necessary in all the fields of biotechnology. India is one of the countries to establish a nation wide Biotechnology Information System network (BTIS net) in 1986-87 (Visalakshi 2005)[123]. BTIS offers a single information resource in the country, converging various interdisciplinary areas of biotechnology and molecular biology. It covers almost the entire country through the centre. The BTIS network consist of 10 distributed information centers and various sub-distributed information centers (Sub-DICS). An apex biotechnology information center at the DBT coordinates the activities of the entire network. An extensive Bioinformatics Network, covering 65 institutions, spread geographically all over the country, has been established. This network consists of Centre of Excellence (CoE), Distributed Information Centres (DICs), Sub-DICs depending upon their activities and the financial support (GOI 2006).[124]

Human resource development has been recognized as an important area for the sustenance of the bioinformatics programme. BTIS had already developed hundreds of data banks on biotechnology. Scientists of this network have published more than 1200 bioinformatics research papers in peer reviewed journals in the last five years

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[122] Visalakshi, S, (2005) "Transferring biotechnology in India: Experiences and Lessons", National Institute of Science and technology and Development Studies, New Delhi. Working paper.
[123] *Ibid*
[124] Government of India, Ministry of Science and Technology, Department of Biotechnology (2006). Report of the Working Group for the Eleventh Five Year Plan (2007--2012) pp 30.

and helped in publishing more than 3500 research papers on biology/ biotechnology. Several international data bases required for application of genomics and proteomics (Proteomics is the large-scale study of proteins, particularly their structures and functions) have been developed in the form of mirror sites as a part of the programme and are linked through high speed and large bandwidth network, to promote faster sharing of the latest information in the field of biotechnology. The DBT has also initiated various programmes to realise the exchange of scientists and technology through international cooperation, to absorb and adopt recent developments in the field of biotechnology and so on.

Four hundred short- term courses had already been organized in different areas of bioinformatics and around 4000 researchers and scientists are working in this area. For the Plan Period, 30 new research and development projects have been supported in this area. Apart from these, 200 softwares and 26 copy rights has been received for the product development through this venture of bioinformatics (GOI 2006).[125] Most of the work in the area of bioinformatics that happen in India is of the work out sourced from the US. Thus the Indian bioinformatics sector is slowly increasing their share in the US$ 6 billion bioinformatics sector. One of the reasons cited for the growth of bioinformatics centers in India is its well established IT industry and cost-effectiveness. Ernst and Young (2007) states this; "India's proven strengths in computer science and software, along with a large pool of trained professionals in life sciences, have made for a prosperous bioinformatics segment" (Ernst & Young 2007: 84).[126] Basically, in India, the bioinformatics centers are concentrated around the Information Technology centers. Most of these companies are opened by the major IT companies as their subsidiaries. Some of the successful ventures in this field includes Tata Consultancy Services (TCS), IBM India, Infosys etc. One of the areas in which the bioinformatics companies in India focus is on the genomic analysis as we own a diversity of human gene pool.

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[125] Government of India, Ministry of Science and Technology, Department of Biotechnology (2006). Report of the Working Group for the Eleventh Five Year Plan (2007–2012) pp 31.

[126] Ernst and Young (2007), "Beyond Borders: the Global Biotechnology Report", pp 84. URL:www.ey.com/beyond borders, Accessed online on January 12th 2008.

2.6 In Five Year Plans:

In India the developmental allocations are generally made for a period of five years under the National Five Year Plans. The Sixth Five Year Plan (1980-85) was the first policy document which addressed the issue of the development of biotechnology in the country (Kumar 1988).[127] It proposed to strengthen and develop capabilities in the areas of immunology, genetics, communicable disease, etc. The Plan also discussed the programmes of the area which included tissue culture application for medicinal plants, fermentation technology and enzyme engineering for chemicals, antibiotics and other medical product development; and emerging areas like genetic engineering and molecular biology (GOI 1980: 326)[128].

Early initiatives from the government and setting up of a separate department of biotechnology can be cited as the first investment in this sector in India. There has been remarkable increase in the Government of India's outlays for biotechnology over the past decade (Chaturvedi 2002).[129] The allocation for the department has increased manifold since its formation in 1986. from a minimal of Rs. 4.04 crore in 1987-88 to Rs. 11.38 crore in 1997-98 and to Rs. 18.63 crore by 2002. If the allocation for the department for the financial year 2005-06 touched Rs. 458.60 crore, the allocation for the 2006-07 was Rs.521 crore. If the total outlay for the 10th Five Year plan was 1450 crores, the recent Draft Plan document published by the Planning Commission of India outlays a whopping amount of Rs. 12000 crore for the department for the 11th Five Year Plan (2007-2012) (GOI 2007).[130]

The following table provides the budget allocation to the Department of Biotechnology over the years.

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[127] Kumar, Nagesh (1988). "Biotechnology in India", *Development* (Special issue on Biotechnology), Research and Information System (RIS)for the Non-Aligned and other Developing Countries, New Delhi. Working paper. Working paper.

[128] Government of India, Planning Commission, Sixth Five Year Plan, 1980-85, New Delhi, p. 326

[129] Chaturvedi, Sachin (2002), "Status and Development of Biotechnology in India: An Analytical Overview", Research and Information System (RIS)for the Non-Aligned and other Developing Countries, New Delhi. Working paper.

[130] GOI (2007), *Op cit.*

Table: 6 Department of Biotechnology Budget (1986-87---2002-08)

Year	Amount in Crores
1986-87 (Revised estimate)	17.94
1987-88 (Budget Estimate)	40.99
1988-89	(NA)
1989-1990 (Budget estimate)	53.82
1990-91 (Budget estimate)	59.35
1991-92 (Budget estimate)	64.03
1992-93 (Budget estimate)	76.13
1993-94 (Budget estimate)	81.04
1994-95 (Revised Estimate)	84.01
1995-96 (Budget estimate)	88.14
1996-97 (Budget estimate)	91.38
1997-98 (Budget estimate)	95.44
1998-99 (Budget estimate)	114.25
1999-2000 (Budget estimate)	127.77
2000-01 (Budget estimate)	150.81
2001-02 (Budget estimate)	186.34
2002-03 (Budget estimate)	235.58
2003-04 (Budget estimate)	286.7
2004-05 (Budget estimate)	323.45
2005-06 (Budget estimate)	458.60
2006-07 (Budget estimate)	534.60
Eleventh Five Year plan	12000

Source: compiled from Five Year Plans since 1986

As we can see there, is a sharp increase in the allocation to the department in the Five Year plans since 1986. From an allocation of 17.94 Crore in 1986 the allocation has increased to 534.60 crore by 2006 which represents an increase of 335.58 per cent. Moreover the budgetary allocation has shown a marked increase since 2000. Till now more than 3100 crore rupees had been spent on this sector and the Eleventh Five Year Plan promises a outlay of 12000 crore. More than 50 per cent of the investment in this department is made with in the last five to eight years. It is also estimated that the

industry employs around 10-20000 people. The share of Indian biotechnology market was estimated at about 3455.60 crores (US$800 million) in 1999 and has risen approximately to 10798.74 Crores (US$2.5 billion) this year (Konde 2008).[131] Looking at the allocations in the Five Year Plans of the DBT, we could say that the periodic increase in the allocation has helped in promoting biotechnology research and development, along with the establishment of biotechnology facilities, product and process development, human resource development, and other activities.

2.7 Medical biotechnology in India:

Health care is a big industry in India. As in the other parts of the world, in India too the biotechnology industry is dominated by the health care sector.. Essential parts of the medicine available to the patients today are the products developed through biotechnology techniques. Medical biotechnology is strongly related to the pharmaceutical industry. The evolution/growth of the health care biotechnology firms has its roots in the pharmaceutical industry. The following table represents the sector wise distribution of biotechnology firms in 2003.

Table: 7 Sector wise distribution of biotechnology firms in 2003

Sector	No. of firms	Per centage
Healthcare	142	44
Agriculture	130	40
Industrial biotech	37	11
Equipment	36	11
Bioinformatics	20	6
Environment	15	5
Contract Services	2	0.6
Total	321	100

Source: Arora 2005[132]

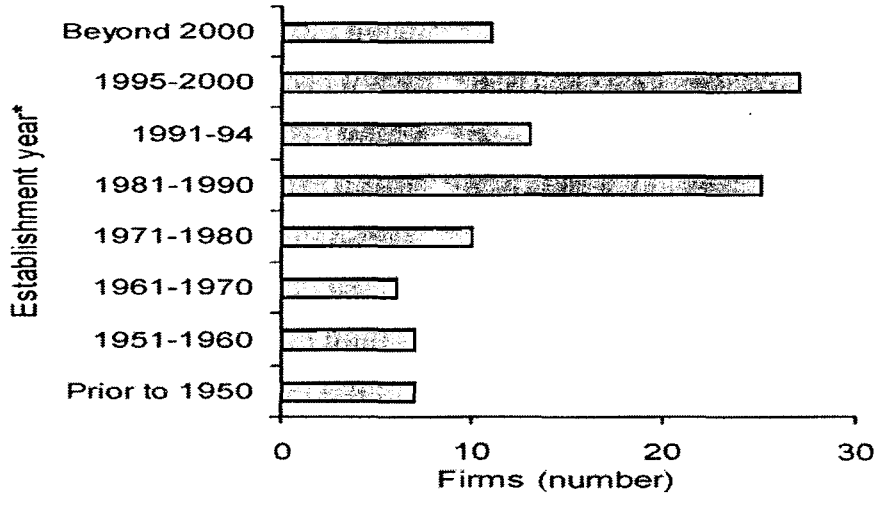
[131] Konde, Viren (2008), "Biotechnology In India: Public-Private Partnerships", *Journal Of Commercial Biotechnology*, vol 14. no 1, January pp 43–55.

[132] Arora, Praveen (2005), "Health care biotechnology firms in India: Evolution, structure and growth", *Current Sience,* Vol 89, No 3. August 10

Form the table it is clear that similar to the global biotechnology industry the Indian biotechnology sector is also dominated by health care biotechnology with a share of 44 per cent followed by agriculture, at 40 per cent. Bioinformatics, which is closely related with the medical biotechnology, owns a share of 6 per cent among the other Indian firms.

The number of technologies transferred to the industry from the department of biotechnology suggests that medical biotechnology is mainly focusing on vaccines and diagnostics. At present it is estimated that there are more than 300 companies working in this field. Among this, the top 20 companies commanda 50 per cent revenues from this sector. Out of the total business 42.17 per cent of revenue was from export and 73.15 per cent of these exports are of bio-pharma products which includes vaccines, therapeutics, and diagnostics (Konde 2008).[133] The figure below represents an account of the establishment of different health care firms over the years.

Figure: 5 Health care firms by establishment and year



Source: Arora 200[134]

It is clear from the above graph that the majority of the heath care biotechnology firms are established recently. 72 per cent of them were established after 1980's and 38 per cent during the 1991-2000 period. After 2000 only 11 per cent of the firms were

[133] Konde Viren (2008), "Biotechnology In India: Public-Private Partnerships", *Journal Of Commercial Biotechnology*, vol 14. no 1, January pp 43–55

[134] Arora, Praveen (2005), "Health care biotechnology firms in India: Evolution, structure and growth", *Current Sience,* Vol 89, No 3. August 10

established. Arora (2005) notes that firms which were established before 1980's were primarily focused on the pharmaceutical business and later they shifted changed to health care biotechnology. Examples of such companies are Lupin Ltd, Hindustan Antibiotics Ltd, Gland Pharma etc. Post 1991 has witnessed the emergence of the Dedicated Biotechnology Firms (DBFs) (Arora, 2005)[135]. This includes the renowned firms like Bharat Biotech Syngene International, Xycton Diagnostics, Strand Genomics, Shantha Biotechnics etc. Apart from these, the pharma majors like Ranbxy, Reddy Research Foundation, Dabur and Cadila and the subsidiaries of MNC's like GlaxoSmithKline and Eli Lilly also had their entrance to the Indian health care sector. In the later period certain firms developed tie- ups with the global leaders of biotechnology for product development and marketing. Most of the firms in the health care biotechnology operate in multiple segments like manufacturing, research and development, of biotechnology products and process, marketing etc. Certain firms also took up the role of providing consultancy and services. Arora (2005), states that around sixty per cent of firms are also engaged in specialized activity domains like recombinant drugs, DNA, proteins, hormones, micro-arrays, diagnostics and vaccines

Today Indian biotech sector has a market of biotech products and services which are estimated at around 2 billion dollars (Ernst and Young 2007).[136] If we want to know about the reasons behind the increasing importance of medical biotechnology industry in India we need to look in to some of the key areas of the industry which includes it key competitive areas like, vaccines and recombinant therapeutics, stem cell research, bioinformatics etc.

2.8.1 Vaccines and recombinant therapeutics:- According the Ernst and Young (2007), India has already achieved the leadership position in the vaccine market, which accounts for a third of global vaccine sales and is also the largest producer of recombinant hepatitis B vaccine in the world. The DBT estimates that India has about US 90 dollar million market of the recombinant therapeutic and is growing at a pace of 30 per cent annually (Ernst and Young, 2007). Apart from the Indian government, organizations like WHO, UNICEF etc have engaged companies like Shantha Biotech,

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[135] *Ibid*

[136] Ernst and Young (2007), "Beyond Borders: the Global Biotechnology Report", pp 79. URL:www.ey.com/beyond borders, Accessed online on January 12th 2008.

Serum Institute of India etc as qualified vaccine manufactures and procure from them at highly competitive prices. Many of these firms are now in tie-up with premier research institutes for developing new vaccines.

2.8.2 Stem cell research:- Ernst and Young (2007)[137] reports that one of the areas in Indian biotechnology industry where aggressive investment is taking place in stem cell research. The DBT and the Ministry of Science and Technology had drafted strict guidelines for stem cell research, which are classified into permissible (which includes the adult and umbilical cord blood stem cell research), restricted (which includes embryonic stem cell research) and prohibited (reproductive cloning which includes induction of animal embryo in humans). Both public and private players are included in the stem cell research in India which includes the therapeutic stem cell research work using the bone marrow at the All India Institute of Medical sciences (AIIMS), Reliance Life sciences and other private players. Recently Mr. M.V Subramaniam CEO of Reliance Life Sciences announced their successful clinical trials in the stem cell treatment for ophthalmology and added that the treatment is of the first kind in the commercial sector (Sing, 2008)[138]. The company also added that they are now working on the final phase of introducing stem cell therapies for the diseases including diabetic ulcer, cardiac infarction, and stable vitiligo or leukoderma (a skin disease), which is expected to be introduced commercially in the coming months (Sing, 2008). Even though the progress in the invention of new therapies using stem cell research is giving hopes to those who are in need, the company is yet to announce the cost of the treatment.

2.9 Over view of the Industry:

Peter Singer, M.D., of the McLaughlin-Rotman Center for Global Health at the University of Toronto says that "India's biotech sector is like a baby elephant -- when it matures, it will occupy a lot of space, (Institute of Industrial Engineers, 2007) [139]."

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[137] *Ibid, pp 80.*

[138] Sing, Seema (2008), "Reliance Life readies stem cell therapies, Wall Street Online Journal", URL: http://www.livemint.com/2008/07/02002032/Reliance-Life-readies-stem-cel.html, Accessed online on 2nd July 2008.

[139] Institute of industrial engineers (2007), "India emerges as a global player in biotech industry", URL: http://www.iienet2.org/PrinterFriendly.aspx?id=9534, Accessed online on 18th October 2007.

The Biotechnology industry in India includes biohealthcare, bio-agriculture, bio-industrial, bio-informatics, and contract and clinical research markets. The Planning Commissions 11th Draft Plan (2007-2012) states that

> India is reorganized as a mega bio-diversity country and biotechnology offers opportunities to convert our biological resources into economic wealth and employment opportunities. Innovative products and services that draw on renewable resources bring greater efficiency into industrial processes, check environmental degradation and deliver a more bio-based economy. Indian agriculture faces the formidable challenge of having to produce more farm commodities for our growing human and livestock population from diminishing per capita arable land and water resources. Biotechnology has the potential to overcome this challenge, to ensure the livelihood security of 110 million farming families in our country (GOI 2007:,8). [140]

The Indian biotechnology industry owns a remarkable position in the global biotech industry map. It is counted among the first twelve global biotech destinations and is the third largest in terms of the presence of biotech companies in the Asia Pacific region (Sreedhar *eta,* 2008).[141] The Indian biotechnology industry has its strong presence in several states of the country including Andhra Pradesh, Kerala, Karnataka, Himachal Pradesh, Uttaranchal, Tamil Nadu and Rajastan. India's importance as a genuine biotechnology player has increased manifold at the international level (Jadgale 2008).[142] This has been growing at an average annual rate of 40 per cent during the last five years even though it constitutes only about 2 per cent of the global market. If its turnover was $1billion in 2004-05 it reached $1.5billion by 2005-06 and $2 billion in 2006-07 (GOI 2007).[143] One of the encouraging factors of the Indian biotechnology industry is that the

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[140] Government of India, Ministry of Science and Technology, Department of Biotechnology (2006). Report of the Working Group for the Eleventh Five Year Plan (2007–2012) pp 8.

[141] D. Sreedhar, Manthan D. Janodia, Virendra S.Ligade, "Ajay Pise and N.Udupa (2008), Biotech Industry: Regulatory Overview", *The Pharma Review* (Bimontly) February-March, Kongposh Publications Pvt. Ltd, New Delhi, URL: http://www.kppub.com/pharma_review.htm, accessed online on 5th April 2008.

[142] Jadgale, Sachin (2008), "Indian biotech's global designs", URL: http://www.expresspharmaonline.com/20080215/bioasia2008special01.shtml, Accessed online on 22nd March 2008.

[143] Government of India, Ministry of Science and Technology, Department of Biotechnology (2006). Report of the Working Group for the Eleventh Five Year Plan (2007–2012) pp 30.

Indian market is growing at a pace of 36.5 per cent per annum which is considered as the highest in the world today (Palnitkar 2006).[144]

This growth of the industry can take India to a significant position among the biotech stake- holding nations in the world. Biopharmaceuticals, which includes the vaccines and bio-generics, alone has a great potential and opportunity in the market. Clinical services and outsourced research services also holds a major promise in the industry. The strong pool of scientists and engineers, the vast institutional network, cost effective manufacturing, the 300 and more odd training institutes, producing 500,000 students on an annual basis, medical colleges, practitioners, about 300000 researchers etc are seen as major asset for the rapid growth of this sector in India. It is expected that the biotechnology business segment for India has the potential of generating revenues to the tune of US$10 billion and creating one million jobs by 2010 through products services (GOI 2007)[145]. According to the survey report of the Association of Biotechnology-led Enterprises (ABLE), in 2006-07 the Indian biotechnology industry has made rapid strides with its revenues touching Rs. 8,300, an impressive growth of 30 per cent over the previous year's Rs. 6,485 crore (*The Hindu* 2007).[146] The report also noted that at this pace the biotech industry in India will achieve $5billion revenue by 2010. The table below represents the regional distribution of revenue from the biotech sector during the three financial year period starting from 2003-04 to 2005-06.

Table: 8 Revenue distribution of biotech sector- region wise

Region	Biotech Revenues (Rs Crore)		
	2003-04	**2004-05**	**2005-06**
West	1803.87 (51.91%)	2412.36 (50.84%)	3234.42(49.60%)
South	1367.76 (39.36%)	1898.47 (40.01%)	2367.12 (36.30%)
North	303.37 (8.73%)	434.17 (9.15%)	919.46 (14.10%)
Total Biotech	3475.00	4745.00	6521.00

[144] Palnitkar, Utkarsh (2006), India can become significant global player, Biospectrum, URL: http://biospectrumindia.ciol.com/content/columns/10604111.asp, Accessed online on 12th September 2008.

[145] Government of India, Ministry of Science and Technology, Department of Biotechnology (2006). Report of the Working Group for the Eleventh Five Year Plan (2007–2012) pp 4.

[146] The Hindu, Business (2007), "Biotech Revenues Touches Rs.8300 crores", URL: http://www.thehindu.com/2007/06/08/stories/2007060800991800.htm, Accessed online on August 17th 2007.

Source: GOI 2007 [147]

Geographically the biotech companies have developed in three major bio-clusters across the country viz, West, South and North. In terms of revenue generation the largest is the western bio-cluster followed by the south and northern bio-clusters (Konde 2008).[148] Even though the bio cluster in the west dominates in revenue sharing with 49.6 per cent, the bio clusters in North are showing steady progress in the revenue sharing compared to the other two. If we look at the geographical location of the biotechnology industries, the concentration of the industries is high in the south, which includes sates like Andhra Pradesh, Banglore, Karnataka, Tamilnadu, Maharastra and Kerala. Out of the 280 companies here 130 are located in Banglore alone (Indian Biotech
Industries 2005).[149] Further expansion of the industry has now begun in the states like Gujrat, Punjab and so on. These states had also developed their own biotechnology strategy to attract more industries to their respective states.

The key opportunity segments working in this sector are bio-pharmaceuticals, bio-agriculture, bio-industry, bio-informatics and bio-services. An Ernst & Young survey says that India is one of the five evolving biotech leaders in the Asia-Pacific region. Japan, Taiwan, Singapore and Korea are the other countries (Ernst and Young 2007)[150]. In the next section we discuss on the different biotechnology segments in India.

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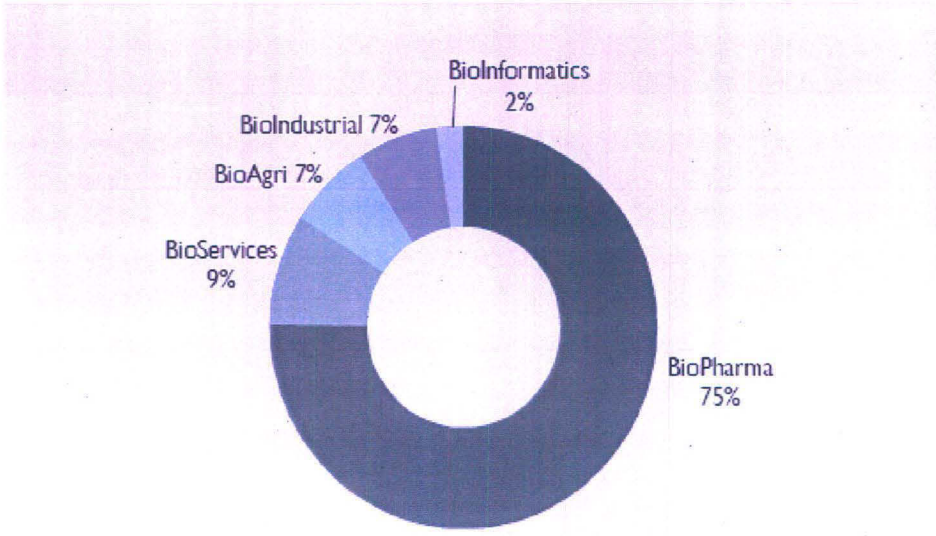
[147] Government of India, Ministry of Science and Technology, Department of Biotechnology, URL: http://www.biotechnews.gov.in/biotech%20industry1.html, Accessed online on 23rd November 2007.
[148] Konde, Viren (2008), 'Biotechnology in India:public-privtae partnerships' Journal of Commercial Biotechnology, vol 14, No 1, January, pp 43–55.
[149] Indian Biotech Industries, (2005), URL: http://www.mindbranch.com/products/R459-95.html, Accessed Online on 11th October 2007.
[150] Ernst and Young (2007), "Beyond Borders: the Global Biotechnology Report", pp 80. URL:www.ey.com/beyond borders, Accessed online on January 12th 2008.

Figure :6 Biotechnology segments in India.



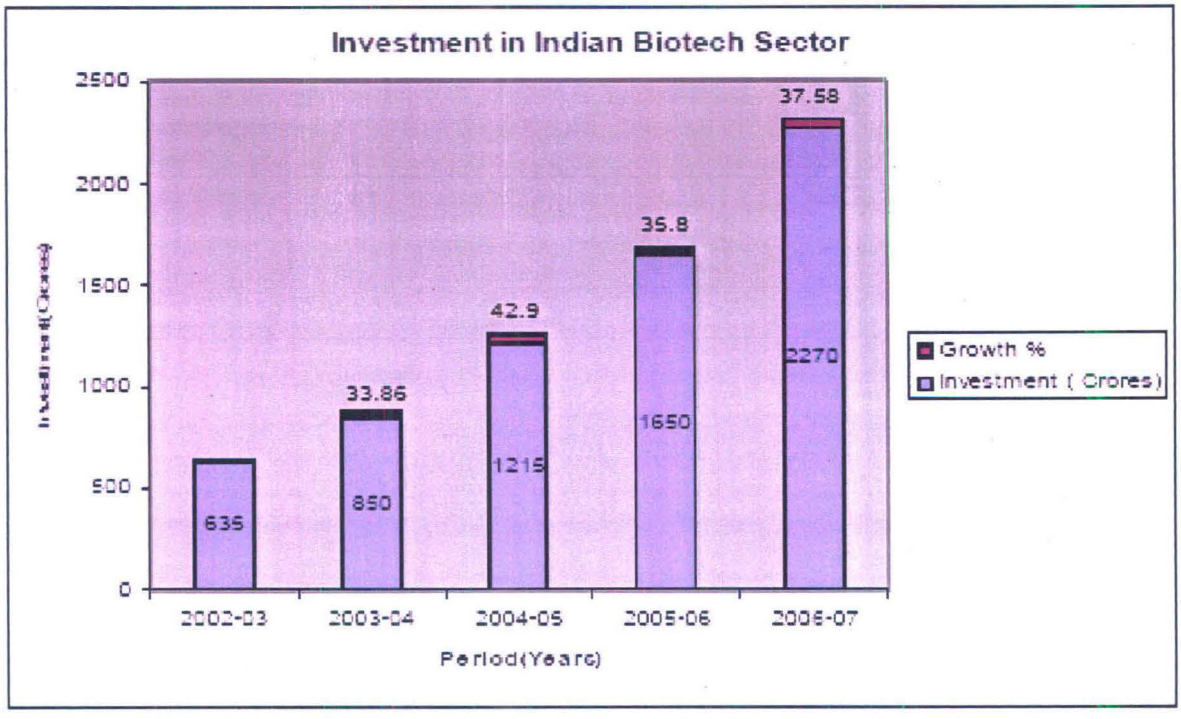
Source: CII[151]

Biopharmaceuticals market dominates with 76 per cent of the industry sale of Indian biotechnology industry. Apart from these the other segment which includes bioservices which is of 7 per cent, the bio agricultural sector with 7 per cent, the industrial biotechnology segment with 5.5 per cent and the bioinformatics with 2.5 per cent of the industry sales (CII 2005: 4).[152]

Acknowledging the factor that the biotech industry is booming in India the, report from the Biospectrum shows that there is heavy growth in investment in biotechnology research and development. The graph below shows that in the last five years there has been a consistent increase of 50 per cent in investment. According to the DBT the total investment alone for the year 2007 touched a high of Rs.2270 Crores.

[151] Confederation of Indian Industries (CII), India Brand Equity Forum, Biotechnology, (2005), URL http://www.ibef.org/download/Biotechnologysr.pdf, Accessed online on 22nd October 2007.
[152] *Ibid*

Figure :7



Source: Biospectrum, March 2008

The recent report published by Ernst and Young on the global biotechnology industry says that Indian biotech industry is becoming more competitive and is transforming itself. One of the reasons for this competitive growth is the positive response from the policy makers towards the industry. The reports notes that

> Government initiatives are helping bridge gaps and Indian companies are competing aggressively in critical competitive niches-reinventing themselves through research and development (R&D), as well as acquisitions and alliances with companies around the world. Indian firms are developing their own brands of recombinant products, which are increasing market share and rivaling leading global brands in their equity (Ernst & Young: 79).[153]

The DBT has announced a number of initiatives for the promotion of the industry. This includes the setting up of numerous biotech parks which intend to bring in companies, universities, and research and development institutes in one location. The 2006 Act of Special Economic Zones (SEZ) and the supportive legislations have increased the flow

[153]Ernst and Young (2007), "Beyond Borders: the Global Biotechnology Report", pp 79. URL:www.ey.com/beyond borders, Accessed online on January 12th 2008.

of investment to this sector. The launch of the first biotech SEZ Serum Bio Pharma Park located near Pune in Maharastra is an example of this. The Government of India has give clearance to certain other major biotech players for setting up biotech SEZ. This includes Biocon and Jubilant Organosys.

The Indian biotechnology industry is focused and is developing through biotechnology clusters in various states. The main biotech clusters are developed in the states of Andhra Pradesh, Himachal Pradesh, Karnataka, Kerala, Maharstra, Tamil Nadu, etc. These states have their own biotechnology policies. They have earmarked funds for the development of biotechnology in the research and development areas and in commercial ventures (Ernst & Young 2007).[154] Various states are developing, establishing, and promoting incentives to biotechnology companies as well as investing in construction of biotechnology research parks to promote biotechnology industry. The bio-clusters developed by these states are expected to promote convergence and coordination among various academic research institutions and different sectors of the industry that might eventually help growth of the biotechnology industry. For example in Bangalore, biotechnology is focusing on coordination between its successful information technology industry and biotechnology industry which provides an impetus to the bioinformatics industry. Apart from these, the Government of India has earmarked funds for the industry through the soft loans from the Technology Development Board (TDB) (Ernst & Young, 2007).

In India the government has been playing a significant role in the growth of biotechnology since the inception of the Department of Biotechnology. Government of India has formulated different policies to enhance its growth of this sector over a period of time. In recent years, the government has taken initiatives to formulate new laws and amending the existing policies so as to support the biotechnology segment. These policies include the research guidelines for stem cell, pharma policy, foreign trade policy, Special Economic Zone (SEZ) Act etc. Apart from these, the government simplified the procedures for registering companies and announced attractive incentives to initiate the investments in this sector from private players. Considering all these

[154] *Ibid*

factors the Department of Biotechnology projects that the Indian biotechnology market will touch 1,079,87.49 crores ($25billion) revenue by 2015 (GOI 2007).[155] The role of government was prominent in the development of biotechnology till 1990's. As a result of globalisation, privatisation and the new economic policies, private players started pitching into this sector heavily and have been playing a substantial role since then. Today a number of Indian biotech companies are acknowledged with the world class tag and are contributing to the world healthcare market. In the next section of this chapter we will discuss the private/ corporate players in the biotechnology industry in India.

2.10 Private /corporate sector in biotechnology:

The private industrial sector was increasingly realizing the importance of biotechnology sector partly in response to the governments' initiative. This was also a reflection of the growing importance of biotechnology in a number of fields internationally. Private sector investment has started concentrating in this sector since the announcement of the draft human genome sequence in the year 2000. Unfortunately there is little authentic information about investment by private players in the industry. Rao citing a report of the DBT notes that there are three hundred odd companies in India. However, he notes that other estimates place the number at around 800 companies operating in various sectors of biotechnology (Rao 2002).[156]

> "The Indian biotechnology industry is fairly concentrated with the top 20 biotech companies holding 60 per cent of the total biotech market. Homegrown domestic companies contribute to 52 per cent of the total biotech business. As of 2005, the larger domestic companies were maturing and consolidating their global positions with some incurring reduced profits " (Sarx 2006: 16).[157]

The companies in medical biotechnology in India can be divided into three broad categories. One is that of small start-up companies that have indigenously developed biotech products, e.g., Shantha Biotech and Bharat Biotech. The second is of large

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[155] Government of India, Ministry of Science and Technology, Department of Biotechnology, URL: http://www.biotechnews.gov.in/panorama1.htm, Accessed on 23rd November 2007.

[156] Rao, S.R (2002) "Indian Biotechnology Developments in Public and Private Sectors - Status and Opportunities", *Asian Biotechnology and Development Review*, Vol.5, No.1, URL: http://www.ris.org.in/abdr_nov1.pdf, Online accessed on 27th August 2007.

[157] Sarx, Johannes (2006), Biotechnology- The next Indian success story?, University of Arizona, Working paper

companies, which have started responding to biotechnology and have in fact incorporated biotechnology in their work plan, for instance, Dr. Reddy's Laboratory (DRL), Ranbaxy Laboratories and Wockhardt Ltd. The third group has start-ups and which are all set to emerge as contract research organizations (CROs). Largely their work comes from Trans National Corporations (Chaturvedi 2002).[158] Some of the top biotech companies from India are Biocon, Serum Institute of India, Panacea Biotech, Nicholas Pirama, Wockhadrt Limited, GlaxoSmithKline, Bharat Serum, Krebs Biochemicals and Industries Limited, Zydus Cadila, Indian Immunologicals, Shantha Biotechnics, Biological E, Bharat Biotech, Ranbaxy and Novozymes. Biocon is the first and the leading biotech company from India. Earlier the main revenue of Biocon was from the enzyme manufacturing but the company has now become more research oriented and had introduced a few drugs for cancer, autoimmune and metabolic diseases in the market. Serum Institute of India is the largest producer of DTP and measles vaccines. For the production of bacterial and viral vaccines Panacea Biotech has introduced its new plant in Himachal Pradesh. Hyderabad-based Shanta Biotechnics in an another leading company from India. Their products includes Hepatitis B vaccine, streptokinase drug and interferon alpha-2b. The following table **(Table 9)** represents the information on some of the leading biopharmaceutical products in India manufactured by the private players.

[158] Chaturvedi, Sachin, (2002), "Status and Development of Biotechnology in India: An Analytical Overview", Research and Information System (RIS) for the Non-Aligned and other Developing Countries, New Delhi, working paper

Sector	Type	Product Name	Application	Producer[a]
Vaccines	Recombinant hepatitis B surface antigen	Shanvac-B	Hepatitis B	Shantha Biotechnics
	Recombinant hepatitis B surface antigen	Revac-B	Hepatitis B	Bharat Biotech
	Recombinant hepatitis B surface antigen	Gene Vac-B	Hepatitis B	Serum Institute of India
	Purified capsular polysaccharide Vi of *Salmonella typhi*	Typbar Vi	Typhoid	Bharat Biotech
Therapeutics	Recombinant human insulin	Wosulin	Diabetes	Wockhardt (Mumbai)
	Recombinant human erythropoietin α	Epox	Anemia	Wockhardt
	Recombinant human interferon α-2b	Shanferon	Cancer	Shantha Biotechnics
	Recombinant streptokinase	Shankinase	Cardiovascular	Shantha Biotechnics
		Indikinase	Cardiovascular	Bharat Biotech
	Liposomal amphotericin B injection	Fungisome	Visceral leishmaniasis	Lifecare Innovations (New Delhi)
	Recombinant human granulocyte colony-stimulating factor	Gramstim	Neutropenia	Dr. Reddy's Laboratories
Diagnostics	Immunoblot assays using recombinant HIV-1 antigens gp41 and C-terminus of gp-120 and HIV-2 antigen gp-36	HIV TRI-DOT	HIV-1 and HIV-2	J. Mitra (New Delhi
	Immunoblot assay using recombinant HIV-1 antigens gp-41 and gp-120, HIV-2 antigen gp-36, and HCV antigens NS-3, NC-4 and NC-5	HIV-HCV Combo	HIV and hepatitis C	Bhat Biotech India (Bangalore)
	Enzyme-linked immunosorbent assay for recombinant HCV core antigens 1b &3g, together with peptides for HCV antigens NS-3, NS-4 1, NS-4 2, and NS-5	HEP-Chex C	Hepatitis C	XCyton Diagnostics (Bangalore)
	Enzyme-linked immunosorbent assay for recombinant version of *Taenia solium* excretory/secretory antigens	Cysti-Chex	Neurocysticercosis	XCyton Diagnostics

Source: Chaturvedi 2007[159]

There are about 20 recombinant products approved in India (Chaturvedi 2007)[160]. From the above table it is clear that out of the approved 20 recombinant products indigenous

[159] Chaturvedi (2007), *Op cit.*

companies are producing six, biopharmaceutical 7 and the rest of the products are imported. Chaturvedi (2007) cites that due to the intensified price competition the vaccine market is largely concentrated on Hepatitis B vaccine. Another area in which the Indian companies engage is the biopharmaceutical out- sourcing. The domestic companies are also creating some headway in diagnostics and therapeutics. The unofficial reporting about the turnover of the Contract Research Organization (CROs) is about $100 million and are largely concentrated on clinical trials and contract manufacturing.(Chaturvei 2007).

Owing to the simplified rules and incentives by the government in the form of allowing rebate on research and development, customs and excise duty wavier on certain products and 100 per cent Foreign Direct Investment (FDI), there are lots of foreign companies that have made their presence in the Indian biotechnology industry. Some of them are already registered in the foreign stock exchange with massive financial backup. As we saw there are more than 300 private companies operating in the area of research and development in the Indian biotech sector.

Being a party to the WTO and TRIPS, India is following the global intellectual property regime. Before the deadline of January 1 2005, as an obligation to the World Trade Organization (WTO) and the TRIPS (Trade related intellectual Property Rights) treaty, the Indian government had amended the Patent Act on December 27th 2004 (Thompson 2005)[161]. The amendment of the Patent Act in 2004 has given due recognition to the growth of biotechnology industry in India. Experts are of the view that the new patent laws are encouraging the domestic drug companies to invest heavily on research and development of drugs (Thompson 2005).[162] So as to create awareness and understanding on the intellectual property rights, the Department of Biotechnology, GOI had also opened a cell named Biotechnology Patent Facilitating Cell. Even though the amended IP law gives a boost to the growth of biotechnology industries and allied activities in India there is still heated debate going on over the trade policy on biotechnology and its related topic of genetic modification of living resources.

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[160] *Ibid.*

[161] Thompson, Laura (2005), "Changing Time for Patenting in India", URL http://www.thomsonscientific.com/news/newsletter/2005-02/8263720/, Accessed online on 24th November 2007.

[162] *Ibid.*

With a turnover of $15.8 billion the Clinical Research Organizations (CROs) are gaining greater importance in the field of clinical trials all over the world. The provision of exempting CROs from the service tax on export services by GOI in 2007 as part of promoting biotechnology had made India the hub of the clinical trials. The next part of the chapter discusses clinical trials in India (GOI 2008).[163]

2.11 Clinical Trials:

> *"To make India a preferred destination for drug testing, I propose to exempt clinical trial of new drugs from service tax,"*[164]
>
> *"Also, total exemption from service tax is being provided to technical testing and analysis for testing of new drugs, vaccines and herbal remedies, on human participants by a CRO approved to conduct clinical trials by the Drugs Controller General of India."*
>
> *"This exemption from Government of India will attract more clinical trial outsourcing as the pharmaceutical sponsors will heavily benefit on their cash outflows on account of their expenses on CRO fees and other variable pass through expenses,"*
>
> P Chidambaram (Finance Minister), presenting the budget for the year 2007-08.[165]

Developing countries accounts for the 20 to 30 per cent of the global clinical trial activities and the involvement of India in global trials is only a decade old (Bhatt 2004)[166]. According to the Department of Biotechnology, the Indian clinical research industry owns a present turnover of $100 million and is expected to reach a size over $250 to $300 million by 2010 (GOI 2008).[167] The clinical trials in India got a boost after the annual budget of GOI for the year 2007-2008, where the finance minister

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[163] Government of India, Department for Science and Technology, Department of Biotechnology, URL: http://www.biotechnews.gov.in/healthcare1.htm, Accessed online on 12th February 2008.

[164] Barnes, Kirsty (2007), "Clinical trials in India Just got Cheaper", URL: http://www.drugresearcher.com/news/ng.asp?n=74588-chiltern-international-india-clinical-trial-cost, Accessed online on February 12th 2008.

[165] Barnes, Kirsty (2007), "Clinical trials in India Just got Cheaper", URL: http://www.drugresearcher.com/news/ng.asp?n=74588-chiltern-international-india-clinical-trial-cost, Accessed online on February 12th 2008.

[166] Bhatt, Arun (2004), " Clinical Trials in India: Pangs of Globalisation", *Indian Journal of Pharmacology*, Vol 36, Issue 4, pp 207-208.

[167] Government of India, Ministry of Science and Technology, Department of Biotechnology, GOI, URL: http://www.biotechnews.gov.in/healthcare1.htm, Accessed online on 12th February 2008.

announced tax exemption for the clinical trial related activities. Sen (2007)[168] states that the clinical trials enterprise alone in United States is around $30 billion and 60 per cent of these are outsourced to India. He adds that, India has shown a welcoming attitude to this enterprise. One of the reasons cited for selecting India has the destination in clinical trial is the cost competitiveness factor. For conducting a clinical trial in the developed country like US the average cost per patient will be around $5404 for phase 1, $6538 for Phase II and $7635 for phase III (Bames 2007)[169]. On the other hand, it is calculated that in India conducting a clinical trial will save up to 60 per cent of the amount what the drug companies spend in US for the same. The number of clinical trials in India is rapidly growing. Even though there is lack of information on the exact number of clinical trials and the number of patients enrolled for clinical trials, reports indicate that there is an increase of 3-5 times in the enrolment of patients since 2001 (Sen, 2007). In spite of governments initiative to control and monitor the clinical trials through different norms and laws there is a huge public outcry about the unregistered and the unethical practice of clinical trials in India. A survey conducted by the ICMR reports that there are about 200 ethical committees functions in different institutions around India with out accreditation (Bhatt, 2004)[170]. However Sen (2007) is of the opinion that public trust in clinical trial sector in India appears to be low which is not very different from what prevails in the US.

The GOI cites that apart from the low cost factor, the well trained English speaking doctors, adequate hospital infrastructure, diverse genetic pool, the presence of world class institutes for clinical research, training and the large chunk of disease burden population are reasons for the growth of clinical trials in India (GOI 2007)[171]. The following table represents the details of certain vaccines that are developed by the public institutions which are under clinical trials in India

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[168] Sen, Falguni (2007), "Global Trends in Clinical Trials and their Impact on India", Working draft presented at the National Consultation on New Reproductive Technologies and their Implications for Women, Jawaharlal Nehru University, New Delhi.

[169] Barnes ,Kirsty, (2007) "Clinical trials in India Just got Cheaper", URL: http://www.drugresearcher.com/news/ng.asp?n=74588-chiltern-international-india-clinical-trial-cost, Accessed online on February 12th 2008.

[170] *Op cit.*

[171] Government of India, Ministry of Science and Technology, Department of Biotechnology, (2007) URL: http://www.biotechnews.gov.in/healthcare1.htm, Accessed online on 12th February 2008.

Table: 9 Vaccines under development in India.

Vaccines under Development in India			
Human Vaccines in Clinical Trial			
Sl. No.	Disease	Type of Vaccine	Institute/Industry
1.	Rotaviral Diarrhoea	Tissue Culture AGMK Vero Cell	Phase-I in adults, and children and infants completed successfully Pilot lot of Vero Cell vaccine produced for pre-clinical studies prepared by Bharat Biotech successfully initiated Phase I/II clinical trial
2.	Cholera	Recombinant (Oral)	NICED & SAS, Kolkata; IMTECH & PGIMER, Chandigarh; and SGPGIMS, Lucknow and CMC, Vellore
3.	Rabies	Combination (DNA + Tissue Culture)	IISc, Bangalore and IIL, Hyderabad
4.	Japanese Encephalitis	Tissue Culture & Inactivated	NII, New Delhi and Panacea Biotech Ltd., New Delhi
5.	Japanese Encephalitis	DNA Vaccine (Adeno-4 based)	NII, New Delhi
6.	Tuberculosis	Recombinant (Protein+DNA)	IISc, Bangalore
7.	Tuberculosis	Recombinant DNA	Delhi University South Campus
8.	Typhoid	Vi-Comb conjugate	AIIMS, New Delhi
9.	Malaria	Recombinant (*P. vivax & P. falciparum*)	ICGEB, New Delhi & MRC, Rourkela

Source: GOI[172]

Introducing a new drug or vaccine in a market involves a lot of time and financial input. As we know apart from the established companies there are also budding companies entering the drug development process. Compared to the established companies the budding companies lack the huge amount for investing in the research and development process. Here comes the role of corporates and venture capitals in financing them. In the next section we will discuss the role of the venture capitals in funding the research and development process of drug discovery of private companies.

2.12 Venture Capitals:

The move from the Ministry of Science & Technology in 1992 to establishment the Technology Development Board (TDB) for providing financial assistance to industrial concerns and other agencies attempting development and commercialization of indigenous technology or adopting imported technology for wider domestic application opened the arena for several established private sector as well as start-up companies investing in biotechnology (Chaturvedi 2002). This, in turn, helped the financial institutions/ agencies, both in public and private sectors, to launch venture capital

[172] *Ibid*

funding mechanism in this sector (Rao 2002).[173] Ernst & Young 2007, reports that venture capital in India is in its nascent stage and only few are interested in investing in biotechnology. Some of the prominent venture capitals involved in this sector includes ICICI (Industrial Credit and Investment Corporation of India), Morgan Stanley, and Small Industries Development Bank of India (SIDBI), Kotak Mahindra, Venture Funds, Yes Bank, Reliance Life Sciences (RLS) and TATA. Ernst & Young (2007) reports that the Guharat Biotech venture fund (GVBF) got a commitment of Rs 50 crore investments for startups and early stage growth.. The International Finance Corporation, the private arm of the World Bank committed equity of $54 million to the Andhra Pradesh Industrial Development Corporation (APIDC) as private equity fund for the startup of the early-stage Indian life science business. Several biotech companies are raising funds from the international banks for expansion. As in the developed countries, in India recently a number of initiatives had started in the form of Public Private Partnerships (PPP) for research and development process. We will discus the about the increasing PPP ventures in the Indian biotechnology sector in the next session.

2.13 Public private partnership in biotechnology:

Recent statements made by the DBT on National Biotechnology Development Strategy (which is open to the public for comment) states that up to 30 per cent of the biotechnology research budget will be spent through the Public Private Partnership (PPP).[174] The reasons which are cited for this initiative includes several factors like the huge network of private sector companies ranging from small-intensive to large multinationals, the large research and development funding available to carry out high return, short-term and long term biotechnology projects, understanding of the market and distribution systems, the largest talent pool of scientific research resources and demand-driven efficient R&D facilities (Konde 2008).[175] As per the technology transfer agreement between the Department of Biotechnology and Biotech Consortium India

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[173] Rao (2002), *Op cit*,

[174] Government of India, Ministry of Science and Technology, Department of Biotechnology, URL: http://dbtindia.nic.in/publication/publicmain.html, Accessed online on 17th August 2007

[175] Konde, Viren (2008), "Biotechnology in India:public-privtae partnerships", *Journal of Commercial Biotechnology*, Vol 14, No 1, January, pp 43–55.

Limited (BICL) around 60 products (Appendix 1) developed by public entities using public funds have been handed over to the private companies for commercialisation. From the total list of the technologies transferred . The majority of them are related to health care compared to other areas like agriculture, environment and industry. The table below presents a brief on the transfer of health care technology transferred to private companies for commercialisation and its out come.

Table: 10 Details of the products developed and transferred, and their outcomes

Name of Product/ Technology	Institution Where Developed	Industry which purchased	Outcome of Transfer
Filariasis Detection Kit	Mahatma Gandhi Institute of Medical Sciences, Wardha	Cadila Labs, Ahmedabad	Comp. Withdrew its kits due to unreliable sensitivity of the kits
Pregnancy Slide Test Latex agglutination	National Institute of Immunology, New Delhi	Ranbaxy Labs, New Delhi	Availability of Similar Products and consumers did not find additional advantage and hence withdrawn
Pregnancy DOT-ELISA	National Institute of Immunology, New Delhi	Ranbaxy Labs, New Delhi	Availability of Similar Products and consumers did not find additional advantage and hence withdrawn
Typhoid Fever Detection Kit	National Institute of Immunology, New Delhi	Lupin Labs, Mumbai	Not yet introduced as company did not find substantial additional advantage over conventional widal test
Amoebic Liver Abscess	National Institute of Immunology, New Delhi	Cadila Labs, Ahmedabad	Introduced to limited extent due to low demand as doctors are not to keen to use this test and would prefer to go by physical symptoms
Typhoid Fever Detection Kit	All India Institute of Medical Sciences, New Delhi	Ranbaxy Labs, New Delhi	Found unusable on validation
Blood Grouping Monoclonals	National Institute of Immunology, New Delhi	Cadila Labs, Ahmedabad	Withdrawn after introduction as more sensitive and reliable products were available
Hepatitis B Detection Kit	National Institute of Immunology, New Delhi	Lupin Labs, Mumbai	Not satisfactory and needs more improvement
Leprosy	National Institute	Cadila Labs,	Not Yet Introduced
Immunomodulator	of Immunology, New Delhi	Ahmedabad	
Leishmaniasis detection kit	Central Drug Research Institute	SPAN Diagnostics Ltd	Manufactured but finds difficulty due to limited market demand
Monoclonals to M-13 phage proteins III and VIII	University of Delhi	Pharmacia Inc	Abandoned by the company after validation

Source:[176] (Visalakshi, 2005)

Visalakshi (2005) notes that out of the 60 products transferred as per the agreement only 10-12 had reached the commercial stage. Apart from these transfer of technologies some of the private companies had already linked their research with the major public research institutes of India in the form of Public Private Partnerships (PPP). The next part of the chapter traces some of the existing PPP initiatives.

"India already has strong assets for the development of a competitive and innovative industry with a countrywide network of research institutions. These institutions have a recognised academic level to transfer their knowledge to the industry, either by institutional collaboration, or by the direct migration of scientists from the public to the private sector" (Konde 2008).[177]

The following table provides an overview of some of the PPP initiatives. This pattern of growth of the biotechnology industry is similar to that in other countries, notably the USA and the UK.

[176] Visalakshi, S (2005) "Transferring biotechnology in India: Experiences and Lessons", National Institute of Science and technology and Development Studies, New Delhi. Working paper.
[177] Konde, Viren (2008), "Biotechnology in India:public-privtae partnerships" *Journal of Commercial Biotechnology*, Vol 14, No 1, January, pp 43–55.

Table: 11 Public private partnership of Indian biotechnology sector:

Private company	Public partners
Avestha Gengraine Technologies Pvt. Ltd., Bangalore	NCBS University of Agricultural Sciences ICRISAT Imperial College, London, UK
Bangalore Genei Pvt. Ltd., Bangalore	CCMB IBA – ICAR
Bharat Biotech, Hyderabad	DBT – AIIMS ICGEB – AIIMS CBT
Biological E., Hyderabad	IISc International Centre for Diarrhoeal Disease Research (ICDDR), Bangladesh. National Institute of Health (NIH), USA. Nederlands Vaccine Institute (NVI), Netherlands
Genotypic Technology, Bangalore	CBT IISc Madhurai Kamraj University
Monsanto, Bangalore	IISc TERI Kenyan Agricultural Research Institute
Nicholas Piramal India Ltd., Mumbai Panacea Biotec, New Delhi	CBT NII Jawaharlal Nehru University, New Delhi Biotechnology Consortium of India National Institute of Health, USA
Rallis India, Mumbai	ICGEB IISc University of Madurai World Health Organization (WHO)
Serum Institute of India Ltd., Pune	World Health Organization, Switzerland Health Protection Agency, UK Program for Appropriate Technology in Health (PATH), USA
Shantha Biotechnics Ltd., Hyderabad	CCMB IISc Bhabha Atomic Research Center NII IICB JNU ICGEB NCCS Anna University Osmania University BARC Tata Memorial Hospital International Vaccine Institute, Korea
Shapoorji Pallonji Biotech Park Pvt. Ltd., Hyderabad	CCMB University of Hyderabad Research Triangle Park, USA Technologie Park Heidelberg, West Germany
Strand Genomics Ltd., Bangalore	IISc CSIR Project Team CDFD
Wockhardt Ltd., Mumbai	ICGEB

Source: Konde (2008).

The table also shows the tie-up between some of the leading research institutes in the public sector and the private companies in the arena of modern biotechnology. If we closely examine the table it is clear that the companies listed here have tie-up with more than one academic or research partner. Konde (2008) sees this as a indicating

factor indicating that the private companies are still in the learning process of working together.

Chaturvedi (2007)[178] notes that Indian scientists from well known research institutions are actively involved in floating companies. This is parallel with the tendency of U.S based companies in 70's and 80's where university scientist floated their own companies. He sites the example of a company called Metahelix Life Sciences with $1.5 million venture capital funding floated by two leading scientists from the Indian Institute of Scientists (IISc), Bangalore, which focuses on contract services in genomics, bioinformatics, molecular markets, which in its due course is planning to develop new molecules of its own.

Konde (2008) notes that The Council of Scientific and Industrial Research (CSIR) has designed a unique PPP called the New Millennium Indian Technology Leadership Initiative (NMITLI). This is said to be the biggest PPP in post-independence India involving 65 private sector companies and 160 institutions and universities with a heavy emphasis on the drugs and pharma R & D partnerships. Even though PPP in the biotechnology may be a comparatively new phenomenon in India, it has played a major role in the advancement of biotechnology especially in the developed countries.

2.14 Conclusion:

"Biotechnology in India has made great progress in the development of infrastructure, manpower, research and development" (Srivasthava 2005).[179] The advancement that the biotechnology field in the last two decade in India is mainly due to the timely initiatives and policies taken by the Government of India especially in accelerating its growth. Today the Indian biotechnology sector comprises more than 300 big and small companies with an estimated revenue of US$2billion, with an annual growth rate of 35-40 per cent, which is considered as one of the best in the world and is expected to reach US$10 billion by the end of the year 2010. Health care biotechnology had gained its momentum mainly in 90's, that too after, the post WTO

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[178] Chaturvedi, Sachin (2007), "Indian innovative systems and Emergence of Biopharmecutical Sector; Issues and Prospects, Research and Information System for the Non-Aligned and other Developing Countries, New Delhi, Working paper.

[179] Srivasthava L.M (2005), "Health care Biotechnology in India", *Indian Journal of Clinical Biochemistry*, Vol, 20 (1) pp 201-207

period (1995) where most of the companies entered as private limited companies. For the last two decades the Government of India had invested considerable amount for the development of biotechnology through the DBT. From a mere double digit (crore) allocation in 80's it has moved to thousands of crores. Even though India contributes only less that 2 per cent to the total revenue of the global biotechnology industry, Indian biotechnology has already created inroads in the world vaccine and therapeutic markets. As a result of the policy and legislative changes that happened in the recent years more multinational corporations in the drug industry have started entering India for clinical trials and stem cell research.

A good number of English speaking people, scientific work force, a well established IT sector, a network of reasonable good infrastructure, a well established pharmaceutical industry, the presence of a number of MNC's, diverse population with the varying gene pool makes India a attractive destination for the biotechnology activities. The timely interventions from the Government of India in the form of fiscal and incentive initiatives from the Central and State governments including the tax holidays, capital subsidies, special policy frame works, creation of biotech parks, Special Economic Zones for biotechnology, incubators, initiative of soft loans to the entrepreneurs with minimal interest from the DBT, the creation of a single window biotechnology authority, opportunities for the increased institution-industry collaboration, the entry of the local venture capitals for investments in the sector etc are cited as the reason for the impressive growth of biotechnology industry and FDI in India. India has shown an exceptional growth in the research and development sector of biotechnology in the last few years and the major part of it has taken place in the private sector.

Chapter 3

Chapter III

Can Biotechnology Solely Address Public Health Issue: An Exploration Of Hepatitis B Vaccination In India.

It is evident from the previous chapters that India has placed biotechnology development as a priority area. In this chapter we attempt to see how far this prioritization helped us to handle diseases. The minimum role which vaccination could play in the cases of Hepatitis B is taken as a case here. Factors such as advanced, innovative, and effective technology and variations in demography have created astonishing demands on the world's healthcare and biotechnology industries. It is also an agreed fact that the unprecedented growth of biotechnology, offering new tools and techniques in healthcare has opened up new scope in research and learning more about human body and diagnosis of ailments. While the major advances in the biotechnology over the last thirty years have transformed the face of medicine in the industrialised countries, its innovations are yet to reach the world's poorest countries, where more than three billion people live on less than two dollars a day (Human Development Report 2007/08).[180] At the same time, whether biotechnology can address all the health issues of the developing world is a question that needs to be debated over, because health issues of these countries have links with major structural issues of the society like poverty.

It is estimated that each year more than 10 million people in the developing world die of infectious diseases such as HIV/AIDS, malaria, tuberculosis, diarrheal diseases, and acute lower respiratory infections (Sachs 1999).[181] Millions more suffer from debilitating parasitic diseases, which often incapacitate people in their most productive years. The burden of infectious illness falls mostly on children and pregnant women. In poor countries, the magnitude of suffering caused by infectious diseases greatly impedes economic development (Sachs 1999).[182] There are currently over 300 drugs products and vaccines in clinical trials aimed at various types of

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[180] Human Development Report 2007/08, URL: http://hdrstats.undp.org/indicators/24.html, Accessed online on 15th March 2008.

[181] Sachs, J, D (1999) "Helping the World's Poorest", *The Economist*. August 14, 352 (8132), pp. 17-20, URL: http://www.owlnet.rice.edu/~poli354/990814_Brazil_Sachs.html, Accessed Online on 12th March 2008.

[182] *Ibid.*

cancer, heart disease, Alzheimer's disease, AIDS and arthritis etc.[183] The unprecedented growth of health care and biotechnology has made such an impact that it has created high hopes and expectations among the patients and their relatives on meeting their treatment-related needs. The attention which the Government of India gives to health biotechnology need to be probed in detail to understand how far biotechnology can or can not address a health issue. In this chapter by taking Hepatitis B as an example an attempt is made to see how vaccination can play only a minimum role.

BRIEF DISCRIPTION ABOUT HEALTH CARE BIOTECHNOLOGY

Health care biotechnology simply means, application of biotechnology in health related issues of a population.

> "Biotechnology in healthcare not only encompasses medicines and diagnostics which are manufactured using a biotechnological process, but also cell and tissue engineered products, and include the use and the application of key biotechnology tools in the research and development of all innovative medicines" (European Association of Bio Industries 2008).[184]

Biotechnology does help in the manufacture of many of the ground breaking medicines which are available in market. Healthcare biotechnology has already started to prove its worth in this sector through the discovery and production of drugs and vaccines, intervention in preventing, diagnosing the disease, and its innovative and effective treatment. But it is also equally important to note that biotechnology solely can not address all the issues related to a disease, because particular disease is not only clinical in nature but has social and economic causes associated with it.

The main focus and the application of biotechnology in healthcare are on fighting the diseases by means of the human body's own weapons. Here the medicines produced through biotechnology techniques including therapies, synthetic proteins, antibodies

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[183]Biotechnology Bioethics and technology, URL: http://www.bio-scope.com/,Accessed online on 22nd January 2008

[184] European Association for Bioindustries, "HealthCare Biotech" URL: http://www.europabio.org/Healthcare/HC_about.htm, Accessed online on 15th March 2008.

and enzymes to fight against the infections and diseases (Govt. of Canada 2008).[185] Apart from these, biotechnology also depends on other living organisms such as plants, yeasts, animal cells and viruses to produce medicines. Medicines, Vaccines, Diagnostics and Gene Therapy are the four foremost areas in healthcare where biotechnology is currently used. Some of the medicines, where biotechnology played a role in its development include the cases of diseases such as hemophilia, diabetes, growth deficiency in children etc. Apart from these, certain biotechnology companies have also developed therapeutics for infections agents including hepatitis B, influenza and HIV.

As already indicated, biotechnology has advanced the pace of treatment of various diseases. The advancement of techniques and tools in the diagnostic sector has helped in such a way that the present state of disease is detected with more speed and accuracy. The biotechnology diagnostics has also advanced to a phase where it is used to detect a broad variety of diseases and genetic conditions. This provides researchers and scientists with an arsenal of informations and tools which will aid the development of vaccines, drugs, diagnostics, treatments and perhaps cure. For example, biotechnology techniques are now used as diagnostic technique to screen blood to assure the safety of the donated blood from HIV and hepatitis virus.

Genes are also used as drugs in the gene therapy for treating certain hereditary disorders. Experiments have succeeded in replacing faulty or missing genes so as to prevent the incidence of genetic diseases. It is also worth noting that gene therapy currently in progress is based on experiments with a few clinical trials involved with human being, which includes the treatment for cystic fibrosis at its early stage. (European Association of Bio Industries 2008)[186].

The advancement in the field of biotechnology in healthcare is focused mainly on the drug development and development of diagnostic tools. Consequently the global biotechnology sector reemphasis the role of techno-centric and biomedical approach

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[185] Government of Canada, "Science and issues", URL: http://www.biobasics.gc.ca/english/View.asp?x=626, Accessed online on 16th March 2008.

[186] European Association for Bioindustries, "HealthCare Biotech" URL: http://www.europabio.org/Healthcare/HC_about.htm, Accessed online on 15th March 2008.

in healthcare. With this approach it is evident that there is an attempt to project biotechnology as a solution to health problems undermining the socio economic and environmental root causes. A close look into many of the disease prevention and treatment technologies shows that it has wholly or partially neglected the epidemiological aspects of diseases (Emanuelle 2005).[187] Infectious diseases account for major part of the overall disease burden in the country; particularly it affects the most vulnerable sectors of the society. In preventing infectious diseases, a major thrust has been given on healthcare programmes such as universal immunization programmes where new generation vaccines and diagnostics are given importance. Technology or vaccines is being suggested as the best and only solution to the diseases which has a very strong relation to poverty, low food intake, low nutrition, adverse sanitary conditions etc. This techno centric-approach has wide support from the international bodies such as WHO, IMF, WB etc and the low and middle income countries are forced to take a position which supports this techno centric policies. This chapter, by taking the case of hepatitis B vaccination as an example analyses what role biotechnology based solutions can play to address this particular disease problem. Before addressing this issue, the next section gives an overall idea about vaccine policy of India viz which all diseases are addressed, present vaccination status of India etc. Hepatitis B is the latest introduction to India's Universal Immunization Programme.

VACCINATION IN INDIA

Vaccines are widely regarded as important in the primary health care as a preventive mechanism especially against infections diseases (Madhavi 2007).[188] The Indian government has identified vaccines as essential drugs and is committed to expand the coverage of vaccination as a part of the global initiatives towards achieving universal immunization. It has also adopted self-reliance in vaccine technology and self-sufficiency in vaccine technology and in vaccine production as a policy objective and

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[187] Emmanuelle, Anne (2005), "Gates's Grandest Challenge: Transcending Technology As Public Health Ideology", URL: http:// image.thelancet.com/extras/04art6429web.pdf, Accessed online on 25th July 2008.

[188] Madhavi, Y (2007), "Transnational Factors and National Linkages; Indian Experience in Human Vaccines", *Asian biotechnology and development review*, Vol.9. No.2, PP 1-43.

has taken the lead in encouraging indigenous technology development and production. In 1970's the world witnessed rapid increase in scientific and technological development in the field of life sciences due to the emergence of greater specialization like biology, immunology, biotechnology etc. This advancement has contributed to production of the new techniques and products for improving the quality of life along with an impact on the economy. Madhavi (2007), notes that these new bio-techniques resulted in the development of several existing vaccines in the west and new vaccines were developed which were safe and potent compared to the conventional vaccines. These developments had encouraged several countries around the world to adopt policies to foster biotechnology so as to harness the potential of biotechnology in their economy. Certain principles had guided the World Health Organization (WHO) in the choice of vaccines in Expanded Programme Immunization (EPI), launched in 1974 and India adopted EPI in 1978 (Dasgupta 2005).[189] By launching the Universal Immunization Programme (UIP) in 1986 the government of India further intensified immunization effort against the vaccine-preventable diseases. Although international agencies such as the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) promote global immunization drives and policies, the success of an immunization programme in any country depends more upon local realities and national policies. This is particularly true for a huge and diverse developing country such as India, with its population of more than 1 billion and with over 25 million new births every year. Vaccine comprises about two per cent of the global pharmaceutical market which represents nearly US$8 billion of the global industry. This is projected to grow at around US$10 billion 2010.Today India is considered as a major buyer and makers of vaccines, locally as well as globally and its current market for vaccines is calculated as US$260 million (Madhavi 2007).[190]

In 1978 under the Expanded Programme of Immunization (EPI), the Government of India (GOI) introduced six vaccines against childhood infectious disease, i.e. tetanus, diphtheria, pertussis, tuberculosis, polio and typhoid. This approach was adopted by the Government in concurring with policy guidelines mentioned by WHO and Alma-

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[189] Dasgupta, Rajib, (2005), "Universalising the Hepatitis B vaccine in India: Pitfalls in Policy and Practice", *Journal of Health and Development*, Vol.1, No. 2& 3, April-September, pp 23-31.
[190] Madhavi (2007), *Op cit.*.

Ata declaration. Measles vaccine was added much later in 1985, when the Indian government launched the Universal Immunization Programme (UIP) and a mission to achieve immunization coverage of all children and pregnant women by the 1990s (Madhavi 2005).[191] On august 14th, 2001, the Government of India announced the inclusion of the Hepatitis B vaccine in the national UIP schedule (Dasgupta 2005).[192] Unlike other vaccines which were included in the UIP easily, the introduction of the hepatitis B vaccine in to the UIP met with a lot of controversies. Taking hepatitis B vaccine as a case we will trace the circumstances which led to the inclusion of this vaccine in UIP, followed by an analysis of epidemiological basis for inclusion of this vaccination and its cost-effectiveness. The inclusion of Hepatitis B vaccine in UIP is influenced by the interests of the market forces while undermining the epidemiological and cost-effective factors.

INCLUSION OF HEPATITIS B IN UIP- ISSUES AND DEBATES

A brief description about the disease:

Hepatitis B is a viral disease which spread by many means, includes the transfer of blood from an infected individual to another, sexual intercourse, from mother to child, probably by insects and can also be spread through fecal-oral route, i.e. through contaminated food and water. This disease can remain as asymptomatic and can cause to irreversible liver damage leading to cirrhosis or liver cancer (Blumberg 1986)[193]. The symptoms of infection are similar to that of jaundice, which can result from any of the five known strains of the Hepatitis virus viz, A, B, C, D & E and also from the other conditions such as alcoholism. Hepatitis A and E are water-borne and transmitted through the feco-oral route, whereas, hepatitis B and C are transmitted through body fluids and are particularly dangerous. Chronic hepatitis can lead to

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[191] Madhavi, Y (2005), "Vaccine Policy in India", *PLoS Medicine Online Journal*, URL: http://medicine.plosjournals.org/perlserv/?request=get-document&doi=10.1371/journal.pmed.0020127, Accessed online on 25th July 2008.

[192] Dasgupta (2005), *Op cit.*

[193] Blumberg, Baruch, (1987), "Comments on the Prevention of Hepatitis B infection in India", Indian Institute of Science, Banglore, Working paper, (This paper as been sent to then Prime Minister of India, Rajiv Gandhi and to government and academic scientist and Physicians).

severe damage of the liver (cirrhosis), leading to liver cancer, hepatic coma and eventual death. (Madhavi 2003).[194]

The consequences of HBV infection depend in a large degree depending up on the age at the time of the acquisition of the infection. Infection acquired in adult life may be symptomatic in the form of typical acute viral hepatitis or may be clinically in apparent. The rate of development of severe liver disease or of death among persons with acute HBV infection is very low. Importantly, most adult individuals who acquire HBV infection recover completely from this infection and clear the virus from their bodies. However, in about 2 per cent to 5 per cent of HBV-infected adults, the virus persists in the body for more than 6 months; this condition is known as chronic HBV infection (Aggarwal 2004: 62).[195]

In contrast HBV infection acquired at birth and during infancy is associated with a milder illness, if any. However, in this age group, the infection is rarely cleared and more than 90 per cent of infected infants develop chronic infection; this phenomenon is related to immaturity of the immune system in neonates and infants. The risk of HBV infection becoming chronic declines with increasing age and reaches the adult level by the age of around 6 years (McMahon, *et al*, 1985: 601).[196] For the persons who fail to clear clear HBV infection, the virus persists for several years and often life-long. These individuals with chronic HBV infection are at an increased risk of chronic hepatitis, liver cirrhosis and hepatocellular carcinoma. These long-term squeal are responsible for most of the mortality and morbidity due to HBV infection; in comparison, acute effects of HBV infection are relatively minor and are only rarely associated with death (Aggarwal 2004: 62).[197]

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[194] Madhavi, Y (2003), "Manufacture of Consent? Hepatitis B Vaccination", *Economic & Political Weekly"*, June 14, pp 2417-2424.
[195]Aggarwal, Rakesh (2004), "Universal Neonatal Hepatitis B Virus Vaccination In India: Why?", *Hepatitis B Annual*, Vol.1, No.1, pp 60-71.
[196]McMahon BJ, Alward WL, Hall DB, et al, (1985), "Acute hepatitis B virus infection: relation of age to the clinical expression of disease and subsequent development of the carrier state", *Journal of Infectious Disease*, Vol.15, pp 599-603.
[197] Aggarwal (2004), *Op cit.*.

Government of India including Hepatitis B vaccination in UIP

On August 14, 2001 the Government announced officially the inclusion of Hepatitis B in the National UIP programme. Unlike other diseases inclusion of hepatitis B in UIP met many controversies, but final result was inclusion of it in UIP. A recent development in hepatitis B vaccine is the attempts to combine DTP vaccine with hepatitis B and develop "combination vaccines" (Madhavi 2006).[198]

The World Health Organisation (1991) has recommended selective immunization in countries where the prevalence of hepatitis B carrier is less than 2 per cent and the universal vaccination where the prevalence rate is higher than 2 per cent. Many of the low income countries did not include universal hepatitis B vaccination in the immunization programme. Owing to the pressure from international organisation and industry in 2001 a pilot project for hepatitis B vaccine was approved by the Government of India. This was launched in 2002 as pilot project in urban slums of 15 cities and in 32 rural districts (Dasgupta and Ritupriya 2002).[199] Madhavi (2003) observed that this step was taken neglecting the debates which were going on in the past five years about justifiability of inclusion of hepatitis B vaccine in the Universal Immunization Programme.

Dasgupta & Ritu Priya (2002) predicted that India being a WHO member state is likely to implement the universal hepatitis B vaccination in UIP and number of dimensions needed to be considered before we actually implement it through the Universal Immunization Programme (UIP). The pilot programme was operational in Delhi from 1996. These mainly include epidemiological evidence, cost- benefit analysis of the programme and issues in the method (like reaching to all new born etc.)

Epidemiological position of Hepatitis B

Ideally it is the epidemiological data that helps the State to priortise and address different diseases. But in many cases, State ignoring the epidemiological data

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[198] Madhavi, Y (2006), "New Combination Vaccines: Backdoor Entry In To India's Universal Immunization Programme?, *Current Science*, Vol.90, No.11, June.

[199] Dasgupta & Ritu Priya (2002), " The Sustainability Of Hepatitis B Immunization Within The Universal Immunization Programme In India", *Health Policy and Planning*, vol.17 (1), pp99-105.

formulates policies which cater the needs and interests of a small group. We can see that case of hepatitis B is also not an exception to this general trend. This paradoxical situation i.e hepatitis B though not a major epidemiological problem being included in UIP is studied by scholars like Dasgupta (2002), Dasgupta and Ritupriya (2005), Madhavi (2003) (2006), Padhke (2005, 2000) and Kale (2000).

Dasgupta (2005)[200] mentions that, the essential purpose of epidemiology is to identify the factors in people and their surroundings that affect occurrence of diseases.

Dasgupta & Ritu Priya (2002), states that as the implementation of the universal vaccination strategy implies a large range of actions and initiatives there is a need to understand the epidemiology of hepatitis B within the total burden of diseases of the Indian population. According to them, this exercise will help to decide the overall control strategies and to best use and implement the vaccination strategies. The burden of various diseases in India is studied by Madhavi (2003)[201] where it becomes evident that the dieases like TB, diarrhoeal related diseases etc. add more burden than hepatitis B. Therefore the Government's decision to assign priority to hepatitis B than diarrhoeal diseases is questionable. The figure below represents (cited by Madhavi 2003: 2418) the burden of diseases which indicates the number of deaths due to different diseases over the year 1990.

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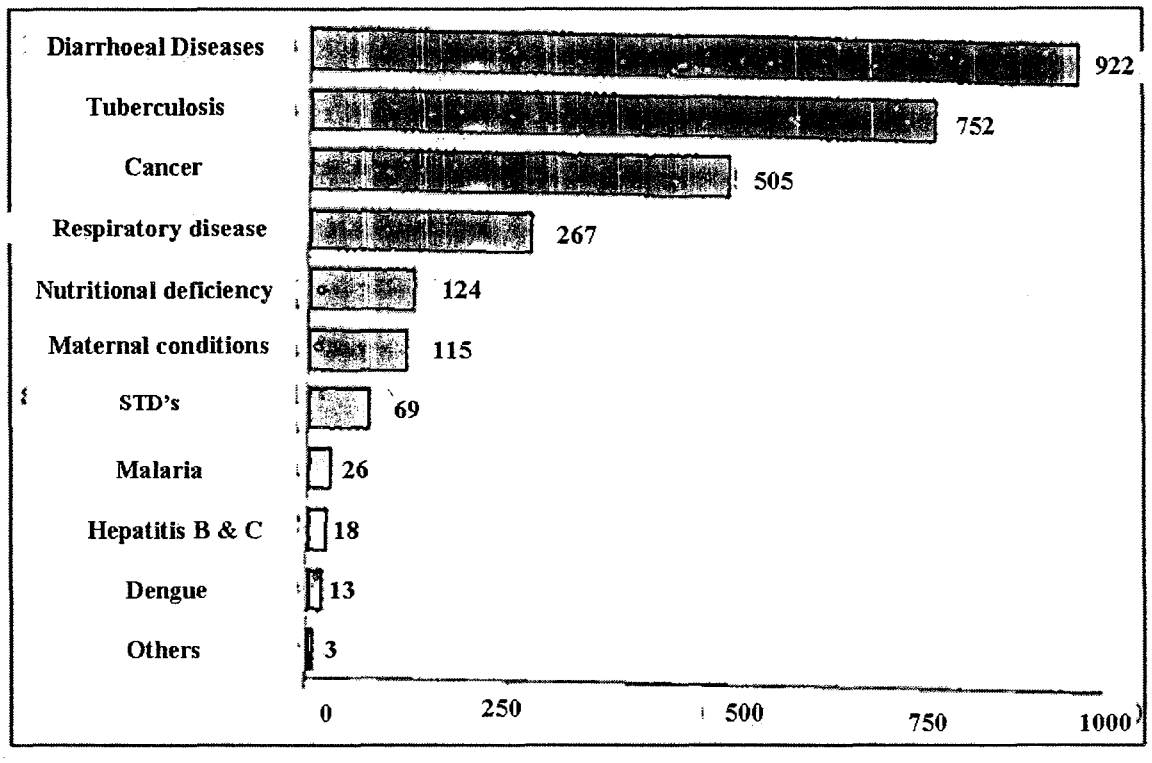
[200] Dasgupta (2005), *Op cit*

[201] Madhavi, Y (2003), "Manufacture of Consent? Hepatitis B Vaccination", *Economic and Political Weekly*, June 14.

Figure: 8 Burden of Diseases (deaths in Thousands)



Source: state of India's Environment, part II: Statistical Database of Citizen's Fifth Report, Published by the Centre for Science and Environment, New Delhi 1999.

Study of Gupta et al, (1992)[202] cited by Phadke and Kale (2000)[203] notes that the overall burden of hepatitis B is much lower than many other diseases like TB, malaria etc. According to them, before recommending Universal Immunization of HepatitisB vaccine, it was necessary to estimate on the basis of available data (Western or Indian), the life years lost per lakh of population due to hepatitis B. They argue that the available data is not sufficient to plan a universal strategy for hepatitis B.

Phadke & Kale (2000)[204] state that there is lack of adequate data on prevalence of HBsAg positivity, its carrier rate in different age groups and on the prevalence of acute and chronic HBV diseases. Because of this it became impossible to estimate the number of life years lost due to HBV compared to other vaccine preventable diseases in India.

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[202] Gupta I., Sehgal R. et al. (1992), " Vertical transmission of Hepatitis B in North India", *Journal of Hygiene, Epidemiology, Microbiology and Immunology*, Vol.36, No. 3

[203] Phadke, Anant & Kale, Ashok (2000), "Epidemiology And Ethics In The Hepatitis B Vaccine", *Indian Journal of Medical Ethics*, Vol.8, No.1, Jan-March.

[204] *Ibid*

The validity and methodology of the studies (which were used by the Government to design hepatitis B vaccination programme) are also questioned by various scholars. Phadke and Kale (2000) question base of the results of 19 studies used for formulating the vaccination strategy, which claims that HBsAg carrier rate in India is 4.7 per cent with an estimated carrier population of 42.5 million on three error points. Firstly the studies are one- time cross- sectional ones which checked the prevalence of HBsAg positivity. Positivity is different from a carrier state — the persistence of infection for six months or more. Secondly, many of these studies are based on data from blood bank donors, including professional blood donors who are known to have a higher prevalence of HBV infection. Phadke and Kale (2000) argue that the results from such groups cannot be used to estimate prevalence in the general population. Thirdly in the studies the average prevalence of 4.7 percent has been arrived at not as a weighted average but by calculating the simple average of the numbers in the individual studies.

Based on their analysis of various studies which supported universal hepatitis B vaccination, Phadke & Kale (2000)[205] argue that the current claims of HBV carrier rate in India are highly exaggerated, unscientific and misleading and a series of errors is being made in estimating the burden of HBV disease and its significance. They add that these errors are to be corrected, and must scientifically assess the burden of morbidity, mortality and consequent loss of life- years due to HBV in India. They also suggest that there should be various options for the HBV vaccination strategy in India on the basis of cost effectiveness and logistical feasibility.

Dasgupta and Ritu Priya (2002)[206], while concurring with Phadke and Kale observe that the research studies conducted to assess the prevalence of hepatitis B in India are largely hospital and laboratory-based and with little evidence on the transmission dynamics, like the role of peri-natal transmission and horizontal transmission among children. Madhavi (2003)[207] identified that the prevalence rate is not uniform through out the population, and the disease is more prevalent among blood donors, homosexuals, drug abusers and medical personnel. Therefore, the basis of formulating

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[205] *Ibid*
[206] Dasgupta & Ritu priya (2002), *op cit.*
[207] Madhavi (2003), *op cit*

a universal vaccination programme merely based on some small, hospital based studies is questioned by the scholars.

It is mentioned by Madhavi (2003) that there is no systematic epidemiological survey of Hepatitis B so far and the studies are blood bank and laboratory based. Therefore it becomes important to check whether this data represent the whole country or not. It is also known (Madhavi 2003, Dasgupta 2005) that the disease prevalence of Hepatitis B is not uniform through out India. Dasgupta and Ritupriya (2002) has cited Tyagarajan et. al 2000[208] where they identified that the geographical polar opposite states of Jammu and Kashmir and Kerala constituted less than 2 per cent zone.. Karnataka, Maharashtra, Delhi, Hariyana, Himachal Pradesh and West Bengal showed a prevalence rate of 2 to 4 per cent. Tamil Nadu, Pondichery , Andra Pradesh, Madya Pradesh, Uttar Pradesh and Arunachal Pradesh belong to less than 4 per cent zone. Therefore considering whole country having same magnitude of the problem is debatable. As per the data given by Dasgupta (2005) different States in India have different prevalence rate for this disease. Prevalence of Hepatitis B in general population ranged from 1.1 per cent to 12.2 per cent with a mean of 3.34 per cent. Different states have different prevalence rate so there is a need to plan different strategy for each state. Since health is a subject which falls in jurisdiction of states of India this strategic planning for each state becomes important.

Next let us see some works which mention about the incidence rate of this disease. According to Madhavi (2003) there is no unanimity among medical professionals about the actual incidence of Hepatitis B in India. She has given example of two studies. As per the study by Tyagarajan et. al (1996)[209] the carrier rate of hepatitis B in India was around 4.7 per cent where as study by Phadke and Kale (2000a) the actual carrier rate of hepatitis B is only 1.42 per cent.

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[208] Thyagarajan, S P, (2000), "Prevalence Of Hepatitis B Virus Infection In General Population Of India", *Indian Journal of Gastroenterology,* Vol. 19 (Suppl.3)

[209] Tyagarajan, SP (1996), "Prevalence of hepatitis B in the general population on India", in S K Sarin &A.K.Singhal (eds), *Hepatitis B in India: Problems and Prevention,* CBS publishers and Distributors, New Delhi.

Dasgupta (2005) has cited a study by Singh et.al. 1997 which mentioned that incidence of viral hepatitis is about 1 per 1000 population. According to them institutional data reveals that Hepatitis B is responsible for upto one third of the acute viral hepatitis cases.

Madhavi (2003) has cited another study by Kale (2000) where it is calculated the life time risk of dying due to consequence of hepatitis B infection is less than 0.1 percent in the general population and is 2.1 per cent in the Hepatitis B carriers.

Apart from the research scholars, health activists have also addressed the issue of universal vaccination of hepatitis B in India. For example, Mathew (2008)[210] argued that mass vaccination against any disease is conducted only when it is capable of developing into epidemic proportions. There has never been any epidemic of Hepatitis B in India. According to him, there are no figures about patients who are diagnosed in the acute stage of infection. The studies about HbsAg, HbeAg and anti Hbe antigen status in the population are done in very small numbers that cannot be generalised. Even such unrepresentative studies show the healthy carrier rate in general population is between 1.62 per cent to 4 per cent (Mathew 2008).[211] The claim which was given by the professional bodies like Pediatric Association that hepatitis B is major threat with carrier rate above 4 per cent in general population is questioned .

Dasgupta(2005:24) has cited Lai et.al (2003) that lack of epidemiological data has led to complexities which again led to giving sweeping statements- that complete eradication of Hepatitis B virus is not possible but the prevention mechanism with vaccination is 95 percent cost- effective. Although there is little doubt about that hepatitis B is a public health problem in India, the implementation of universal immunization of infants with hepatitis B vaccine implies a large requirement and consequent commitment of resources (Dasgupta & Ritupriya 2002). In this context it becomes important for a country like India to check whether vaccination is the only

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[210] Mathew, J (2008), "Why Universal Immunization Of Hepatitis B Is Not Desirable?" URL: http://www.pharmabiz.com/article/detnews.asp?articleid=11352&sectionid=42, Accessed online on 26th July 2008.

[211] Mathew (2008), *op cit.*

solution or is it possible for us to explore other preventive mechanisms which are more cost-effective.

From the above mentioned works it is clear that authentic prevalence, incidence rate data of hepatitis B is lacking. There exists confusion about the incidence rate and its calculation. The studies were largely small sample based and do not represent the general population of India. Further the chance of dying due to hepatitis B is calculated as very small. It has not shown an epidemic pattern in India. Based on this conclusion we can put it safely that the Government's decision to include hepatitis B vaccination in UIP is not supported by epidemiological evidences of the disease.

Inclusion of hepatitis B vaccination in UIP – issue of cost- effectiveness

It is argued by Madhavi (2003) that the vaccine policy in India, rather than being determined by disease burden and demand, is increasingly driven by supply push, generated by industry and mediated by international organisation.

Dasgupta (2005: 23) has observed that over the last decade pediatricians and other specialists in India have shown deep concern for the management of Hepatitis B as a major public health problem. It is mentioned by him that the inclusion of hepatitis B vaccination in Universal Immunization Programme, is motivated by political and economic reasons rather than clinical evidence and reasons.

The inclusion of a vaccination into UIP demands a cost- benefit analysis. It is evident that Government did not do a proper exercise to evaluate the same. Compared to diarrhoeal disease, TB etc. the burden due to hepatitis B and C in the country was less (Madhavi 2003 cites State of India's Environment 1999). In this context, the inclusion of Hepatitis B in Immunization programme was controversial because of the high cost involved (unlike other vaccines of UIP). Despite this, without enough ground level studies Indian Paediatric Association, Indian Association for Study of Liver, WHO , Indian Medical Association all these professional bodies supported the inclusion of hepatitis B vaccination in UIP.

Hepatitis B vaccination in UIP demands huge budget allocation. An analysis by Madhavi (2003), shows that the cost of universal hepatitis B vaccination equals the total budget allotted for health and family welfare. According to her it is six times the combined budget of the national programmes against malaria, kala- azar (Rs.225 crore), leprosy, AIDS (Rs.210 crore) and tuberculosis (Rs.136 crore). However the budget for safe drinking water (Rs.2010 crore) and sanitation (Rs.150 crore) was only half the expenditure on hepatitis B vaccination in 2001-02 (Madhavi 2003)[212]

Not only the Government but the professional bodies associated with this have also made no effort to do a through cost- benefit analysis of the proposed programme. For example, Phadke (2005)[213] observes that the Indian Academy of Pediatrics has recommended Universal Hepatitis B Vaccination of newborns in India, without estimating in any detail the burden of morbidity, and without estimating its cost-efficacy in terms of cost per life years saved due to hepatitis B vaccination.

Other scholars like Dasgupta and Ritupriya (2002) opine that the cost effectiveness of this universal vaccination of Hepatitis also need due attention because the inclusion of Hepatitis B in the Universal Immunization Programme implies large demands on resource allocation and availability. The number of peadiatric doses of Hepatitis B vaccines required annually to fully cover the estimated Indian population for 2002-2006 was 62.6 to 79.5 million doses assuming zero wastage (Dasgupta 2005). The production capacity of Hepatitis B is also inadequate in the public sector. According to Dasgupta and Ritupriya (2002) who has estimated the additional cost for Hepatitis B vaccine to be Rs. 3286.5 million in 2002 and 4173.75 million at the prevailing institutional prices. According to them, allocating such enormous costs for inclusion of one vaccine is to be considered in the light of shrinking resource allocation for other major public health programmes. To address this issue the authors have suggested the necessity of selective, zero-based strategic planning of hepatic B control.

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[212] Madhavi, Y (2003), "Manufacture of Consent? Hepatitis B Vaccination", *Economic and Political Weekly*, June 14.

[213] Phadke, Anant (2005), "New Initiatives In The Immunization Programme", in Ravi, *et al* (ed), *review of health care in India* CEHAT, Mumbai, pp 101-105.

Madhavi (2003) observed that unlike in western countries extensive- cost benefit analysis studies on vaccines were not conducted earlier in India before introducing them in immunization programmes. She has also presented a comparison of hepatitis B vaccine cost with that of many other diseases (see table No 3.1). In her analysis she concludes that universal hepatitis B vaccination is not cost- effective for India.

Table: 12 Cost of Hepatitis B Vaccination Compared to with other Disease.

Cost of all EPI vaccines per child in 1992	17
Estimated cost at present.	30
Current cost of hepatitis B vaccine per child.	100
Number of newborns per year (approx).	25 million
Annual cost of vaccine for newborns	2,500 million
Number of children of the age group 0-4.	110.4 million
Cost of vaccine for 0-4 age group.	11,040 million
Annual cost for 0-4 age group, if covered over 3 years.	3,700 million
No of children of the age group 5-14.	169 million
Cost of vaccine for 5-14 age group.	19,600 million
Annual cost for 0-14 age group, if covered over 3 years.	6,530 million
Total vaccine cost pa for newborns + 0-4 age group.	6,200 million
Total vaccine cost pa for newborns + 0-14 age group.	12,730 million
Current year's (2000) budget on malaria control programme.	2,240 million
Current year's (2000) budget on TB control programme	1.050 million

Source: Madhavi (2003)[214]

Scholars like Aggarwal and Naik (2004)[215] holds the view that Hepatitis B in UIP is cost effective. But their argument is criticized by Phadke and Kale (2000)[216] with

[214] Madhavi, Y (2003), "Manufacture of Consent? Hepatitis B Vaccination", *Economic and Political Weekly*, June 14.

evidences highlighting the methodological issues of the study done by Aggrawal and Naik. Madhavi (2003) has cited Aggarwal and Naik study of 1996, where they have explained how Hepatitis B universal vaccination is cost-effetcive in India. Their argument that inclusion of Hepatitis B vaccination in UIP as cost- beneficial was based on the work which they carried out in Delhi. But Phadke and Kale (2000) were critical of this point because they said the incidence rate is calculated with data based on HBsAg pool and not the HBeAg pool. According to the scholars the selective immunization of identifying and vaccinating all new borns of HBeAg+ve mothers is more cost- effective than universal immunization of Hepatitis B.

Study by Phadke and Kale (2000) is cited by Madhavi (2003) where they have compared the cost of hepatitis B vaccination with the cost of measles vaccination from hypothetical cohort of one million people, for each of the age groups 0-1, 1-5, 5-15, 15-45, 45-70, who would suffer and die due to hepatitis B infection. The cost-efficacy of universal hepatitis B vaccination varied from Rs. 1767 to 5890 per life saved for different age groups compared to Rs 292 for measles vaccination in infants. They states that universal immunization of hepatitis B is neither a priority programme nor cost-effective in India.

Phadke and Kale (2000) argue that, while allocating resources to the vaccination programme, its expense efficacy and contribution to the prevention of diseases in India need to be taken care of. For example, the cost of vaccines of all six vaccine-preventable diseases in the Expanded Programme of Immunization was Rs 17 per child in 1992, which might have increased to Rs 30. Even at a subsidised rate of Rs 100 per child, cost of vaccine alone would be Rs 2,500 million per year (calculated for the new born cases). Extending the programme to the 0- 4 or 5- 14 age groups could make the cost as high as Rs 12,730 million annually. To put these figures in context, this year's (2000) budget for malaria is Rs 2,240 million and TB is Rs 1,050 million.

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[215] Aggarwal, Rakesh (2004), "Universal neonatal hepatitis B virus vaccination in India: Why?", *Hepatitis B Annual*, Vol.1, No.1, pp 60-71.
[216] Phadke & Kale (2000), *op cit.*

Padhke (2005)[217] has made another calculation regarding the financial involvement of the hepatitis B UIP in India. Currently the Hepatitis-B vaccine cost is Rs. 150 /- per child, for three doses. For mass vaccination, he assumes that the vaccine would be available at a lower price, @ Rs. 50 per child. Even then it will be almost equal to the combined cost of the other 5 vaccines in the UIP. The annual cost of the vaccine for the 250 million newborns alone would be Rs. 1250 million (@ Rs. 50 per child). This equals the national budget for TB control, which kills 5 lakh adults annually and is the number one killer disease of adults in India.

The number of years saved due to vaccination is also considered by Padhke and Kale (2002) as an important element to calculate cost- efficacy of the programme. The cost efficacy of different immunization strategies depends on the cost per life year saved from immunization, and cost per unit reduction in the infectious pool.

Phadke (2005) argues this point on the number of years saved as a base to calculate cost- effectiveness. Hepatitis B vaccination ranged from Rs. 440 to Rs.6433 per life year saved for different age groups, with a weighted average of Rs.2713. For infants, the cost efficacy of Hepatitis-B vaccination was Rs. 558 (12.4 US dollars) as compared to Rs. 43 (0.96 US$) per life year saved in case of measles vaccination. The question which Phadke and Kale (2000) raised is that can we afford to introduce a vaccination strategy with a cost efficacy of say Rs 15,000 per life year saved when our per capita annual income is around Rs 10,000?

While all the EPI vaccines estimated to cost Rs. 30, the Hepatitis B vaccine alone was estimated to cost Rs. 100 per child (Dasgupta 2005).[218] According to estimates by him this demands investments worth as much as the malaria control or double the Tuberculosis programme that too excluding the cost of cold storage and assuming zero wastage.

It is evident from the above mentioned works that hepatitis B vaccination in universal mode demands huge resource allocation. The cost- effectiveness of this programme is not properly done by Government of India. The scholars have done this exercise and

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[217] Phadke (2005), *op cit*
[218] Dasgupta (2005), *op cit.*

argue that the programme with universal focus is not beneficial for India in a long run. But the professional associations opined that the programme is cost- effective. Government adopted a position which favoured the interests of the professional groups. Apart from the cost involvement, there are logistics, supply related issues involved in this programme which is explained in the following section.

Strategic issues related to the Universal approach of hepatitis B.

The Centre for Disease Control (CDC) and WHO recommend the use of both Hepatitis B vaccine and Human Immunoglobulin for neonates within 12 hours of birth for effective control of perinatal transmission.

In this context the vaccination reaching to all new born within 12 hrs is difficult in Indian situation where institutional deliveries are not 100 per cent. According to Dasgupta and Ritu Priya (2002) who analysed NFHS II data, going by institutional deliveries for the country as a whole, only one- third of the children could possibly have access to a zero-dose, and taking assisted deliveries into account, the figure will be 42.3 per cent.

Madhavi (2006) again showed concern over the recent trend in the Indian vaccine industry to move towards expensive new combination vaccines despite mounting shortages in the supply of primary affordable vaccines. Combination vaccine is the recent trend in Universal Immunization Programme. These combination vaccines are supposed to provide protection against multiple diseases. This inclusion is mainly done where one Non- UIP vaccine is combined with one UIP vaccine. Madhavi considered this as a move by the private companies to push the demand for non-UIP in the country.

Mathew (2008)[219] has placed his suggestion about what the government should do in the case of hepatitis B. He suggested that vaccination should be restricted to persons who need it. It should be understood that Hepatitis B is mainly an adult problem and

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[219] Mathew, J (2008), "Why Universal Immunization Of Hepatitis B Is Not Desirable?", URL:http://www.pharmabiz.com/article/detnews.asp?articleid=11352&sectionid=42, Accessed online on 26.07.08

children should never be vaccinated on a mass basis. He feels that the government should make it mandatory that all pregnant mothers shall be routinely tested for Hbs Ag which is cheaper and safer than vaccinating indiscriminately all children. He also opines that the hepatitis B vaccine should be given to children born to Hbs Ag positive mothers and shouldl not be given to other children.

The vaccine shortage and the issue of Indian companies in ability to meet the demand are highlighted by Madhavi (2005)[220]. India enjoyed the advantages of early initial successes in vaccine R&D and indigenous production in the public sector, but the country is increasingly unable to cope with the growing gap in the demand and supply of UIP vaccines The availability of UIP vaccines from the private sector is also on the decline in India and abroad, in favour of more expensive new vaccines and combination vaccines, whose public health need has not been unequivocally established in India with sound epidemiological and cost-benefit data. Therefore, India (and indeed, every country) must evolve its own national strategies to meet its vaccination needs within its budgetary constraints.

Dasgupta & Ritu Priya (2002) argue that in case of HB immunization we need to compute the result of the programme within our own context of epidemiology, health resources and functioning of health services. Political support, health manpower training, vaccine procurement and distribution logistics are some of the key inputs necessary for the success of the programme. It is observed that in all these areas-logistics, supply, reaching to all new born India do face challenges as far as hepatitis B UIP is concerned.

The role of market and pharmaceutical companies in inclusion of hepatitis B in UIP

It is evident from the above that the Government included hepatitis B vaccination in UIP without considering 1) epidemiological data 2) cost- effectiveness 3) strategy related issues. Then the next question which arises in the mind is about, whose interest is that the Government trying to protect. The literature gives evidences about the role of pharmaceutical companies and various professional bodies which

[220] Madhavi (2005), *op cit.*

deliberately pressurized the government to take a position which support their interests.

Dasgupta (2005) has questioned the State's decision of including Hepatitis B in universal immunization programme. In his own words "why is the universal strategy being pushed so aggressively in the absence of a convincing epidemiological data, relatively low immunization coverage in general and delivery of the zero-day dose in particular and large commitment of resources and doubtful sustainability?"(2005:28) We could see mainly professional bodies, local pharmaceutical companies and MNCs in the pharmaceuticals have played role in this regard.

Madhavi (2003) argues that various powerful professional bodies have supported the universal programme where as public health analysts and activists have opposed the programme.

Dasgupta(2005) observed that Global Alliance for Vaccines and Immunization (GAVI) is under contract with large multinational corporations that manufacture and market vaccines. He continues with relevant data that India need 75 million doses of Hepatitis B vaccine doses (three doses for each 25 million infants) annually and is the single largest market for the vaccine. This leads to a large demand and further leads to establishment of new manufacturing units by pharmaceutical companies.

The above mentioned 75 million doses which India need annually is the single largest market in the world. High profit margins of the vaccine and hopes of a captive market through Universal programme also induced Indian companies to venture into the domestic hepatitis B vaccine market in 1990s. Madhavi (2003) notes that Shanta Biotech is the first Indian company which ventured into the domestic hepatitis B vaccine market, with a lower price than the Smith Kline Beecham's (SKB) vaccine. Another company, Bharat Biotech of Hyderabad in 1998 priced hepatitis B at a lower price. The entry of more of domestic industries into the market led to competition and it became a common practice to capture the market of hepatitis B. Madhavi (2003) has given the case of Panacea Biotech which marketed a Cuban vaccine at an even lower price than the earlier tow mentioned companies.

The plea of the international organizations that the immunization is one of the most cost effective health intervention is influenced by the interests of the drug companies especially various Multi National Corporations MNCs (Madhavi 2003: 2420). She has given the incident where in Andra Pradesh the vaccine supplied by Bharat Biotech met some controversy and this led the Government to buy vaccines through UNICEF. This international body gets its drug and vaccine supply mainly from various MNCs.

Shanta Biotech is one among various which have attracted attention of scholars because of its policies on hepatitis B vaccine. As per Madhavi (2003: 2442) who cited Priyadarshini (1999) this company conducted awareness camps in Bangalore and such campaigns and efforts of the pharmaceutical industries are helping them to create an artificial demand for the vaccine in the market. The Company sold four lakh doses of the vaccine when it conducted a camp in Bangalore which was worth Rs. 4.8 crore. The campaign supporters and organizers were provided with free gifts etc. by Shanta Biotech. It is concluded by the scholar that such campaigns create unnecessary panic and doubts in the mind of people which will further boost the artificially created demand upwards and ultimately the companies would benefit. Lodha and Kabra (2001)[221] observed that the misleading propaganda by vaccine manufactures to the "popularity" of Hepatitis B immunization camps at local levels.

Madhavi (2006) has argued that the introduction of combination vaccine is a strategy to push market demand. She has taken the case of Shata Biotechnics Ltd which has proposed to launch its first combination vaccine "Shantetra" against diphtheria, tetanus, pertussis and hepatitis B. In 2004 the company announced its plan to combine DTP- Hepatitis B vaccines with the help of soft loans from the Government of India.

The role of public sector in the supply of vaccines for universal immunization programme is shrinking. Self-sufficiency in vaccine production as policy objectives in theory, the growing gap between demand and supply meant that in practice, India had increasingly to resort to imports. In some cases, indigenously manufactured vaccines were stopped in favour of imported vaccines (Madhavi 2005)..

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[221] Lodha, R and Kabra (2001), "Letters to Editor (Reply)", *Indian Pediatrics,* Vol.38, pp-1322-1325.

Rather than demand driven, hepatitis B vaccine is becoming price- driven. Industries are pushing national governments to bring changes in legislations to create favourable markets for their products. The pressure of Indian pharmaceutical companies, coupled with international organizations policy directions led Government of India to take a position which protects market interests rather than the public health needs of general population.

How hepatitis B disease is addressed in various countries

It is always observed that the developed countries address their health issues entirely in a different way than the developing countries. Usually, they give emphasis to basic public health measures (like sanitation, water etc.) and they pressurize the developing countries to go for short term, technology based solutions. Pulse Polio immunization is the best example in this regard. Same way, hepatitis B is also addressed differently by different countries. Some countries have adopted selective immunization where as some others have gone for universal coverage.

The United Kingdom has decided to screen all the pregnant women and to vaccinate all new born babies. What we have to understand is that in a context of UK where there is 100 per cent institutional deliveries this mechanism will work out. Adopting same policy in India might not give the same result, because as it is mentioned in this chapter (by Dasgupta and Ritupriya 2002) India does not have 100 per cent institutional delivery. Phadke (2005: 105) has given evidence that 77 per cent of Indian delivery cases are non-institutional.

It is observed that in many cases the vaccination has become mandatory to low income countries. For example- in North America school children are forced to accept the immunization in order to get admission into schools (Madhavi 2003 cited Fisher 2000). In several countries in Europe like Italy, Portugal, Romania etc. have included hepatitis B vaccination in Universal Immunization Programme though the decision makers of many of these countries are not convinced abotu the need of universalizing hepatitis B vaccination. (Madhavi 2003)

Phadke & Kale (2000) observe that the supporters of universal immunization quote the US decision to switch from selective, high- risk vaccination to universal

immunization. The scholars counter that there is a vast difference between the predominant mode of transmission and age distribution of acquisition of HBV infection in developing and developed countries. Most HBV infections in the developed world occur among adults primarily through sexual transmission, whereas perinatal infection is the most important mode of HBV perpetuation in developing countries. For these reasons, Phadke and Kale suggest that India should consider the option of selective immunization of newborns of HBsAg positive mothers or of all pregnant women. Logistically this is feasible, because unlike the high risk groups in the US, this vulnerable group in India (newborns/ infants) is visited by the health services anyway, for immunization work.

In the West many countries have introduced Hepatitis B vaccination. In some countries it is selective immunization where as in some other countries it is universal immunization. There was no uniformity in the cost benefit analysis among various countries. The table below gives further clarification on position of various countries regarding hepatitis B vaccination. Madhavi (2003) has noted that these studies are based on incidence data and in India authentic data is missing.

Table: 13 Cost benefit studies of hepatitis B

Country	Population under Study	Variables Tested	Conclusion of the Study	Recommended for UI/SI (Priority Order)
England and Wales	Children	UI	Cost-effective	UI, SI
China	Children	UI/SI	Cost-effective	UI, SI
U.S	Adults	With and with out screening	Screening before vaccination is cost-effective (annual attack rate >5 per cent) cost-effective	SI
Belgium	Physicians, medical personnel	SI with and without screening	Screening before vaccinations is cost effective	SI
Sweden	High-risk groups	Plasma derived Vs recombinant hepatitis B	Cost-effective	
California	Pregnant prenatal women	Hepatitis B screening	Not cost-effective	
Africa	Patients (7984)	Screening for carriers with CAH	Cost-effective	
study by CVI (WHO)	Across countries indifferent income groups	UI	Cost-effective in all countries (few exceptions)	UI
Germany	Children (1-15, 11-15 age groups)	Hepatitis A and B wit or without vaccination	Immunisation of 11-15 age group is most cost-effective	Initial use of combined hepatitis A and B instead of only B)
British India	School children (11-15 years age)	UI of 11-15 years children	Cost-effective	UI in North American schools (In high endemic areas
Germany	Children, adolescents	UI of 11-15 years children	Cost effective	UI of 11-15 years children followed by all children plus adolescents
Italy	Infants, children, adults	UI	Hepatitis b reduction in children	UI for all children

Source; Madhavi (2003)

Chowdhury (1999)[222] argues that the significance and magnitude of the problem vary from country to country. The developed countries of Northern Europe and America have considerably controlled the infection by means of effective vaccination and improved sanitation & particularly measures taken for transfusion safety. According to his calculations, HBV infection is present in less than 1 per cent of the population of these countries and contributes to only 5-10 per cent chronic liver diseases. This contrasts with the situation in the developing countries of Asia and Africa, particularly those of Far East and South Africa. In these countries, HBV infection occurs in 5-10 per cent of the general population and is responsible for more than 50 per cent of chronic liver diseases, constituting a public health priority.

Phadke 2005 recorded evidence about selective vaccination policy of many of the countries. Selective vaccination is in use in low prevalence countries like Japan, U.K. Netherlands. Thus on the grounds of low carrier rate alone, it is clear that the Universal Strategy is not applicable in India. Final decision should depend upon our health-care priorities, funds required and comparative cost-efficacy of different options.

CONCLUSION

We started this chapter with an attempt to see what role biotechnology plays (or is playing) in addressing various health issues. While appreciating the advancement which biotechnology made in the field of healthcare, we could not undermine the narrow interests of the policy makers and the market lobbies. This had resulted in a situation where over emphasis is given to technology and its solutions in public health scenario.

Taking vaccine as an application of biotechnology this chapter argues that it solely cannot eradicate or eliminate a particular disease. Structural issues like poverty, equity etc. do play a role, because health has its roots in politic and economic spheres of the society. Further, inclusion of hepatitis B vaccination in UIP is taken as a case to highlight following points. Firstly, hepatitis B is not a major public health problem in

[222] Chowdhury, A (1999), "Epidemiology of HBV infection in the general population: Impact of rural – urban differences and socio-economic factors", *Indian Journal of Gastroenterology,* Vol.18 (Supplement 1), No.21.

India (in comparison to TB and malaria). It is not the major killer disease in India. Secondly, India's public health finance is shrinking year by year and sanitation, drinking water etc. is at the last priority. In this backdrop, including hepatitis B into national vaccination policy of India, that also on a universal basis raises questions.

To address this question three aspects of the issue were considered in this study- epidemiological evidences, cost- effectiveness and strategical issues of the programme. The literature shows that epidemiological evidence does not support inclusion of hepatitis B vaccination into UIP. Again, the cost- effectiveness of the programme is questioned by many of the scholars. Issues like supply, procurement of vaccine and reaching to all new born etc. is also highlighted by the scholars. It is observed that ignoring all these, the Government decided to include hepatitis B vaccination into immunization programme on a universal basis. This led us to a further question that whose interest is the State trying to protect? Is it of the common people or of the market. Scholars like Madhavi (2003), Choudary (1999) and Dasgupta (2005) have clearly established the link between the market and government initiatives related to hepatitis B vaccination. The analysis of experiences of various other countries also gives evidence that the policy adopted by the state is led with narrow interests.

There are other diseases (like tuberculosis) which need immediate attention from a public health point of view rather than Hepatitis B. Further addressing these diseases only though vaccination campaigns, will not make any result in a long term period. In the case of Hepatitis B and many other diseases, safe water and safe surroundings do play a major role. Addressing issue of safe water supply and sanitation, need more attention than the reductionist narrow down strategy of vaccination. A multi-sectoral approach for Hepatitis B is lacking (Dasgupta 2005: 30).

Madhavi (2003: 2417) has identifies 5 components which are to be taken care of before inclusion of particular vaccine in universal immunization programme. They are 1) Total disease burden and prevalence rate 2) Relative importance of the disease in the overall disease scenario 3) Threat of disease transmission to other communities 4) Burden on public exchequer for its intervention 5) Cost- benefit analysis of different preventive and control measures based on incidence pattern and disease burden.

Though vaccination is an effective preventive tool, that is not the only strategy which will address the disease at all time and across all the countries. The epidemiological position of the disease and cost- effectiveness becomes very important before deciding whether the vaccination should be universal or not. These issues are not addressing in the present vaccination policy of hepatitis B.

Discussion

DISCUSSION

In medicine, biotechnology has become an integral part in diagnostics, treatment, stem-cell treatment, gene therapy and in the development and production of drugs. Initiatives taken by the Government of India in the field of accelerating the growth of biotechnology sector since its inception, especially in the last one decade, have paid rich dividends. The Indian administration has identified biotechnology sector as a strategic area since 1980s. This was accompanied by mooting various public institutions for promotion, monitoring and research in order to determine the scope of this sector and for stimulating its growth. The decision of Government of India to allocate special budget provisions in its Five Year Plan for the sector since 1986 had fueled the growth of the biotech industry in India. This has resulted in the generation of world class infrastructural setup and public funded institutions to pursue biotechnology research over the years. The successful development and commercialization of several monoclonal antibodies-based diagnostics, recombinant and traditional therapeutic and prophylactic vaccines, bio-therapeutics and bio-devices are all examples of these researchs.

The advent of globalization, and the subsequent liberalization policies adopted by the governments had helped the private players, both domestic and international, to enter to the biotechnology arena in India, and lately to dominate the sector. Since then, biotechnology has constantly been in the news. Biotechnology appears to be a new and heavily value-added sector which is contributing to the growth of Indian economy. Today the Indian biotechnology sector is considered as one of the most powerful and potential players in the global biotechnology sector. Similar to its counterparts of the world, Indian biotechnology sector is also dominated by the medical biotechnology sector. The bio-pharmaceutical sector, which includes vaccines, therapeutics and diagnostics, represent the lion's share, i.e., about seventy two per cent of the industry's total revenue.

The growth of biotechnology sector in India is directly related to the developments in the international biotech scenario. From the role of a simple domestic player producing vaccines and drugs for domestic purposes, the biotechnology industry in India today is on their way to meet the growing demands of the world. Following the

footsteps of the U.S biotech industries, the number of public research institutes which are engaged in relationship with private biotech companies is increasing in India. As we discussed in chapter two, scientists of public institutes are floating companies of their own, funded by the major biotech companies, which was only seen in the U.S. Venture capital has now identified biotechnology as a potential sector and are now pumping huge amounts in its research and development process. Accordingly the globalization and liberalization policies had a huge influence on the entry of foreign biotech companies in Indian market both in terms of productions and sales of the bio-generics. The decision of the Indian government to allow 100 per cent FDA and SEZ policies in this sector had attracted several multinational corporations to come here and involve in research and development, capitalizing India's historic strengths in low-cost and high quality generic drug manufacturing. Respective state governments throughout India are also in a hurry to set up infrastructure and special parks and to frame attractive polices to invite biotech industries. All these factors helped Indian biotech industry to achieve the global recognition of "low cost producer of quality bulk drugs and formulations".

India has now become an emerging hub of collaborative and outsourced research and development activities. However, over the last few years, the landscape of the Indian biotech companies is changing rapidly due to the increased demand of biotech products; both from domestic and international circles. Experts in this field are of the view that Indian biotech companies have begun to apply the business model which navigates their competition and opportunity. As a result of this, the industry is becoming capable of manufacturing practically the entire range of therapeutic products, and is in a position to produce raw materials for the manufacture of a wide range of bulk drugs. The fact that certain leading Indian companies have established their manufacturing and marketing activities in over 60 countries around the world including the U.S and Europe signifies the importance of Indian biotech companies and their products in the global markets. The recent controversy over the quality of the products sold in the U.S. by the India based pharma giant Ranbaxy is likely to put a check over the products of Indian companies, at least in that country for a while.

The increased globalization, need for new technologies, competition and moreover the cost consciousness are factors that are putting pressure over the companies in a significant way. To get rid of the ballooning cost in the research and development of products and to compete with the current market, global companies especially the pharmaceutical companies are looking outwards to developing countries like India to tap their new business opportunities. Companies are opting to outsource the research and development process to the developing countries through contract research organizations or by setting up their subsidiaries in these countries. The data on the outsourcing companies in India shows that there is a sharp increase in the number of contract research organizations registered in India for the last few years. Similarly the demand for clinical trials in India has boomed in recent years as drug developers are looking for less expensive ways to test their drug. The good supply condition for this experiment and the favourable policies from the authorities including the tax concessions are stimulating the increased clinical trials in India.

Intellectual Property (IP) is central to the biotechnology industry, and brings with it a dimension, facilitating collaborative activity, whether it is drug discovery or clinical or market-related trials. Prior to the Amendment Act 2005, Section 5 of the Patent Act, grant of Product Patent to inventions relating to drugs, chemicals and food processing was not allowed. In line with the TRIPS, such restriction was dropped. Prior to 2005 Indian policy allowed cheap generic medicines, but encouraged a focus on manufacturing rather than R&D of NCEs (New Chemical Entities). This has forced Indian pharma to increase R&D and aggressively engage with the U.S. and global patents system. This has also increased competitiveness encouraging consolidation within the industry, as well as collaboration with big pharma. In response to the global needs India has introduced a new provision for compulsory licensing of pharmaceutical products. At the request of any country facing a shortage of a patented drug, India can order compulsory licensing of such a patented drug exclusively for the purpose of export to that country alone. A strong patent system makes the scenario more competitive. But the question is, how many of our pharmaceutical companies are capable of developing new drug molecules and how many of them hold a share in the global market. There are only a few Indian companies who can develop drug molecules, (as it involves immense research and input) say Ranbaxy, Dr. Reddy's or Nicholas Piramal etc. The prime concern is

whether the Indian pharma sector, which presently meets 80 per cent of the domestic drug demand indigenously, will continue to do so after 10 years from now. The question that lies is that, while this research and development generates financial return, is it likely to be directed to the diseases that afflict us?

The policies of liberalization and globalization implemented in India since 1991 under pressure from the World Bank and IMF led the marginalisation of the public sector and allowed easy entry to foreign companies. It is no coincidence that around the same time, multinational companies from the west were seeking newer markets to release their biotech products. The markets for these new technologically developed products were created through indirect means by lobbying for their inclusion in the national immunization programmes. The case of hepatitis B in India illustrates how its introduction in UIP overburdens the national governments and how the local realities such as disease incidence, endemicity and local priorities of vaccination have been over looked while considering the introduction of hepatitis B in to UIP. This case itself proves the strong hold of the transnational and international organisations in deciding the priority of healthcare intervention programmes in developing countries like India. The government cannot afford to leave the health security of a nation like India to the vagaries of the market. Instead from the given limited resource available, the government should prioritize the new techniques like biotechnology for correct policy decisions.

Appendix

Appendix I

Technologies transferred in biotechnology till 2005 from Public Funded R&D

S.No.	Technology/Product	Institution where Developed	Industry which Purchased
1	Pregnancy Slide Test	National Institute of Immunology, New Delhi	Ranbaxy Laboratories, New Delhi
2	Latex Agglutination	National Institute of Immunology, New Delhi	Ranbaxy Laboratories, New Delhi
3	Pregnancy DOT-ELISA	National Institute of Immunology, New Delhi	Ranbaxy Laboratories, New Delhi
4	Typhoid fever detection kit	National Institute of Immunology, New Delhi	Lupin Laboratories, Mumbai
5	Typhoid fever detection kit	All India Institute of Medical Sciences	Ranbaxy Laboratories, New Delhi
6	Amoebic lever abscess	National Institute of Immunology, New Delhi	Cadila Laboratories, Ahmedabad
7	Polypeptide P from bitter gourd	University of Rajasthan, Rajasthan	Lupin Laboratories, Mumbai
8	Bamboo by tissue culture	University of Delhi, Delhi	The Tata Energy Research Institute,New Delhi
9	Animal Birth Control Injection (TALSUR)	National Institute of Immunology, New Delhi	Karnataka antibiotics and Pharmaceuticals Ltd, Bangalore
10	Osmotolerant and high alcohol tolerant yeast strain	Institute of Microbial Technology, Chandigarh and Vittal Mallaya Scientific Research Foundation, Bangalore	United Breweries, Banagalore
11	Blood Grouping monoclonals	National Institute of Immunology, New Delhi	Cadila Laboratories, Ahmedabad
12	Microbial conversion of benzaldehyde into L-phenylacetylcarbinol	Central Drug Research Institute, Lucknow	Atlus Laboratories, Ambala
13	F-MOC derivatives of 12 amino acids	Centre for Biochemical Technology, New Delhi	Atual Products, Bulsar
14	Hepatitis B detection Kit	National Institute of Immunology, New Delh	Lupin Labs Ltd., Bhopal
15	Leprosy Immunomodulator	National Institute of Immunology, New Delh	Cadila Laboratories, Ahmedabad
16	Leishmaniasis detection kit	Central Drug Research Institute, Lucknow	Span Diagnostics Ltd. Surat
17	Monoclonals to M 13 phage proteins III & VIII	University of Delhi, South Campus	Pharmacia Inc., U.S.A.
18	Liposomal Amphotercin - B	Seth S.G. Medical College & Hospital, Mumbai	ACE Diagnostics, New Delhi

19	Western Blot Test for HIV-I & II	Cancer Research Institute, Mumbai	J. Mitra & Co., New Delhi
20	Development of a drug Forumulation for prevention of Septic shock in burn patients	National Institute of Immunology, New Delh	Gufic Health Care Ltd.Mumbai
21	Process know-how manual for infections Bovine Rhinotracheitis(IBR) vaccine as developed by BAIF Foundation,Pune	BAIF Foundation,Pune	Hoechst Roussel Vet India Ltd. (HRV)
22	Agglutination based detection of HIV- 1/11 antibodies in human blood	University of Delhi South Campus	Cadila Pharmaceuticals Ltd.,Ahemdabad
23	Plant Tissue Culture	TERI, New Delhi	Cadila Pharmaceuticals Ltd.,Ahemdabad
24	Plant Tissue Culture	NCL, Pune	Cadila Pharmaceuticals Limited, Ahmedabad
25	Mass Production of Mycorrhiza	TERI, New Delhi	Cadila Pharmaceuticals Limited, Ahmedabad
26	Lipase for food industry	UDSC, New Delhi	Techno Emo, New Delhi
27	Mass production of rhizobial fertilizer	RRL, Jammu	M/s Prathistha Industries, Secunderabad & M/s Javeri Agro Industries & Investment Co Ltd, Amravati
28	Mass production of Biopesticides - Trichoderma	RRL, Jammu	M/s Prathistha Industries, Secunderabad & M/s Javeri Agro Industries & Investment Co Ltd, Amravati & M/S Bee Zed Biotech., Gurgaon
29	Mass production of Biopesticides - Trichogramma, Heliothis NPV	TNAU, Coimbatore	Crop Health Products Ltd. Ghaziabad
30	Mass production of Biopesticides - Trichoderma	TNAU, Coimbatore	Crop Health Products Ltd. Ghaziabad Hoechst AgrEvo, Bombay Maharashtra Cooperative Oil Seed Federation, Jalgaon
31	Mass production of Biopesticides - Aspergillus niger	IARI, New Delhi	Cadila Pharmaceuticals Ltd., Ahmedabad

32	Amaranthus protein gene for nutritionally enriched animal feed	NCPGR, New Delhi	Cadila Pharmaceuticals Limited, Ahmedabad
33	The IgM Mac ELISA for the detection of Dengue	National Institute of Virology,Pune	Zydus Cadila Health Care, Ahmedabad
34	The IgM Mac ELISA for the detection of Japanese Encephalitis	National Institute of Virology,Pune	Zydus Cadila Health Care, Ahmedabad
35	The IgM Mac ELISA for the detection of West Nile	National Institute of Virology,Pune	Zydus Cadila Health Care, Ahmedabad
36	ELISA system to measure alpha-feto protein levels in pregnant women	Indian Institute of Chemical Biology	Shantha Biotechnics, Hyderabad
37	An IgM based system for the detection of Hepatitis A virus using monoclonal/ polyclonal antibodies	National Institute of Virology,Pune	Bharat Biotech Ltd, Hyderabad
38	Urine based system (ELISA) for the detection of 4 Reproductive Hormones	Institute for Research in Reproduction, Mumbai	Zydus Cadila Health Care, Ahmedabad
39	**Western Blot for detection of HIV-1 & 2**	**Cancer Research Institute, Mumbai**	**J.Mitra & Co., New Delhi**
40	**Liposome Intercalated Amphotericin B formulations for treating systemic fungal infection**	**Seth G.S. Medical College & Hospital, Bombay**	**ACE Diagnostics, New Delhi**
41	A technology utilizing Yarrowia lipolytica expressing Hepatitis B surface and pre S genes (yielding high level of proteins / single step purification)	University of Baroda, Baroda	Biological Evans Ltd., Hyderabad
42	A technology for expressing hCG using Pichia patoris system	Indian Institute of Sciences, Bangalore	Cadila Pharamaceuticals Ltd., Ahmedabad
43	**OIL ZAPPER Technology for Oil Spill Treatments**	**TERI, New Delhi**	**Sriram Biotech Ltd., Hyderabad BPCL, Mumbai**
44	Recombinant protective antigen (rPA) against Anthrax	Centre for Biotechnology, JNU, New Delhi	Panacea Biotec Ltd. New Delhi
45	Diagnostic test for peste des ruminants virus	Madras Veterinary College, TANUVAS, Chennai	Indian Immunologicals, Hyderabad
46	Production of Xanthan Gum	Birla Institute of Scientific Research, Jaipur	M/s Shriram Biotech Ltd., Hyderabad
47	**Simultaneous detection of white-spot shrimp virus (WSSV) and monodon baculo virus (MBV) for aquaculture industry**	**College of Fisheries, Mangalore**	**Mangalore Biotech Laboratory, Mangalore**
48	Process for targeted and site specific gene/drug delivery system	University of Delhi, South Campus, New Delhi	Panacea Biotech Ltd. New Delhi
49	Development of Nutraceuticals	Anna University, Chennai	Parry Nutraceuticals Chennai

50	Polyherbal formulation (BHU-x) for atherosclerosis	Institute of Medical Sciences, Banaras Hindu University, Varanasi	Surya Pharmaceuticals Varanasi
51	Elite lines of Mucuna pruriens with improved yield and high L-dopa content	Zandu foundation of health care. Valsad, Gujrat	Zandu Pharmaceutical works. Mumbai
52	**Shantest AFP (Alphafeto protein)**	**Indian Institute of Chemical Biology, Kolkata**	**Shantha Biotechnics, Hyderabad**
53	**Development of Diagnostic kit for detection of HIV antibody in human serum or plama – Western blot HIV1 & HIV2 kit**	**Cancer Research Institute, Mumbai**	**J. Mitra & Company, Delhi**
55	Mycorrhiza biofertilizer mass production	TERI, New Delhi	Sheel Biotech, New Delhi
56	A polyclonal antibody-based immuodiagnostic assay for the detection of white spot syndrome virus – a simple diagnostic test kit	Anna University & C Abdul Hakeem College	Poseidon Biotech, Chennai
57	DNA/MVA based HIV-I subtype 'C' candidate vaccine	AIIMS, New Delhi	Panacea Biotech Ltd, New Delhi
58	**Jev Chex- a rapid detection kit for CSF and serum forJapanese Encephalitis in humans**	**AIIMS, New Delhi**	**Xcyton Diagnostics Limited, Bangalore**

Source:[223] (Visalakshi, 2005)

[223] Visalakshi, S, (2005) "Transferring biotechnology in India: Experiences and Lessons", National Institute of Science and technology and Development Studies, New Delhi. Working paper.

Bibliography

Bibliography:

Books and Articles:

1. Abdelgafar B, Thorsteinsdóttir H, Quach U, et al, (2004), "The emergence of Egyptian biotechnology from generics." *Nature Biotechnology*. Supplement, December pp 25 to 30.

2. Aggarwal, Rakesh (2004), "Universal neonatal hepatitis B virus vaccination in India: Why?", *Hepatitis B Annual*, Vol.1, No.1, pp 60-71.

3. Arora, Praveen, 2005, "Health care biotechnology firms in India: Evolution, structure and growth", *Current Science,* Vol 89, No 3. August 10.

4. Bhatt Arun (2004), " Clinical Trials in India: Pangs of Globalisation", *Indian Journal of Pharmacology,* Vol 36, Issue 4, PP 207-208.

5. Blumberg, Baruch, (1987), "Comments on the Prevention of Hepatitis B infection in India", Indian Institute of Science, Banglore, Working paper, (This paper as been sent to then Prime Minister of India, Rajiv Gandhi and to government and academic scientist and Physicians).

6. Blumenthal D (2003), "Academic-industrial relationships in the life sciences", *NEJM*, 349.

7. Blumenthal D, Causino N, Campbell EG, Louis KS. (1996), "Relationships between academic institutions and industry in the life sciences—An industry survey", *New England Journal of Medicine*, 334.

8. Boyd E and Bero L (2000), "Assessing faculty financial relationships with industry: A case study", *JAMA*, 284(17).

9. Brock, Thomas D (1961), "*Milestones in Microbiology*", Science Tech Publishers. Madison, Wisconsin.

10. Bunch, Bryan and Hellemans, Alexander (1993), "*The Timetables of Technology*", Simon & Schuster, New York, pp. 490.

11. Burrill, G.S (2004), "*Biotech 2004 Life Sciences: Back on Track*, 18th Annual Report on the Industry", Burrill & Company LCC, San Francisco, CA, USA.

12. Campbell EG, Blumenthal D, Louis KS (1998), "Looking a gift horse in the mouth: Corporate gifts that support life science research", *JAMA*, 279(13).

13. Carr, K, (1999), "Cuban biotechnology treads a lonely path", *Nature*, Vol. 398, Issue 6726, Apr Suppl, pp A22-23.

14. Chaturvedi, Sachin (2007), "Indian innovative systems and Emergence of Biopharmecutical Sector; Issues and Prospects", Research and Information System for the Non-Aligned and other Developing Countries, New Delhi.

15. Chaturvedi, Sachin, (2002), "Status and Development of Biotechnology in India: An Analytical Overview", Research and Information System (RIS) for the Non-Aligned and other Developing Countries, New Delhi, Working paper.

16. Cohen, J (2006), "Global health. The new world of global health", *Science,* 311(5758): p. 162-7.

17. Cohen, W.M. (2004), "Patents and Appropriation: concerns and evidence", *the Journal of Techonology Transfer*, 30 (1-2).

18. D. Sreedhar, Manthan D. Janodia, Virendra S.Ligade, Ajay Pise and N.Udupa (2008), "Biotech Industry: Regulatory Overview", *The Pharma Review*, February- March, Kongposh Publications Pvt. Ltd, New Delhi.

19. Dasgupta & Ritu Priya (2002), "The sustainability of hepatitis B immunization within the Universal Immunization Programme in India", *Health Policy and Planning*, vol.17 (1), pp99-105.

20. Dasgupta, Rajib, (2005), "Universalising the Hepatitis B vaccine in India: Pitfalls in Policy and Practice", *Journal of Health and Development*, Vol.1, No. 2& 3, April-September, pp 23-31.

21. Gandhi, N.R., et al, (2006), "Extensively drug-resistant tuberculosis as a cause of death in patients co-infected with tuberculosis and HIV in a rural area of South Africa", *Lancet*, 368(9547): p. 1575-80.

22. Global Forum for Health Research (2002), "*The 10/90 Report on Health Research 2001-2002*", Geneva, Switzerland.

23. Government of India, Ministry of Science and Technology, Department of Biotechnology (2006), "*Report of the Working Group for the Eleventh Five Year Plan (2007–2012)*", New Delhi.

24. Government of India, Planning Commission, "*Sixth Five Year Plan, 1980-85*", New Delhi.

25. Gupta I., Sehgal R. et al. (1992), " Vertical transmission of Hepatitis B in North India", *Journal of Hygiene, Epidemiology, Microbiology and Immunology*, Vol.36, No. 3.

26. Hellemans, Alexander, and Bunch, Bryan (1988), "*The Timetables of Science*", Simon & Schuster, New York.

27. Konde Viren (2008), "Biotechnology In India: Public-Private Partnerships", *Journal Of Commercial Biotechnology*, vol 14. no 1, January pp 43–55.

28. Joe Rigert and Maura Lerner (1992), "Audits say 'U' knew of ALG problems", *Star Tribunes*, August 23, 1B, 3B.

29. Krimsky Sheldon (2003), "Science in the private interest; has the lure of profits corrupted biomedical research?", Rowman and Littefield Publishers Inc, USA.

30. Kumar, Nagesh (1988), "Biotechnology in India", *Development* (Special issue on Biotechnology), Research and Information System (RIS)for the Non-Aligned and other Developing Countries, New Delhi. Working paper. Working paper.

31. Lodha, R and Kabra (2001), "Letters to Editor (Reply)", *Indian Pediatrics,* Vol.38, pp-1322-1325.

32. Madhavi, Y (2003), "Manufacture of Consent? Hepatitis B Vaccination", *Economic & Political Weekly",* June 14, pp 2417-2424.

33. Madhavi, Y (2006), "New combination Vaccines: backdoor entry in to India's universal immunization programme?, *Current Science*, Vol.90, No.11, June.

34. Madhavi, Y (2007), "Transnational Factors and National Linkages; Indian Experience in Human Vaccines", *Asian biotechnology and development review*, Vol.9. No.2, PP 1-43.

35. McMahon BJ, Alward WL, Hall DB, et al, (1985), "Acute hepatitis B virus infection: relation of age to the clinical expression of disease and subsequent development of the carrier state", *Journal of Infectious Disease*, Vol.15, pp 599-603.

36. Morrow, Tom (2007), "Biotechnology Faces Cost Challenges in Consumer Driven Health Care Environment", *Journal of Managed Care,* Vol 9, No 2 pp 27-31.

37. Nagaratnam A (2001), "Biotechnology in India: Current Science", *Defense Science Journal.* Vol. 51. No. 4. October 2001.

38. Phadke, Anant & Kale, Ashok (2000), "Epidemiology and ethics in the hepatitis B vaccine", *Indian Journal of Medical Ethics*, Vol.8, No.1, Jan-March.

39. Rao, S.R (2005), "Indian Biotechnology Developments in Public and Private Sectors - Status and Opportunities", *Asian Biotechnology and Development Review*, Vol.5, No.1.

40. Rojer L.Geiger's (1993), "*Research and relevant knowledge*", Oxford university press, Oxford.

41. Sarx, Johannes (2006), "Biotechnology- The next Indian success story?", University of Arizona, Working paper.

42. Sen, Falguni (2007), "*Global Trends in Clinical Trials and their Impact on India*", Working draft presented at the National Consultation on New Reproductive Technologies and their Implications for Women, Jawaharlal Nehru University, New Delhi.

43. Sheila Slaughter & Larry.L.Leslie (1997), "*Academic Capitalism*", The John Hopkins University Press, Baltimore.

44. Spranger TM (2003), "Patent protection for stem cell procedures under the law of the European Union". Med Etika Bioet. 10(1-2).

45. Sujith Bhattacharya (2007), "*Patenting in biotechnology*", *DESIDOC Bulletin of Information Technology,* Vol. 27, No. 6, November 2007, pp.

46. Thyagarajan, S P, (2000), "Prevalence of Hepatitis B virus infection in general population of India", *Indian Journal of Gastroenterology,* Vol. 19 (Suppl.3).

47. UNDP (2001), "*United Nations Development Report on Making new technologies work for human development*", Oxford University Press, New York, pp 47.

48. Visalakshi, S (2005) "Transferring biotechnology in India: Experiences and Lessons", National Institute of Science and technology and Development Studies, New Delhi. Working paper.

49. WHO/TDR and Hotez, P.J., et al, (2007), "Control of neglected tropical disease", *New England Journal of Med*, Vol: 357(10).

Web References:

50. Arizona State University, "Introduction to Biotechnology". URL: photoscience.la.asu.edu/photosyn/courses/BIO_343/lecture/biotech.html, Accessed online on 18th March 2008.

51. Barnes, Kirsty, (2007), "Clinical trials in India Just got Cheaper", URL: http://www.drugresearcher.com/news/ng.asp?n=74588-chiltern-international-india-clinical-trial-cost, Accessed online on February 12th 2008.

52. Bio ventures for global health (2007), closing the Global Health Innovation Gap: A role for the biotechnology Industry in Drug Discovery for Neglected Diseases, Washington, p 10, URL: http://www.bvgh.org/documents/InnovationMap.pdf, Accessed online on 20th March 2008.

53. Biotechnology and Health Care, URL: http://www.bmb.psu.edu/courses/biotc001/health.htm, Accessed online on 20th March 2008.

54. Biotechnology Industry Organisation (BIO), Biotechnology Industry facts, URL: http://www.bio.org/speeches/pubs/er/statistics.asp, Accessed online on 12th January 2008.

55. British Liver Trust, Fighting Liver Disease, Hepatitis B Supporting Statistics, URL: http://www.britishlivertrust.org.uk/home/media-centre/campaigns/national-think-b-fore-you-go-day/hepatitis-b-supporting-statistics.aspx, Accessed online on 17th March 2008.

56. Campbell EG, Koski G and Blumenthal D (2004), The triple helix: University, government, and industry relationships in the life sciences. AEI-Brookings Joint Center for Regulatory Studies Working Paper 04-12, http://aei-brookings.org/admin/authorpdfs/page.php?id=1000, Accessed online on 16th February.

57. Canadian Medical Association (CMA, 2000) Journa,l Hepatitis B.. URL: www.cma.ca/cmaj/vol-156/issue-7/1033.htm, Accessed online on 17th March 2008.

58. Checklist of cancer treatments, Time Magazine 18th May 1998, URL: www.time.com/time/magazine/1998, Accessed online on 17th March 2008.

59. Confederation of Indian Industries (CII), Trade and Investment Relations with India, URL: http://cii.in/menu_content.php?menu_id=1133. [Online, Accessed online on 24th August 2007.

60. Confederation of Indian Industries, India Brand Equity Forum, Biotechnology, (2005), URL http://www.ibef.org/download/Biotechnologysr.pdf, Accessed online on 22nd October 2007.

61. Department of Science and Technology, Technology policy statement 1983, URL: [Online: web], Accessed on 17th August 2007, URL: http://dst.gov.in/stsysindia/sps1983.htm, Accessed online on 17th August 2007.

62. Emmanuelle, Anne (2005), "Gates's grandest challenge: transcending technology as public health ideology", URL: http:// image.thelancet.com/extras/04art6429web.pdf, Accessed online on 25th July 2008.

63. Ernst & Young (2007), Global biotechnology makes historic advances, URL: http://www.ey.com/global/content.nsf/International/Media_-_Press_Release_-_Beyond_Borders_2007, Accessed online on 12th January 2008.

64. Ernst and Young (2007), "Beyond Borders: the Global Biotechnology Report", pp 84. URL:www.ey.com/beyond borders, Accessed online on January 12th 2008.

65. Ernst and Young (2007), Global Biotechnology makes historic advancement, URL: http://www.ey.com/Global/assets.nsf/Slovak_Republic_E/2007_Global_Biotechnology_2007_EN/$file/PR_EY%20Biotech_2007_EN.pdf, Accessed online on 27th December 2007.

66. European Association for Bioindustries, "HealthCare Biotech" URL: http://www.europabio.org/Healthcare/HC_about.htm, Accessed online on 15th March 2008.

67. Fact sheet on Academia-industry-government relations in research, URL: opa.faseb.org/pages/advocacy/coi/FactSheet.pdf, Accessed online on 15th December 2007.

68. Federation of American Society for Experimental Biology (FASEB), Statement on Use of Apolipoprotein e Testing for Alzheimer Disease.. URL: www.faseb.org/genetics/acmg/pol-21.htm>, Accessed on line on 16th March 2008.

69. Global biotechnology makes historic advances, URL: http://www.ey.com/global/content.nsf/International/Media_-_Press_Release_-_Beyond_Borders_2007, Accessed online on 12th January 2008.

70. Government of Canada, Science and issues, infectious disease, URL: http://www.biobasics.gc.ca/english/View.asp?x=766, Accessed online on 17th March 2008.

71. Government of India, Ministry of Finance, Budget Documents, URL: http://www.indiastat.com/india/ShowDataSec.asp?secid=393451&ptid=391226, Accessed online on 24th August 2007.

72. Government of India, Ministry of Science and Technology, Department of Biotechnology, 1985-86 to 2001-2002, Annual Reports, New Delhi, URL: http://dbtindia.nic.in/publication/publicmain.html Accessed online on 27th August 2007.

73. Government of India, Ministry of Science and Technology, Department of Biotechnology, URL: http://dbtindia.nic.in/organisation/org.html, Accessed online on 17th August 2007.

74. Government of India, Ministry of Science and Technology, Department of Biotechnology, URL: http://www.dbtindia.nic.in/, Accessed online on 17th August 2007.

75. Government of India, Ministry of Science and Technology, Department of Biotechnology, Annual reports 2005-06, URL: http://dbtindia.nic.in/publication/publicmain.html, Accessed online on 17th August 2007.

76. Government of India, Ministry of Science and Technology, Department of Biotechnology, GOI, URL: http://www.biotechnews.gov.in/healthcare1.htm, Accessed online on 12th February 2008. Hepatitis Foundation International, Diagnosis and Treatment. URL: www.hepfi.org/Hepinfo/diagnosis.htm, Accessed online on 17th March 2008

77. Human Development Report 2007/08, URL: http://hdrstats.undp.org/indicators/24.html, Accessed online on 15th March 2008.

78. India's emerging biotechnology industry, URL: http://www.worldcolleges.info/happenings_biotech.php, [Online: web], Accessed on 26th March 2007.

79. Indian Biotech Industries (2005), URL: http://www.mindbranch.com/products/R459-95.html, Accessed Online on 11th October 2007.

80. Institute of industrial engineers (2007), India emerges as a global player in biotech industry, URL: http://www.iienet2.org/PrinterFriendly.aspx?id=9534, Accessed online on 18th October 2007.

81. Internal Revenue Service (IRS), USA Department of Treasury, "Biotech industry overview-history of industry", URL: http://www.irs.gov/businesses/article/0,,id=169544,00.html, Accessed online on 27th August 2007.

82. Jayaraman K S , (2004), "Among the best", *Nature,* ;436:492–495, URL: «http://www.nature.com/nature/ journal/v436/n7050/full/436492a. html». Accessed online on 14th January 2008.

83. Langridge (2000), W.H.R. Edible Vaccines. Scientific American, URL: www.sciam.com/2000/0900issue/0900langridge.html, Accessed online on 18th March 2008.

84. Laura Thompson (2005), Changing Time for Patenting in India, URL http://www.thomsonscientific.com/news/newsletter/2005-02/8263720/, Accessed online on 24th November 2007.

85. Madhavi, Y (2005), "Vaccine Policy in India", *PLoS Medicine Online Journal*, URL: http://medicine.plosjournals.org/perlserv/?request=get-document&doi=10.1371/journal.pmed.0020127, Accessed online on 25th July 2008.

86. Mathew, J (2008), "why universal immunization of hepatitis B is not desirable?" URL: http://www.pharmabiz.com/article/detnews.asp?articleid=11352&sectionid=42, Accessed online on 26th July 2008.

87. Michigan State university, "The history of biotechnology", URL: http://www.agriscience.msu.edu/specialprojects/biotechnology/biotechpart3.htm, Accessed online on 2nd November 2007.

88. Murphy,Ann and Judy Perrella (1993), "A Further Look at Biotechnology." Woodrow Wilson Foundation Biology Institute. Princeton, NJ, URL: http://www.accessexcellence.org/RC/AB/BC/Overview_and_Brief_History.php. Accessed online on 12th August 2007.

89. National Health Museum, USA 1977-1999 the dawn of biotechnology, URL: http://www.accessexcellence.org/RC/AB/BC/1977-Present.php,

90. National Science Board (2002), *Science and Engineering Indicators- 2004*, Washington, DC: U.S. Government Printing Office, URL: http://www.nsf.gov/sbe/srs/seind04/start.htm, Accessed online on 15th December 2007.

91. National Science Board (NSB), Task Force on Industry Reliance on Publicly Funding Science (1998), *Industry Trends in Research Support and Links to Public Research*. NSB 98-99. Arlington, VA: National Science Foundation, URL: http://www.nsf.gov/pubs/1998/nsb9899/nsb9899.htm, Accessed on 12th February 2008.

92. National Venture capital Association , economic impact of the venture capital industry on the U.S economy 2001, URL: venture capital industry on the U.S economy, NVCA 2001, Accessed online on 12th January 2008

93. Purohit S.S & Mohan S.K (1996), "Biotechnology fundamental and applications", Agro Botanical publishers, India. URL : http//www.biotechnology/BT210/introl.html, Accessed online on 12th August 2007.

94. Rubin, R (2001), Genes and Vaccines Might Ward Off the Sun. US News On-Line. February 26, URL: www.usnes.com/usnews/issue/vacc.htm, Accessed online on 17th March 2008.

95. SAAVI (South African AIDS Vaccine Initiative). Background and establishment of SAAVI, URL: «http://www.saavi.org.za/index.htm», Accessed online on 14th January 2008.

96. Sachin Jadgale (2008), Indian biotech's global designs, URL: http://www.expresspharmaonline.com/20080215/bioasia2008special01.shtml, Accessed online on 22nd March 2008.

97. Sachs, J, D (1999) "Helping the World's Poorest", *The Economist.* August 14, 352 (8132), pp. 17-20, URL:http://www.owlnet.rice.edu/~poli354/990814_Brazil_Sachs.html, Accessed Online on 12th March 2008.

98. Sachs, J.D, "Helping the World's Poorest", *The Economist.* August 14, 1999., 352 (8132), pp. 17-20, URL: http://www.owlnet.rice.edu/~poli354/990814_Brazil_Sachs.html, Accessed Online on 12th March 2008.

99. Sing Seema (2008), "Reliance Life readies stem cell therapies", *Wall Street Online Journal*, URL: http://www.livemint.com/2008/07/02002032/Reliance-Life-readies-stem-cel.html, Accessed online on 2nd July 2008.

100. Terry Collins (2007), India's biotech industry emerging as aworld innovator, collaborator, competitor, URL: http://www.eurekalert.org/pub_releases/2007-04/pols-ibi040107.php, Accessed online on 27th August 2007.

101. The Centers for Disease Control (CDC); The World Health Organization (WHO), URL: http://www.cdc.gov/datastatistics/, Assessed online on 15th March 2008.

102. The Eurpoean Association of Bioindustries (EAB), URL: http://www.europabio.org/Healthcare/, Accessed online on 20th March 2008.

103. Top Ten Infectious Disease Events of the 20th Century. Bartlett's Top Ten, URL: hopkins-id.edu/idfun/topten/events.html, Accessed online on 17th March 2008.

104. Tyagarajan, SP (1996), "Prevalence of hepatitis B in the general population on India", in S K Sarin &A.K.Singhal (eds), *Hepatitis B in India: Problems and Prevention,* CBS publishers and Distributors, New Delhi.

105. Utkarsh Palnitkar (2006), India can become significant global player, Biospectrum, URL: http://biospectrumindia.ciol.com/content/columns/10604111.asp, Accessed online on 12th September 2008.

106. Venture Capital Investments by Sector, URL :http://www.frbsf.org/csip/data/charts/chart23b.cfm, Accessed on line March 23rd 2008.

107. Wallman, Sonia (1997), A short history of biotechnology, URL: http://www.biotech.nhctc.edu/BT220/Section_1_0_0.html - 7k, Accessed online on 12th August 2007.

108. What some World Leaders and Organiasations Say about Biotechnology, URL:http://www.africabio.com/status/quotes.htm, Accessed online on 12th March 2007.

109. WHO, Global cancer rates could increase by 50% to 15 million by 2020, URL: http://www.who.int/mediacentre/news/releases/2003/pr27/en/, Accessed online on 17th March 2008.