Strengthening Postgraduate Programmes towards Research Excellence and Industrial Relevance

Foresight of Biotechnology Industry Needs

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Introduction

Globally, modern biotechnology is now a little over three decades old (Baltimore, 2008). Having gone past the infancy stage it is now in its maturing phase of striving to achieve its agenda for the millennium, namely to heal, feed, fuel and clean the world. In Malaysia, the industry lags behind achievements by the major global players (Ahmad Zaharudin, 2005). However, significant growth has occurred during the current Ninth Malaysia Plan (9MP) primarily due to strong political will. There has been a substantive increase in commitment of resources to support the National Biotechnology Policy (NBP) launched in April 2005 (Abdullah, 2005). The budget allocation for Science, Technology and Innovation (STI) more than doubled (Table 1) between 8MP and 9MP (Ninth Malaysia Plan, 2006), and has accordingly encouraged significant growth of the industry. Biotech Corp reports that 92 BioNexus companies with a total approved investment of RM1.3 billion have already been established (Iskandar, 2009). Without a doubt, it is the Government that drives the Biotechnology Industry in Malaysia.

TABLE 1: Budget expenditure and allocation for S&T&Innovation (2001-2010)

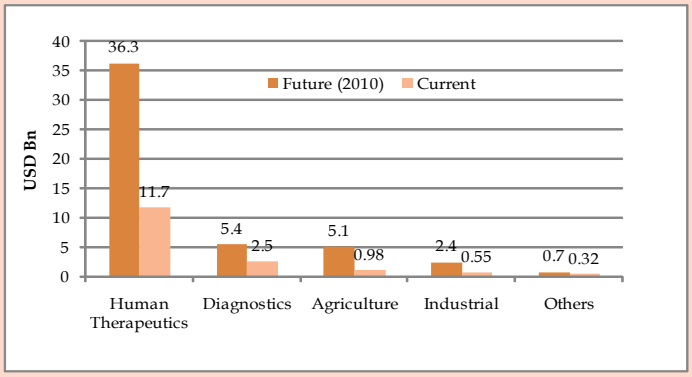
	8MP	9MP
	(RM millions)	
R&D	926.6	1,581.6
Technology Acquisition	70.7	142.6
Commercialisation of Technology	267.5	1,843.3
S&T Human Resource Development & Awareness	123.1	650.6
S&T Infrastructure	1,950.0	1,035.1
Total Allocation	**2,337.9**	**5,253.1**

Source: 9MP Doc., Economic Planning Unit, 2006-2010

It is against such a scenario that this report, on foresight of the needs for the biotechnology industry, is presented as an appropriate framework towards strengthening postgraduate programmes geared to achieve research excellence, as envisaged for Malaysia (Malaysia and the Knowledge Economy: Building a World-Class Higher Education System, 2007) that will in turn impact on developing the national biotechnology industry. What is required is to introduce postgraduates to the Blue Ocean Strategy (Kim and Mauborgne, 2005) in their research training so that they will be the catalyst for further development of the biotechnology industry and compliment one of MoHE's Strategic Plans, which is to generate 100,000 world class Science and Technology doctorates within 15 years (Ministry of Higher Education, 2005).

What is the Future for Biotechnology?

The global market is predicted to expand to reach a value of USD1.76 trillion by 2050 (Beyond Border: The Global Biotechnology Report, 2008)! If Malaysia aims to harness even 0.01 per cent of this market it will amount to a total value of USD176 billion by 2050! Based on a survey conducted by Ernst and Young in 2002, the global biotechnology industry is set to move forward significantly in four major fields, namely human therapeutics, diagnostics, agriculture, and industrial with the prime mover being in healthcare where a larger than three-fold increase is expected to occur by 2010 (Figure 1), while agricultural and industrial biotechnology will more than double in value. The prognosis is therefore, very good for growth of the industry.



Source: Report on Global Biotechnology, 2002

FIGURE 1: Global biotechnology industry

While Malaysia needs to take note of these global trends, R&D training should be directed primarily towards working on local solutions to regional and global problems. The abundant natural resources are there to provide the raw material from which innovative new solutions may be derived. There are three main areas of focus for development of the biotech industry in the country, as stated in the NBP (Ahmad Zaharudin, 2005; Abdullah, 2005). These are Agribiotechnology, Healthcare-related Biotechnology and Industrial Biotechnology. Malaysia's Biotech strategy is to responsibly exploit its mega biodiversity of plants, animals and microbes in order to create new economic opportunities for wealth creation and social well-being of its people, through better health, food, fibre and fuel, while judiciously conserving natural resources and the environment. The targets set by the NBP are to create by the year 2020, 280,000 jobs in the biotech sector as well as to establish at least 400 biotechnology companies and to attract RM270 million per annum in investments.

The Biotechnology Industry in Malaysia

The current status of the Biotechnology Sector *vis a vis* Human Capital Development, R&D activity and Industry, as summerised in Table 2, shows that biotechnology presence in the country is quite limited. Forty-three institutes help to train man-power for the sector, while only 95 entities are actively engaged in the biotechnology-related businesses (Biotech Clusters, March 2009).

TABLE 2: Entities in the Malaysian biotechnology sector

Institutes for Human Capital Development and R&D Training	Number
Universities	
Public	15
Private	15
Research Institutes	13
Biotech Companies and Related Activities*	
Agriculture	21
Healthcare	28
Industrial	3
Bioinformatics	9
R&D	5
Incubators	24
Others	5

* Includes 13 GLCs (Government-linked companies)
Source: Biotech Corp (Biotech Clusters, 2009)

This situation is unsatisfactory. A new paradigm promulgated by MoHE is for "A People-led Economy" (Ministry of Higher Education, 2006), the rational being that researchers with in-depth knowledge will be able to generate new technology platforms to innovate new products ("brain power *versus* brawn power"!!). The process flow will then proceed smoothly through the route of R&D ⟶ Technology ⟶ Innovation ⟶ Funding ⟶ Market.

All R&D activities require funding. In developed countries, funding is almost equally supported by public as well as private enterprise (Beyond Border: The Global Technology Report, 2006). However, in developing countries less than one per cent of R&D funding comes from the private sector. In Malaysia, this is especially so for the fledging biotech industry (Ahmad Zaharudin, 2005). As such, it is initiatives by the Government that have stimulated growth of the industry. In particular, two policy documents present the foresight framework for the Biotechnology industry, namely Chapter 6 on Biotechnology, in the 9MP (Ninth Malaysia Plan 2006-2010) and the NBP document of April 2005 (Abdullah, 2005). Research and development as well as commercialisation of biotechnology-related science have been programmed to develop in the following three major areas: Agricultural Biotechnology, Healthcare - related Biotechnology and Industrial Biotechnology, with a supportive role from Bioinformatics. Research in Biotechnology began more than two decades ago and reasonable expertise is now available. Arising from this and present developments in the industry, it is timely to take stock on the status of R&D activity in these areas. The anticipated developments in the short-to-medium term as well as the medium-to-long term are set out in Table 3.

Table 3 outlines in general terms, the specific areas where current research and development in biotechnology is on-going and what probably lies ahead. The specifics need to be carefully developed to ensure knowledge-based economic returns. Current strengths need to be capitalised on and new innovative approaches sort to solve national issues. Primarily, these include: wealth creation, food security, alternate/renewable energy, environmental degradation, water resource management, health and wellness of the people. Blue Ocean Strategies (Kim and Mauborgne, 2005) need to be developed to address these within the framework of what is already available in terms of resources and knowledge banks.

In particular, since Malaysia is globally recognised as a country that has built up an impressive knowledge-bank in plantation crops, the tools of modern biotechnology should be judiciously used on these crops for potentially gainful economic returns. The crops of interest include oil palm, rubber, coco, and rice as well as horticultural crops like tropical fruits, flowers and vegetables. In Animal Biotechnology, attention should be on the fledging livestock industry in cows, goats, the established swine and a robust poultry industry. Aquaculture and marine biotechnology for tropical fishes and marine organisms (including seaweeds) should be developed further so that new industrial and food-based products can be introduced.

Although the Healthcare Industry is receiving a lot of support globally, its R&D has focused on diseases and issues relevant to temperate countries (Beyond Borders: The Global Technology Report 2006; 2008). It is time for Malaysia to address R&D issues pertaining to local and regional scourges and health-related problems e.g. dengue, typhoid, cholera, tuberculosis. The long-term focus should be to also develop innovative products from our wide biodiversity as viable solutions to address health and well-being issues. Indigenous knowledge in traditional foods and remedies should be documented and researched on. It would provide a conduit to new intellectual property with potential for the start of a green - gold economy in Malaysia. In the short-term, customising vaccines and diagnostic kits for local applications is providing important value-added products.

Industrial biotechnology readily draws upon innovation arising from the knowledge - base in Agricultural Biotechnology and Healthcare and Medical - related Biotechnology. Energy and environmental issues will see new products such as biofuels, and environmentally friendly-technologies for pollution control and water and resource management develop so long as researchers are suitably trained to handle these new challenges. Expanding downstream processing of produce such as rice and plantation crops, herbals, fruits and vegetables should also stimulate the food industry with value-added products for

TABLE 3: Foresight for Biotechnology Industry – Focus areas (2006-2020)

Area	Short-to-Medium Term (2006-2012)	Medium-to-Long Term (2012-2020)
Agricultural Biotechnology	Clonal propagation of selected horticultural, plantation and forestry crops	Clonal propagation of commercially useful recalcitrant plants and new crops (e.g. for biofuels, biopharmaceuticals, biopharming)
	Innovative seed production technologies	Cryopreservation and artificial seed technology
	Improvement of selected livestock and poultry through *in vitro* technologies	Transgenic livestock with genes that add value (e.g. disease resistant, better meat quality)
	Crop improvement by conventional methods	Crop improvement by molecular breeding and transgenic technology
	Aquaculture of selected ornamental and commercial fish, prawns and other aquatic organisms	Aquaculture of transgenic fish for disease and pest control; improved nutritional/food value
	Transgenic production of selected crops with genes for pest and/or disease resistance/tolerance	Production of selected transgenic crops with value-added qualities, e.g. nutritionally enhanced or better quality; enhanced postharvest longevity; reduced chemical and other inputs (e.g. water, fungicides)
	Food production from down-stream processing of fresh produce (e.g. edible oils, fruits, vegetables)	Food processing from new, value-added transgenics and non-transgenics (e.g. heart-healthy cooking oils; orphan crops)
	Halal food production and development of biomarkers	Halal food bio-validation and certification
	-	Genomics, proteomics of selected plants and animals; gene mining to unravel gene regulation of novel and useful characteristics
Healthcare Biotechnology	Development of diagnostic kits vaccines and other biologics for major infectious tropical diseases	Development of new biopharmaceuticals, nutraceuticals and cosmeceuticals from natural resources, especially plants used as traditional/complementary medicines, or health products
	Herbal product development and quality characteristics	Systems biology to understand mode of action of selected herbal plant products
	Biomarkers for major diseases and health-related problems in Malaysia; association with ethnicity	Proteomics, genomics and systems biology of major illnesses and diseases
	Bioinformatics of genes associated with major diseases and illnesses	Pharmacogenomics and personalised medicine
	Stem cell banking technology	Stem cell science; tissue engineering
Industrial Biotechnology	Bioremediation of biological, industrial and environmental wastes	Development of biocatalysts for selected industrial applications
	Feed production from natural resources and biological wastes	Recombinant technology to harness useful microbes for bioremediation and selected industrial processes
	Down-stream processing of selected fruits and plant products	Production of recombinant proteins for food and feed preparation
	Biofuel from edible crops	Biofuel from non-edible crops
	Development of clean air and water technology	Development of biosensors for industrial applications (e.g. environmental pollution)
	Bioreactors for food and feed industry	Recombinant technology for use in selected bioreactor systems
	Special industrial production systems e.g. for cultivation of mushrooms; seaweeds	New biomaterials for industrial applications; nanobiotechnology
	-	Genomics of selected microbes useful for industrial applications

the local and international market. The Nation's various culinary customs provide numerous possibilities for innovative developments that could help local foods penetrate into global markets. The possibilities are countless for the ingenious mind!

Postgraduate Training Programmes for Biotechnology

"People are the same around the world; free them and they start expressing their individual creativity" (Baltimore, 2008). If that is the case then, it is essential that the teaching and training curriculum, especially at the tertiary level (inclusive of postgraduate training) should be especially liberating and should stimulate critical thinking and ingenuity in order to encourage new discoveries and new innovations. The industry is especially in need of such scientists.

The brick-and-mortar to build a solid foundation must still be a bedrock of relevant basic information essential to successfully mould the graduate into his field of choice. Table 3 indicates that the exposure should be varied

enough to enable the Malaysian postgraduate student of biotechnology to delve into R&D areas relevant to Agricultural Biotechnology, Healthcare and/or Industrial Biotechnology, as these are the strategic areas projected for biotechnology development in the country. Postgraduate biotechnology programmes should have embedded in them a good balance of the basic and applied sciences, whether the programme is project- or course work-based, for it is basic science that makes the leap to produce the breakthrough concepts. Additionally, an exposure to the main elements of good entrepreneurship is also essential since discoveries and innovations in biotechnology eventually find a home in a commercial environment. Finally, training in critical thinking that is out-of-the-box and directed to innovative solutions will ensure that the postgraduates will be able to play a vital role in rapid development of the biotechnology industry in the country.

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Without doubt, the building of science and technology capability is a long-term effort and several developing countries are rapidly moving forward in following this agenda (Baltimore, 2008). Countries with the political will to support it in a sustainable manner by high quality human capital development, commitment of adequate resources and the implementation of harmonious regulatory regimes will no doubt reap the benefits of working on local solutions to global problems. The country can then rightfully claim a place among the developed nations of the world!

Summary

- The Biotechnology Industry is at an early phase of development in Malaysia.
- The primary objective of biotechnology development is for wealth creation and social well-being.
- The primary driver is the Government.
- There has been significant growth since the launch of the National Biotechnology Policy in 2005 and the Ninth Malaysia Plan (2006-2010).
- The Industry revolves around Agricultural Biotechnology, Healthcare-related Biotechnology and Industrial Biotechnology.
- Forty-three institutes are involved in Human Capital and R&D training for the biotechnology industry.
- At least 95 companies are engaged in biotechnology-related activities.
- The Biotechnology Industry requires postgraduates with high knowledge content and good R&D skills in relevant areas pertinent to the industry.
- R&D focus in biotechnology should be to look for local solutions to regional and global problems, by effective team-work.
- An R&D priority should be to draw on available strengths and expertise in the agricultural and plantation sectors.
- Innovation and new product/technology development efforts should focus on indigenous resources among plants, animals and microbes.
- Particular research focus should be given to achieve food security, develop non-food-based biofuels, remedies for tropical diseases, new and innovative products as nutraceuticals, cosmeceuticals and biopharmaceuticals and a clean environment.
- Training postgraduates towards research excellence and industrial relevance in biotechnology can be realised if postgraduates are exposed to R&D handled via a Blue Ocean Strategy that is fuelled by a relevant amount of basic research.
- Basic entrepreneurship training is essential for biotechnology graduates.
- Well-trained postgraduates who also have good communication skills will help to drive forward the biotechnology industry in the country.

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