DEVELOPMENT OF MOLECULAR BIOLOGY & BIOTECHNOLOGY IN ASIA & THE PACIFIC RIM

REPORT OF THE PRIORITY NEEDS COMMISSION

FOR

THAILAND

2000

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Asia-Pacific IMBN Priority Needs Commission Report on The Status of Molecular Biology and Biotechnology In Thailand

Contents

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1. Background to the Asia-Pacific Priority Needs Commission and the National Commission Reports

The Asia Pacific International Molecular Biology Network (IMBN) was founded in the belief that molecular biology and biotechnology can contribute greatly to the benefit of humankind. Furthermore, the Network believes that the full potential of biotechnology can only be fostered through close cooperation and collaboration amongst scientists, scientific institutions, national and international agencies and industry. Asia Pacific IMBN aims to serve as a platform to discuss issues of import and to develop and implement mechanisms to advance excellence in biotechnology, especially in Asia and the Pacific Rim.

In order to fulfill its goals, the Network decided to establish a series of Asia Pacific IMBN Expert Commissions to examine issues of concern to the Network and the region. The findings of these Commissions would result in recommendations on how Asia Pacific IMBN can play an effective role towards developing excellence in areas of interest and priority for the region. Furthermore, these Commissions would provide an opportunity for interested scientists and like-minded members of society to collaborate, contribute and hence to get involved in Asia Pacific IMBN work.

The Commissions' findings would be disseminated by publication and by presentation at international meetings. It is envisaged that the data and recommendations generated, as well as Asia Pacific IMBN's active implementation of the recommendations, will send strong signals to the international community of Asia Pacific IMBN's expertise and commitment to the development of biotechnology and molecular biology in Asia and the Pacific Rim.

Currently, there are two active commissions::

- Priority Needs for Molecular Biology and Biotechnology Development in Asia and the Pacific Rim

- Developing a Long-Term Strategic Vision and a Strategic Plan for Asia-Pacific IMBN: Working Together to Translate a Dream into Reality

1.1 The Asia-Pacific IMBN Priority Needs Commission for Molecular Biology and Biotechnology Development in Asia and the Pacific Rim

Molecular biology and biotechnology are recognized globally as powerful scientific and technological platforms with wide ranging applications. Advances in molecular biology and biotechnology are rapidly changing the nature of the biomedical, environmental and agriculture food industries, have created new industry sectors and are expected to impact all aspects of our lives.

Internationally, governments have identified molecular biology and biotechnology as potential sources of high wealth and job creation that will boost the national economy and address national concerns. As such, governments worldwide are eagerly making efforts to build up the so-called "biotech industry". However, the unique

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characteristics of the biological sciences and technologies have to be recognized and addressed if the full benefit from these new technologies is to be realized.

Research in the biological fields is long term in nature and heavily dependent on excellence in upstream basic science. While commercial applications for the results of upstream basic research can sometimes be rapidly identified, the route to commercialization is usually high-risk, capital intensive and dependent on further, often multi-disciplinary, research. In short, long term financial support for upstream, applied, industrial research is required.

National governments are the most reliable source of long-term stable support for research. However, governments unfamiliar with the biological field and answerable to an often equally uninformed populace are loath to make long-term heavy financial investments into basic "ivory tower" research. While the differences between governments' priorities of wealth and job creation and the scientific community's priorities of knowledge creation should be acknowledged, the objectives of the two parties need not be mutually exclusive.

Aim

This Expert Commission is an attempt to bridge the two communities and to develop a strategy that would fulfill the aim of advancing scientific knowledge while still addressing national and regional concerns and priorities. This Commission is co-chaired by Dr Jerry Wang and Dr Yim Jeongbin. Current members of the commission include Dr Louis Lim, Dr Yoshikazu and Dr. Nic Nicola.

Objectives

Focusing on the 14 member economies of the Asia Pacific IMBN, and understanding that existing capabilities and resources in many economies may be inadequate to meet the challenges and issues posed by these new technologies, the Commission on Priority Needs will :

i. Conduct a comprehensive and systematic assessment of the current state of molecular biology and biotechnology development in Asia and the Pacific Rim,
ii. Identify opportunities and challenges for molecular biology and biotechnology development in the region,
iii. Provide a basis for strategic investment and program development for Asia-Pacific IMBN.

The goal of the Commission is to develop recommendations and an action plan to scientific infrastructure, to improve educational levels in science and to ensure the establishment of an environment so as to advance scientific excellence in biotechnology while addressing the needs and concerns of regional economies.

The findings of this Commission will provide Asia Pacific IMBN with the foundation to develop an efficient and effective framework for action in the region and to play a substantial international role toward developing biotechnology and molecular biology for Asia and the Pacific Rim.

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To support the Commission, APEC's support for the work of the Priority Needs Commission, as it relates to APEC economies, was obtained. (The details of this proposal are shown in Annex I.) This proposal is regarded as a sub-set of the Asia Pacific IMBN Commission work as it does not include Asia Pacific IMBN member economies such as India and Israel.

C*onstitution and Work of the National Commissions*

Members of the Commission will establish National Commissions consisting of representatives of Asia Pacific IMBN, the academic community, policy-makers and industry. The role of the National Commission is to conduct an objective, open and effective analysis of the country's scientific capabilities, priorities and concerns.

In particular, the Commissions are to :

i. Examine the scientific capabilities and areas of particular expertise
ii. Identify knowledge gaps
iii. Analyze the existence and effectiveness of available people, resources, institutions and support facilities.
iv. Compile published and unpublished reports and data regarding the current state of development of molecular biology and biotechnology in each country.
v. Examine national goals and policies in relation to molecular biology and biotechnology (i.e. how national priorities may affect scientific funding, how regulations may hamper/enhance research, etc)
vi. Make preliminary recommendations of what can and should be done to strengthen capabilities at the institutional, national and international level (including how Asia-Pacific IMBN can contribute to strengthening capabilities)

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2. Members of the Thailand National Commission

The Asia-Pacific IMBN Priority Needs National Commission Report for Thailand was prepared by:

- Professor Yongyuth Yuthavong, (Chairman of Thailand National Commission), Director Thailand Graduate Institute of Scence and Technology (TGIST), National Science and Technology Development Agency (NSTDA)
- Professor Jisnuson Svasti, (Secretary of Thailand National Commission), Department of Biochemistry, Faculty of Science, Mahidol University
- Dr Sakarindr Bhumirat, Director, National Centre for Genetic Engineering and Biotechnology (BIOTEC)
- Dr Suthat Sriwatanapongse, National Centre for Genetic Engineering and Biotechnology (BIOTEC)
- Dr Saksit Tridech, Pollution Control Department, Ministry of Science, Technology and Environment

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3. Overview of Thailand

Bordered by Myanmar, Cambodia, Laos and Malaysia, Thailand has a total land area of 514,000 km^2 with a long coastline of 3,219 km. The country's natural resources include tin, rubber, natural gas, tungsten, tantalum, timber, lead, fish, gypsum, lignite and fluorite.

Thailand's population has grown steadily over the years (Fig.1), reaching an estimated 61.7 million in 1999. With a total fertility rate of 1.82 children born/woman in 1992, the population's age structure of Thailand is-24% of the population aged between 0-14 years old; 70% aged between 15-54 years old and 6% over 65 years old.

A major agricultural exporter, over 34% of Thailand is arable land of which over 44,000 km^2 is under irrigation. This focus on agriculture is echoed in the 54% of the 32.6 million labor force being involved in agriculture (15% of the labor force involved in industry, 31% in services).

In 1997, after decades of growth, Thailand entered into an economic crisis upon the devaluation of the Thai bath in July of that year. In August 1997, the International Monetary Fund devised a rescue package that the Thai government has adhered to strictly. While GDP growth has been negative in 1997 and 1998 and industry problems still abound, 1999 GDP is estimated to show a slight positive growth rate of +2%.

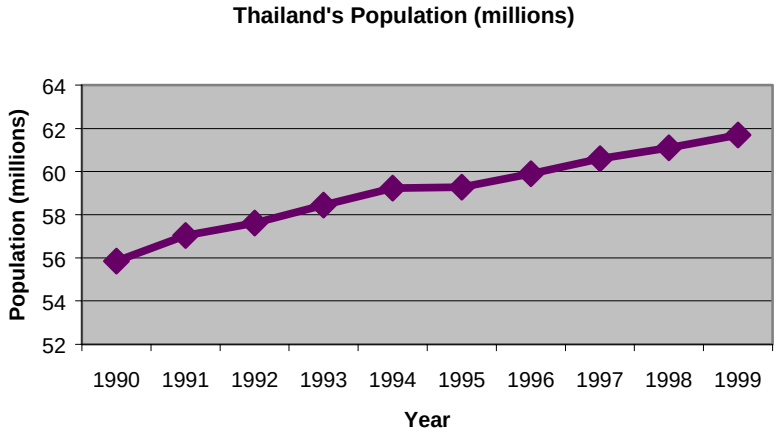

Figure 1: Thailand's Population Growth

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4. Overview of Government Policies

Spurred by the need for rapid economic recovery and growth after the 1997 Asian economic crisis, the Thai government's industry policies are aimed at:

i. Increasing the value added of products
ii. Lowering production cost
iii. Increasing the knowledge base of the industrial sector
iv. Lowering the pollution from manufacturing
v. Expanding manufacturing base to rural areas.

Particular areas of interest that have been identified include semi-conductor manufacturing, agriculture and agro-industries, diagnostic kit development and manufacturing, environmental remediation/protection and the service industries. With the above in mind, the Thai government has taken a broad approach to encouraging industrial development. The strategies in use include attraction of foreign investment; increasing trade liberalization and internationalization via conformance to World Trade Organization (WTO) guidelines; and encouraging the development of technical capabilities through building up local capabilities and through support of technology development by foreign organizations. Specific tools used by the Thai government include soft loans to industries (e.g. Innovation Development Fund, company-directed R & D loans), grants for application-oriented projects and the development of Science Parks.

4.1 Policies for the Development of Science in Thailand

The Thai government recognizes the role of science and technology in ensuring long-term economic growth and is strongly committed to the development of scientific and technological capabilities in the country. This commitment is reflected in the integration of Thailand's science and technology plans into the nation's 5 year National Economic Development Plans; the creation of specialized science and technology agencies (e.g. National Science and Technology Development Agency) and new funding agencies (e.g. Thailand Research Fund); and the passage of laws promoting/supporting science and technology under the new constitution. Specific examples of initiatives related to the development of molecular biology and biotechnology are listed in Table 1.

Thailand's long term vision and commitment to science and technology is also evidence in its "S & T 2020"initiative in which the government is generating visions and strategies through a participatory foresight process involving the public sector, private industry, non-governmental organizations and the public.

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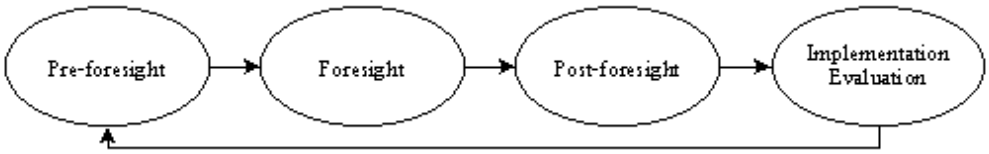
Time Frame

Oct 1999	Jan - Sep 2000	Oct 2000-	Oct 2000 -

Process



Objectives

Preparation and Generation of Public Awareness

Foresight and Development of National S&T Visions and Strategies

Promotion of the Result. Generation of Public Knowledge and Acceptance and Preparation for Implementation

Implementation of Strategies towards the National Visions among Organizations and Individuals, and Evaluation

Activities

1. Public Congress on S&T for Development
2. . Research on Background Information
3. Gathering of Visions of National Experts
4. Panels of Experts
5. Public Congress throughout the Country
6. Comprehensive Surveys of Opinion
7. Summary Report
8. Dissemination of Results to the Public and Public Hearing
9. Inputs to the 9th National Economic and Social Development Plan

Examples :
- Revision of the Roles of MOSTE
- Revision of the Roles of Public R&D Agencies

Figure 2: Thailand's S & T 2020 Planned Activities

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Regulations	Agencies Involved	Administration/ Enforcement procedures	Impact on Research
Intellectual property rights protection	- Department of Intellectual Property, Ministry of Commerce	- Patent Law - Legal measures for Intellectual Property Protection	- Less "copying" of R & D, - More indigenous R & D
Good Laboratory Practice	- BIOTEC/NSTDA - Ministry of Public Health	- Training Courses, - GLP registration	- Many laboratories have GLP registration (e.g. ISO 25) - GLP registration and general awareness increased
Good Clinical Practices	- BIOTEC/NSTDA - Ministry of Public Health	- Establishment of Clinical Research Management Unit (CMU) under BIOTEC	- Clinical Research more coordinated especially in the area of Tropical Diseases Research
Good Manufacturing Practices	- Ministry of Industry - BIOTEC/NSTDA	- Support toward GMP registration	- Development of drugs at manufacturing level increased - Increase in companies with GMP
Ethics Committees	- BIOTEC/NSTDA, - National Research Council of Thailand (NRCT), - Individual agencies and universities	- Committees and guidelines set up	- Research regulated with respect to ethical practice
Biosafety Committees	- BIOTEC/NSTDA, - Ministry of Agriculture	- Committees and guidelines set up - Guidelines for Lab/field environmental release published and adopted	- Research regulated with respect to biosafety

Table 1: Overview of Regulatory Infrastructure

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5. Infrastructure for Science and Technology

The development and application of cutting edge science and technology is dependent on the existence, availability and access to physical infrastructure (e.g. modern telecommunications systems, power supply) and scientific infrastructure (e.g. research institutes, universities, etc) and capabilities. In a bid to develop excellence in science and technology and to drive/attract industry investment in high-tech industries, governments around the world have invested heavily in both physical and scientific infrastructure.

5.1 Physical Infrastructure for Molecular Biology and Biotechnology

The Thai government is in the midst of establishing an 80 acre Science Park situated 20 km from the Bangkok International Airport. The first buildings scheduled for completion in Yr 2000 are:

i. The Park's Main Building- 21,000m^2
ii. The National Electronics and Computer Technology Center (NECTEC-16,000m^2
iii. The National Centre for Genetic Engineering and Biotechnology (BIOTEC)-13,000m^2
iv. The National Metal and Materials Technology Centre (MTEC)-13,000 m^2

Aiming for a "one-stop shop" concept, facilities that are planned at the Park include:

i. Incubator units
ii. Pilot plants
iii. Greenhouses
iv. Management and financial support
v. Legal services
vi. Accommodation

With regards to supporting infrastructure, there is already a robust network of digital and conventional library facilities in place amongst the major universities and government agencies. Supplementing this is the Technical Information Access Centre which has been in operation for the past ten years. Furthermore, supporting capabilities such as nucleotide/peptide synthesis, nuclear magnetic resonance facilities are already available and there is a competitive reagents and equipment supply industry.

5.2 Scientific Infrastructure for Molecular Biology and Biotechnology

The keystone of Thailand's scientific infrastructure for molecular biology and biotechnology is the National Center for Genetic Engineering and Biotechnology (BIOTEC). BIOTEC was established in 1983 and charged with providing the resources for Thailand to develop the critical mass of researchers necessary to achieve excellence in biotechnology. The activities of BIOTEC include conducting R & D, facilitating technology transfer from overseas, human resource development, the establishment of institutions, development of information services and fostering public understanding of the benefits of biotechnology. The center is both a granting

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and implementing agency with over 70% of its budget being allocated to support universities and research projects around Thailand.

Together with financial support from BIOTEC and armed with a long history and experience in agriculture and aquaculture and food production, there has been a large increase in molecular biology and biotechnology activities around the country (Table 2). Particular areas of excellence include tropical disease, immunology, food science and technology, fermentation and some areas of plant biotechnology. Further, capitalizing on natural resources, large germbanks and natural product libraries have been established for agricultural research and for bioactive compounds screening.

Also, recognizing the benefits of inter-institutional and international cooperation and collaboration, international collaboration has been strongly encouraged with all universities undertaking international collaborations of some form. There is strong support from the Thailand Research Fund Golden Jubilee PhD project and the Thailand Graduate Institute of Science and Technology to facilitate such collaborations. In addition, a new project TARUN (Target Research Unit/Network) is now being established to encourage multidisciplinary research for drug/vaccine/diagnostic development.

To further encourage scientific excellence at the institutional level, peer review systems have been set in place for:

- Project evaluation at NSTDA, TRF, NRCT, and other universities
- Publication in Science Asia (formerly Journal of the Science Society of Thailand)
- Academic positions (e.g. Professor, Associate Professor, Assistant Professor), with appointment to Professor requiring peer review at a national level.

However, challenges still exist, such as:

i. Capabilities in physical and mathematical sciences and in process engineering need to be developed and enhanced.

ii. Loyalty to particular institutions and a lack of regular communication across institutions and between disciplines hamper optimal return from research activities and investments.

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Name of Institute	Groups Involved	Areas of Research
Chulalongkorn University	▪ Aquatic Resources Research Institute	- Marine pollution monitoring - Dev't of hatchery and production systems for various marine organisms (fish, shellfish, etc.)
	▪ Biotechnology of Plant Biomass Utilization	- Bioconversion of plant residues - Biotechnology of fungal enzymes & yeast
	▪ Mushroom Research Unit	- Physiology, genetics & breeding of mushrooms - Pest control and post-harvesting technology
	▪ Plants of Thailand Research Unit	- Recording plant biodiversity
	▪ Malaria Research Unit	- Biological characterization of human malaria - Drug susceptibility of malaria
	▪ Biomedical Analysis Research Unit	- Drug analysis for new drug formulation, bioavailability, etc
	▪ Pharmaceutical Biotechnology Research Unit	
Kasetsart University	▪ Dept of Biotechnology	
	▪ Dept. of Food Science and Technology	
	▪ Dept. of Plant Pathology	- Molecular cloning of bacterial & viral genes - Biological and chemical control of pathogens
	▪ Dept of Entomology	
	▪ Kasetsart University R & D Institute	- Administrative & coordinating body for R & D - Initiates and collates research - 9 research centers under management mostly in agriculture
	▪ Kasetsart Agricultrual and Agro-Industrial Product Improvement Institute	
Mahidol University	▪ Dept. of Biochemistry	- DNA diagnosis of infectious disease - Parasite biochemistry - Human disease - Plant molecular biology
	▪ Dept of Biotechnology	- Bacterial genetics - Fermentation - Plant biotechnology
	▪ Dept of Biology	- Plant biotechnology - Environmental conservation
	▪ Dept of Microbiology	- Infectious diseases
	▪ Dept of Plant Science	
	▪ Dept. of Pharmacology	- Drug-receptor interaction - Anti-malarial drug dev't - Toxicology
Thammasat University	▪ Dept of Agricultural Technology	- Plant production - Animal production
	▪ Dept of Biotechnology	
King Mongkut's University of Technology	▪ School of Bioresource and Technology	- Algal biotechnology - Biohydrometallurgy - Bioprocess monitoring

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		- Biosensor dev't
	▪ Algal Technology Laboratory	- Strain improvement - Production system dev't
	▪ Fermentation Technology	- Dev't of commercial scale fermentation of yeast, fungi and other microbes - Dev't of drying techniques for fermentation products - Culture of baculovirus
Srinakharinwirot	▪ Dept of Biology	
Khon Kaen University	▪ Dept. of Biotechnology	- Fermentation technology for food and agriculture products - Bioprocessing
	▪ Dept. of Food Technology	- Food chemistry/biochemistry - Food production
	▪ Dept. of Biology	
	▪ Dept. of Biochemistry	
Chiang Mai University	▪ Dept. of Biology	- Environmental monitoring - Parasitology - Microbial and fungal biodiversity
	▪ Dept of Horticulture Science	- Coffee research - Post harvest technology
	▪ Multiple Cropping Center	- Sustainable agriculture
	▪ Dept of Plant Pathology	- Tissue culture - Plant biotechnology
	▪ Dept. of Animal Science	
	▪ Dept. of Food Science & Technology	
	▪ Dept. of Food Engineering	
Prince of Songkla University	▪ Faculty of Agro-Industry	- Agro-industry processing
Suranaree University of Technology	▪ School of Biotechnology	- Rhizobium research - DNA diagnostics
	▪ Animal Production Technology	- Genetic variation/genotyping
	▪ Food Technology	- Fermentation - Food processing
Naresuan University	▪ Dept of Agricultural Science	
	▪ Dept. of Agro-Industry	- Food processing and biotechnology
Mahasarakham University	▪ Dept of Biology	- Plant biodiversity - Medicinal plants - Rhizobium studies
	▪ Dept of Biotechnology	
Assumption University	▪ Faculty of Biotechnology	
Thailand Institute of Scientific and Technological Research	▪ Biological science Research Dept	- Biotechnology for dev't of products for environmental rehabilitation and protection - Processing of industrial waste.
	▪ Microbiological Resources Center	- Microbial acquisition, collection & maintenance
Chulabhorn Research Institute		- Natural products - Environmental toxicology - Biomedical research
Dept of Agriculture		
Dept of Fisheries		
Royal Forest Dept		
Dept of Medical Science		

Table 2: Overview of areas of research in molecular biology and biotechnology

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6. Human Resource Status

As with any high tech industry, the availability of trained human resources are a key factor for success. This has been identified as a key area of concern for Thailand which, over the last ten years, has only seen the number of researchers per 10,000 population increase from 2 per 10,000 to 3 per 10,000. This low proportion of scientists can be partially attributed to the low number of science-trained graduates produced in Thailand.

Thailand has 24 Public Universities (18 Limited Admission Universities, 2 Open Universities, and 4 Autonomous Universities), 21 Private Universities, and 21 Private Colleges. In 1997, a total of 108,903 graduates were produced, 126 at Ph.D. level, 14,865 at Master's Level, 90,531 at Bachelor's level, and 2,225 at Certificate/Diploma level. However, it is estimated that only 17,000 BSc graduates with science-based training are produced each year. With regards to molecular biology and biotechnology, only 500 biotechnology-trained MSc students graduate per year and only 20 PhDs in biosciences/biotechnology, mostly from Mahidol University, are produced per year. Other challenges include, a poor background in physical sciences and mathematics and an acute need for trained human resources in specialty areas such as:

i. Plant biotechnology
ii. Bioinformatics
iii. Process engineering
iv. Structural biochemistry

Acknowledging the need to develop and enhance human resources, the Thai government has launched a series of initiatives aimed at increasing the quality of teachers, shifting the emphasis from memorization to active thinking and motivating students towards science and technology versus the traditional paths of medicine and engineering. Such initiatives include:

i. The Reverse Brain Drain project
ii. Local and international scholarships
    a. "Junior Science Talent" project of the NSTDA for local and overseas studies
    b. Sri Trang Tong project of the Faculty of Science, Mahidol University
    c. Por Sor Wor Tor project of the Institute for the Promotion of Science and Technology
    d. Full scholarships from the Ministry of Science, Ministry of University Affairs and the Civil Service Commission for post-graduate degree programs overseas
    e. "Sandwich-program" scholarships for study at Thai Universities which include a component of 6-12 months research overseas
iii. "Science in Schools" initiative, headed by the Ministry of Education and the Ministry of Science, to promote science and technology

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The Reverse Brain Drain Project (RBD)

The RBD was established in January 1997 as part of the National Science and Technology Development Agency (NSTDA). With a ten-year approved budget of 2.2 billion baht, the RBD was charged to:

- Identify and attract experienced highly trained Thai professionals working in the S & T arena who are currently living overseas to participate in mission-oriented projects and to develop and lead core R & D teams. (This is the key emphasis of the RBD.)
- Promote and facilitate the return of Thai professionals overseas to work in government agencies or in the private sector.

In particular, the RBD project team works to facilitate the development of international linkage, to serve as an information center for career opportunities in Thailand and to develop a database of Thai students and professionals living overseas. The budget allocated to the program is utilized for public relations campaign, funding of Distinguished Professors, monetary incentives to attract top personnel, etc.

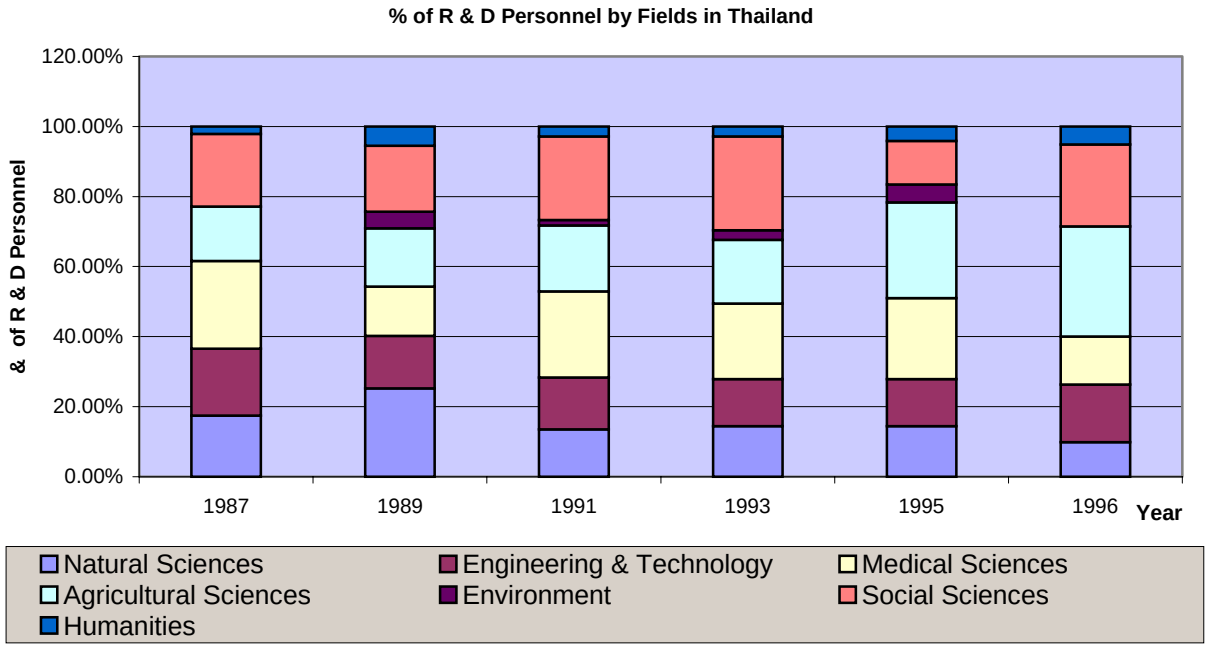

Figure 3: Percentage of R & D Personnel in Thailand Classified by Fields

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7. Support for Research and Development

In terms of actual amount, the Gross Expenditure on Research and Development (GERD) in Thailand has increased substantially- from 2.66 billion baht in 1987 to 5.53 billion baht in 1996. In addition, private sector contribution to R & D also increased over the same period- from 17.79% of GERD to 28.95%. However, in comparison to Gross Domestic Product growth, expenditure on R & D has actually decreased slightly.

	1987	1989	1991	1993	1995	1996
GERD/GDP	0.21%	0.16%	0.16%	0.14%	0.13%	0.12%
Gov't Contribution	82.21%	80.46%	85.51%	83.71%	84.77%	71.05%
Private Sector Contribution	17.79%	19.54%	14.49%	16.29%	15.23%	28.95%
Actual Expenditure on R & D (million Thai baht)	2,664.39	2,908.95	3,928.05	4,471.41	5,174.23	5,528.13

Table 3: Research and Development Expenditure from 1987-1996

Most of the funding for research in Thailand still originates from the government and private funds for research are very limited. As such, the availability and sufficiency of research funds are a key challenge in furthering excellence in this area.

There are currently four main organizations/avenues which are in charge of administering and managing government funds for research. These are:

Funding Agency	Fund Available (US$ million)	Funding Criteria/Priority	Funds Administration and Project Evaluation	Average Grant Size (USD)
NSTDA	10 million	Application orientated	Peer review	50,000
Thailand Research Fund (TRF)	15 million	Basic and applied research	Peer review	50,000
National Research Council of Thailand (NRCT)	3 million	Basic and applied research	Peer review	10,000
Via Universities	20 million	Basic and applied research	Peer review at university level	2,500

Table 4: Summary of Government Funds Available

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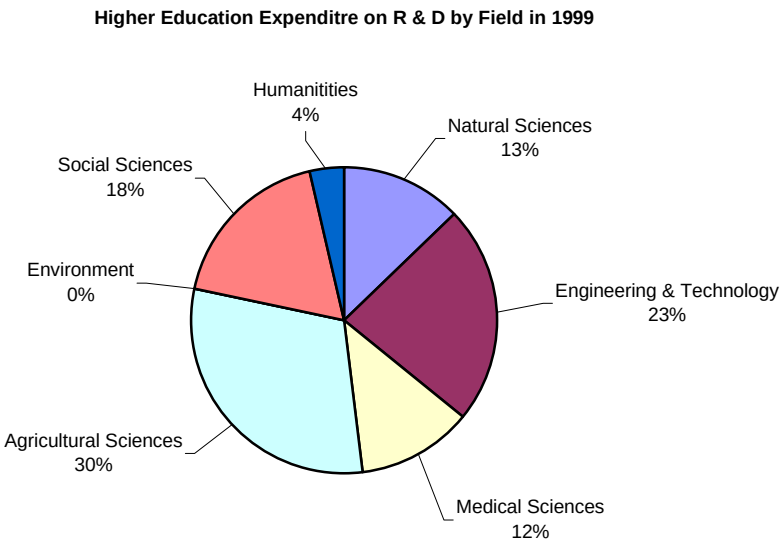

Figure 4: Higher Education Expenditure on R & D Classified by Field in 1999

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8.Overview of Industry

8.1 Industry Overview

With a strong agricultural base, it is not surprising that Thailand has a strong food processing and production industrial sector (over 240 companies) with particular interest in the use of molecular biology and biotechnology for:

- Food processing and increasing value add of products
- Genetic improvement of plants and livestock
- Development of diagnostics (There are around approximately 2-3 companies producing locally developed diagnostics and 4-5 companies producing diagnostics developed overseas.)
- Aquaculture
- Development of biological products, especially for biological control in agriculture.

With these interests in mind and aware of the costs involved in research, industry linkages with local institutes are often on a consortium basis. Examples include:

- BIOTEC has linkages with the Environment Technology Club and the Fermentation Industry Consortium
- Mahidol University is collaborating with the Soya Sauce Industry Consortium
- King Mongkut's Institute of Technology Thonburi has linkages with the Algal Production Industry and a consortium interested in anaerobic treatment of agro-industrial waste.

While the use of diagnostics/therapeutics/ vaccines, fermentation techniques, DNA sequencing and tissue culture may be common, Thailand has recently banned the import of genetically modified seeds for production use, so as to capitalize on the higher economic value of being an "organic" producer nation. Yet, funding for research into genetically modified organisms continue as the government acknowledges the potential benefit of molecular biology and biotechnology.

8.2 Scientific Entrepreneurship

The drive towards scientific entrepreneurship is still in its infancy in Thailand and like many countries in Asia and the Pacific Rim, the translational infrastructure requires significant development. For example, while support for technology transfer is available for start-up companies and intellectual property personnel have been allocated to assist researchers in exploring commercialization potential, the numbers of these trained personnel are limited. Moreover, with regards to technology transfer, intellectual property from projects funded by the NSTDA are owned by the agency and royalty fees vary according to each project. There are also no set rules or precedents yet to incentive investigators who spin-off companies or develop products which are licensed to industry. However, government support for scientific entrepreneurs is in place with the NSTDA Investment Center (NIC) and the Venture Capital Fund of the Department of Industrial Promotion offering potential investment support to start-ups. Other parties, who are receptive to such investments, include the Nomura JAFCO Capital Co Ltd, which makes deals of approximately 10 million baht.

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9. Identification of Strengths, Opportunities and Challenges

The government of Thailand has long recognized the potential of molecular biology and biotechnology to benefit the nation's economy and to meet the needs of its populace. With a large industrial sector and in-depth experience and expertise, Thailand's strength in molecular biology and biotechnology lies mainly in the agricultural sector.

	Strengths	Challenges	Opportunities
Government policies	▪ Plant Variety Protection Act to be implemented soon	- Insufficient R & D budget - Lack of continuity in R & D policies	- Cabinet to decide soon on the establishment of: o A National Council for Agricultural Research to guide and monitor research o A National Agricultural Products Standards Institute
Physical Infrastructure	- Network of research stations at provincial level	- Insufficient budget for modern biotech instruments	-
Scientific Infrastructure	- Strong capabilities in commercial-scale micropropagation - Strong capabilities in DNA fingerprinting	- Capabilities in modern biotechnology such as genetic engineering and process development need to be enhanced - Most of the R & D capabilities reside in public institutions	-
Manpower Supply	- High quality human resources trained in agricultural R & D	- Insufficient number and quality with respect to agricultural biotechnology	-
Industry	- Large industry sector willing to invest in R & D	- Little in-house R & D capabilities	- Good opportunities for collaboration/ field testing of research

Table 5: Summary of Strengths for the Agricultural Sector

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10. Recommendations and Conclusions

10.1 Recommendations

The government of Thailand is already committed to the development of science and technology and has launched a range of initiatives aimed at improving local capabilities in areas of interest.

To further enhance Thailand's ability to obtain maximum return on its investments and to derive optimal social-economic benefits from molecular biology and biotechnology, it is recommended that further efforts be made to:

- Strengthen basic research and development
- Increase public education and understanding
- Enhance inter-institutional and multi-disciplinary collaboration and cooperation

In addition, while scientific entrepreneurship is in its infancy, efforts to increase the supporting infrastructure required to bring discovery research to the commercial arena would be advisable and timely. The capabilities required would include skills such as intellectual property management, strategic visioning, resource mobilization, business development and public and investor relations management.

10.2 Conclusion

Discoveries in molecular biology and biotechnology hold great potential to meeting the needs of the global population and the environment in this new millennium. If all humankind is to benefit from the new understanding gained from the intensive international research efforts, economies around the world have to move rapidly to ensure that their populations have the necessary understanding and capabilities to operate in the new world brought about by molecular biology and biotechnology and that the necessary infrastructure is in place to maximize benefits while minimizing risks to the public and the environment.

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Appendix 1: Thailand's International Collaborative Relationships

1. Bilateral/Multilateral Agreement

Australia.

- Waste Water Treatment Technology Transfer and Cleaner Production Demonstration Project. BIOTEC accepted a Coordinating Agency role for the Waste Water Treatment Technology Transfer and Cleaner Production Demonstration Project. This project is an activity under the third phase of the ASEAN – Australia Economic Cooperation Program (AAECP) with an objective to provide technology transfer in Wastewater Treatment and Cleaner Production from Australia to ASEAN countries.

- The Memorandum of Understanding between NSTDA and RMIT The MOU was signed on 14 November 1997 in light of cooperation in curriculum development, joint research, staff exchanges, consultancy, training programs, cooperation in international projects and the investigation of potential joint ventures for commercial applications. As BIOTEC is part of NSTDA, biotechnology is also included in this collaboration.

- Promotion of Environmental Consciousness for Rural Thai Youth This is a collaborative project between BIOTEC and AusAID in providing public education on biotechnology and biodiversity via workshop activities, exhibitions and booklets.

Canada.

- Through the NSTDA Graduate Research and Education Consortium (GREC), BIOTEC has developed linkages with Canadian academic institutes such as Waterloo University, University of Saskatchewan, McMaster University and Simon Fraser University. GREC program was organized to help Thai universities effectively establish and run graduate programs in selected areas at the graduate level in line with the assistance from overseas universities. Selected areas of BIOTEC's concern are Chemical and Bio-Process Engineering, Biotechnology and Molecular Biology.

- Cooperation with the Canada-ASEAN Centre in Biotechnology. The activities include researcher and staff exchanges, consultancy and training programs, with supporting experts from various Canadian governmental agencies.

- The NSTDA-NRC Joint Science and Technology Development Agreement for cooperation in curriculum development, joint research projects, staff exchanges, consultancy, and training programs. The Agreement provides an umbrella for a collaboration in the areas of biotechnology, metal and materials, and electronics and computer.

Japan

- The 1999 Follow-up Activities to the Research and Cooperation Project on Conservation and Sustainable Use of Tropical Bioresources The Agreement between NSTDA and the New Energy and Industrial Technology

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Development Organization - NEDO embraces the research activities and the human resources development.

Malaysia

- Thailand-Malaysia Cooperation on Science, Technology and Environment between the Ministry of Science, Technology and Environment of Thailand and Malaysia The collaboration in biotechnology includes joint research and human resource development.
- MOU for the collaboration on research projects, the exchange of scholars and research staff, academic information and scientific materials between the University of Malaya and BIOTEC

Belgium

- Cooperation in Tapioca-starch Industry The Program was implemented by the Thai Tapioca Development Institute (TTDI), Belgian Administration of Development Cooperation (BADC), and BIOTEC. Three main activities are:

  1. Waste audit of tapioca-starch plants
     - Quality control and plant efficiency
     - Wastewater treatment system
  2. Technology transfer through conducting workshops in
     - Waste minimization and wastewater treatment
     - Control of sulfur dioxide in the manufacturing process
     - Efficiency improvement in drying process
     - Improvement in dewatering process
  3. Research promotion
     - Waste minimization project
     - Project on improvement in drying process
     - Project on control of sulfur dioxide.
     - Project on improvement of dewatering process.

Lao PDR

- MOU for the collaboration on research projects, the exchange of scholars and research staff, academic information and scientific materials between the Science Technology and Environment Agency (STEA) and BIOTEC

Vietnam

- Development of a Registration and Quality Standard System of Animal Feeds for Vietnam. This is a joint project of the Institute of Biotechnology and

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BIOTEC with the support from the Department of Technical and Educational Cooperation of Thailand.

Novo Nordisk A/S

Sponsor Research Agreement for a Thai Ph. D student to perform enzyme screening in Denmark between NOVO NORDISK A/S and BIOTEC

Rockefeller Foundation

- An Establishment of Plant Biotechnology Products Development Center with joint funding from the Rockefeller Foundation, Kasetsart University and BIOTEC

ASEAN Committee on Science and Technology (COST)

ASEAN comprises countries in the Southeast Asian region—Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam. The Committee on Science and Technology (COST) is a part of the ASEAN function to support the cooperation among ASEAN countries in Science and Technology. Biotechnology is one of the areas in collaboration and is implemented by the ASEAN Sub Committee on Biotechnology. The activities range from organizing ASEAN workshops to coordinating collaborative research.

Asia-Oceania Network of Biological Sciences (AONBS)

BIOTEC has been designated a Regional Secretariat of the Committee on Science and Technology in Developing Countries (COSTED), an international body affiliated with the International Council of Science (ICSU). The Regional Secretariat was established in 1995 under the name the Asia-Oceania Network for Biological Sciences (AONBS), with the following objectives

- To develop human resources, by training more biologists for countries of the south
- To help and to build up regional scientists in scientific infrastructure so that they are better able to undertake their own research and development not only on the pressing problem that confront them in agriculture, food production, medicine, biotechnology and environment, but also on the underlying basic scientific disciplines
- To obtain a proper balance between fundamental and applied research
- To determine research priorities correctly in relation to the special problems of the region in order that maximum economic and social impact may be achieved.

2. International Cooperation Centers

- Department of Technical and Educational Cooperation (DTEC) DTEC is operated under the Office of Prime Minister. Its role is to coordinate and provide funding to Thai governmental organizations in projects collaboration

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with overseas governmental agencies. The collaboration covers all areas, including science and technology.

- International Cooperation Division, Ministry of Science, Technology and Environment
- International Cooperation, NSTDA
- International Relations, BIOTEC
- International Cooperation, Thailand Institute of Scientific and Technological Research
- Translation and International Relations, National Research Council