subsidiary, started construction of its global contact lens-manufacturing facility during 2004. MDS Sciex, a subsidiary of Canadian-based MDS, announced that it would set up a manufacturing facility to produce its mass spectrometers, its first site outside Canada. A local Singapore company, Forefront Medical Technology, will be expanding its plant to contract manufacture medical devices used in the field of anesthesia.

Co-Investments by Bio*One further boosted industry growth

EDB's dedicated BMS investment arm, Bio*One Capital, manages S$1.2 billion in several funds. Last year, Bio*One committed a total of S$95 million to investments in 16 projects, including new investments as well as follow-on investments in existing portfolio companies. 90% of the investments were made in Singapore-based companies to help build and grow the companies, and in overseas projects with linkages and activities in Singapore.

In 2004, Bio*One's key portfolio companies made significant strides.

- A-Bio Pharma commenced its first major partnership with leading vaccines company GSK Biologicals (Belgium) to develop and manufacture new generation vaccines.
- S*Bio has developed a highly competitive oncology program focused on the development of histone deacetylase (HDAC) inhibitors and is on track to deliver its first candidate for clinical development in 2006.
- MerLion Pharmaceuticals (Singapore) entered into further partnerships with international pharmaceutical and biotechnology companies for natural product drug discovery.
- One of the world's leading stem cell company, ES Cell International (Singapore), received a resource infrastructure enhancement award from the US National Institutes of Health (NIH) and a research grant from the Juvenile Diabetes Research Foundation (JDRF) to look into research for the treatment of diabetes.

2004 saw another important milestone for Singapore's BMS industry with the setting up of BioSingapore, a trade association representing the interests of local biosciences enterprises. This signifies a coming of age for the industry. BioSingapore will play an important role in helping local BMS companies to engage the financial community and other key stakeholders.

Conclusion

Singapore's vision is to be the Biopolis of Asia (Box 2). To achieve this, Singapore has built up world-class capabilities across the entire value chain from drug discovery and clinical research, to manufacturing and health care delivery. Singapore offers an efficient and comprehensive network of support that enables companies to invest here with ease. Going forward, there will be an increasing emphasis on building up expertise in translational research and on exploring the interface between biomedical sciences and engineering. Singapore will also continue to nurture world-class research talent to further enhance its attractiveness in this sector.

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Biotechnology in India

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Biotechnology hubs are emerging all over the world. The Americas, Europe, Eurasia, Southeast Asia, Western Asia and the Pacific rim all have hotspots of biotechnology.

India is particularly suited to become the country of choice for biotechnology initiatives and endeavors. The rich human capital in this country of over one billion people is its most valuable asset. India has a large English-speaking base, and the official language of virtually all universities, businesses and research institutes is English. India produces ~2.5 million graduates in the IT, engineering and life sciences, >650,000 postgraduates and 1500 PhDs qualified in the engineering and life sciences each year [1].

The environment for biotechnology in India holds an advantage over other countries for those ventures that seek to capitalize on the immense biodiversity that is available. The Indian subcontinent occupies only 2.4% of the world's land mass but accounts for 7.6% of all species of mammals, 12.6% of all bird species, 11.7% of all fish species and 6.0% of all higher flowering plant species. For its size, the Indian subcontinent contains a disproportionately large share of the world's biodiversity [1].

> 'India produces ca 2.5 million graduates in the IT, engineering and life sciences each year...'

The financial opportunity

Today India has more than 200 biotechnology companies. Of these, 75% were incorporated in the past five years, so the industry is young.

The biotechnology industry in India grew by 40% last year, principally in the areas of pharmaceuticals, agriculture and bioinformatics. Net revenue for this growing industry was US$705 million, which was the third rank in the Asia-Pacific region, behind Australia at US$1 billion and China at US$800 million. India has 60 FDA-approved facilities within its borders, which is second only to the USA [1]. Without question, India has made remarkable progress in a very compressed time frame.

Sectors of Biotechnology

Biotechnology in India has been categorized in several different ways, and it is instructive to examine these categories. The largest and fastest growing overall segments have been termed as the following:

- medical biotech segment
- agri biotech segment
- services segment

The medical biotech segment is expected to grow to an innovative US$25 billion industry by 2010, from a 2003 US$5 billion generic based drug business. The agri biotech segment is very large in India, since this

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country is the second largest food producer in the world. India has 13,000 miles of shore land and marine resources therefore holds much promise for development. The contract services segment is driven by pharmaceutical companies from all over the world who are looking to offshore many of the preclinical compound development steps and, more recently, clinical development projects. The driving force here for foreign companies is to access a qualified workforce at a minimized cost.

Many of the more than 200 biotechnology companies, as well as the large pharmaceutical companies such as Ranbaxy, Dr. Reddy's Laboratories, Aurobindo, Cipla, Wockhardt and Nicholas Piramal, engage in contract research services with pharmaceutical companies from all over the globe. This outsourcing is now valued at US$120 million and is growing at a phenomenal rate of 75% per year. It is predicted that this business will reach the US$1 billion mark in the next five years [2]. Recent reports have described the contract research services offered by Indian companies in detail [3,4].

Proactive state government support

Several of the state governments have realized the importance of nurturing the biotechnology industry. The leaders here are Andhra Pradesh, Tamil Nadu, Maharashtra, Karnataka and Himachal Pradesh [1,5]. The major funding agencies in India that are supporting initiatives in the various Indian states are the following: Department of Scientific and Industrial Research (DSIR); Department of Science and Technology (DST); Department of Biotechnology (DBT); Indian Council of Agriculture Research (ICAR); Indian Council of Medical Research (ICMR); Council of Scientific and Industrial Research (CSIR); and the University Grants Commission (UGC) [5]. Biotechnology parks (BT parks) are following from the success of IT parks in India, and have been created by the states of Andhra Prasdesh, Karnataka and Tamil Nadu.

The 'bio' words

A number of 'bio' words have emerged from subdisciplines of biotechnology, and these 'biodisciplines' are all prevalent in the Indian subcontinent. Here are some of these terms and definitions:

- Bioprospecting: the search for commercially valuable chemical, biochemical and genetic resources in plants, animals and microorganisms [6].
- Bioremediation: the use of natural resources, eg grass, water, trees and microbes, to minimize or mitigate the effects of natural hazards and environmental damage caused by human activities.
- Biofertilizer: a large population of one or more beneficial micro-organisms that are incorporated aseptically into sterile carrier materials such as peat, lignite or charcoal. These organisms enhance the productivity of soil by the fixation of atmospheric nitrogen, solubilizing phosphorous in the soil or stimulating plant growth by the synthesis of growth-promoters. Biofertilizers derive from renewable resources and are based on rhizobium, azospirillium, azotabacter and phosphate stabilizers [7].
- Biopesticide: a compound that kills organisms by virtue of specific biological effects rather acting as a broad spectrum chemical poison. Biopesticides are more likely to be biodegradable. Specific types of biopesticides include bioinsecticides and biofungicides. In contrast to biocontrol agents, which actively seek the pest to be destroyed, biopesticides are passive agents [8].
- Bioengineering: the use of artificial tissues, organs and organ components to replace parts of the body that are damaged, lost or malfunctioning [8].
- Biodiagnostics; the use of sophisticated instrumentation and noninvasive techniques to allow medical professionals to make earlier and more accurate diagnoses. Integrative disciplines include biochemistry, computer science, engineering, medicine, physics and physiology [9].
- Biosensor: a device that detects, records and transmits information regarding a physiological change or the presence of various chemical or biological materials in the environment. A biosensor is a probe that integrates a biological component, such as a bacterium, an enzyme or an

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antibody, with an electronic component to yield a measurable signal. Biosensors can detect and measure specific bacteria or hazardous chemicals. Biosensors can also use bacteria for detection [10].
- Biomaterial: living tissue or artificial material used for implantation. Biomaterials must be nontoxic, noncarcinogenic, stable, chemically inert and mechanically strong [11].
- Biomechanics; application of classical mechanics to biological or medical problems. Biomechanics has led to the development of the artificial heart and heart valves and artificial joint replacements [11].

Strengths

Biotechnology in India has real and perceived strengths and weaknesses. Certainly, the strengths predominate and here is a list of some of the advantages associated with conducting biotechnology in India:
- Annual revenues are >US$700 million.
- Large pool of talented scientists.
- Low manufacturing costs.
- Full time equivalent (FTE) rate is 20–30% of the US and/or European rate.
- Multinational companies (such as Eli Lilly, Sanofi-Aventis, GSK, Roche, Novo Nordisk and Bayer) are already heavily partnering.
- 60 FDA-approved drug manufacturing facilities.
- Scientists and companies are on a steep learning curve.
- Outsourcing is now valued at US$120 million.
- Large patient population available locally for chronic illnesses such as cardiovascular disease, cancer and diabetes
- The Foreign Exchange Regulation Act, which limited the investment by foreign companies in Indian companies to 40%, has been eliminated.
- Clinical trials are now being done in India by multinational pharmaceutical companies.

Work ethic and attitude are very positive and free from the 'not-in-my-backyard' syndrome, and environmental regulations are not overly limiting.

Success has led to the dismantling of chemistry programs in western countries. Specifically, the closing of the chemistry departments at King's College London, Queen Mary, University of London and the University of Wales, Swansea [12] has been connected and attributed [4] to the creation of jobs in India.

Weaknesses

The following are weaknesses and obstacles to success which India must address for biotechnology companies to succeed in their way forward:
- Protection of intellectual property rights will be an issue until companies proactively demonstrate that their commitment, under a WTO agreement, to recognize drug patents from other companies is real. Some companies, like Cipla, do not yet endorse the recognition of product patents.
- The regulatory framework is still developing, and is now a multiplicity of bureaucratic organizations and processes.
- It is presently difficult to get regulatory approval for animal experimental protocols.
- Trained scientists in some disciplines, eg molecular biology, are difficult to find.
- Country infrastructure, eg roads, bridges ('flyovers') and consistent electrical power, is lacking.
- Scientific training in national universities is good in many respects, but lacking in some. For instance, chemistry students graduating with a master's degree do not generally perform any laboratory research.
- Research budgets are limited, so biotechnology companies cannot afford modern instrumentation such as gene sequencers or high field nuclear magnetic spectrometers.
- Speed in producing deliverables for foreign partners is an issue.
- There is no appreciable local market for biotechnology products.

Conclusion

There are basically three types of pharmaceutical companies in India [4]. The top tier comprises the largest companies, approximately half of which have gained international recognition. The middle tier is composed of a few hundred companies that have developed niche or greater expertise, and have many relationships with foreign partners. This middle tier comprises the biotechnology sector in India. In the lower tier are thousands of little companies, some of which are 'mom-and-pop' shops that are struggling to break into the middle tier. The middle tier, of course, is aspiring to join the top tier.

This is a critical juncture for biotechnology in India. The biotechnology sector, or the large middle tier of Indian companies, is presently the heart of the industry and growing fast, and how well it will really perform depends on how well the weaknesses are addressed. Number one on this list of weaknesses is the issue of compliance with WTO commitments. When this compliance is demonstrated, the floodgates of western business will open for India and biotechnology in India will really begin to flourish.

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