Chapter 1:

Alexandria Renaissance: the New Life Sciences and Society

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Alexandria is a name synonymous with light and learning. In ancient times, it was the location of the Lighthouse of Alexandria, one of the seven wonders of the ancient world. It was also home to the ancient Library of Alexandria, the world's first international library and a centre for scientific research and philosophical discourse. Amongst the Library's scholars was the geographer Eratosthenes who used the light of Alexandria and the shadows it cast to calculate correctly the circumference of the earth. Here too scholars such as Archimedes, Euclid and others, coming from different branches of science and philosophy, developed the principles and values of science and used these to help resolve the issues of their time.

Today, a beautiful new library, the Bibliotheca Alexandrina, has been built close to the site of the first library, across the water from where the ancient lighthouse stood. The new library aims to live up to the great tradition of tolerance, dialogue, rationalizing and learning that characterized the ancient library that disappeared some 1600 years ago. The new library will promote the values of science – Creativity, Challenge and the Search for Truth – and facilitate dialogue, debate and consensus building on issues of concern to society today. It is a place where scholars can come to examine the issues of today, and the needs of tomorrow.

Alexandria Dialogue – Voices of the South and North

In March 2002, a group of modern scholars met in Alexandria at the newly built library, (before its formal inauguration). Their task was to review the state of the art in relation to the applications of biosciences in human health, food and agriculture and the environment, and address the ethical, institutional, regulatory and socio-economic issues that affect their use. Their goal was to identify ways and means by which science and especially the new life sciences can be mobilized in the service of humanity and to improve the livelihoods of poor people.

There is a revolution taking place in bioscience and biotechnology, driven in recent years by the advances in genomics and proteomics, which is now looking to deliver benefits, in human health, in food and agriculture and in the environment.

The conference provided rare opportunities for cross-sectoral and cross-disciplinary interactions. The dialogue amongst people knowledgeable about the key themes of human health, food and agriculture, the environment and ethics provided for sharing knowledge and experience and cross-fertilization of ideas.

For each of these themes, the conference addressed the following issues:

- New scientific developments.
- Case studies from developing countries.
- International experiences.
- Emerging issues.
- The way ahead.

The developments in biosciences are linked to new developments in the physical sciences, which are feeding a revolution in information technology. The developments in physical sciences and in communication, which have led to mobile phone use, are a much more demonstrably physical revolution than anything we have seen in biotechnology to date. We need to look at what might be the desirable integration of new developments in the biological, physical, and social sciences – the applications of technology that are not only technically feasible but also socially responsible and environmentally friendly.

Human Health

State of the science

Biology is in a fundamental revolution as knowledge acquisition is exponential. Post-genomic pharmaceutical, targeted drugs are based on the following discoveries in science and technology:

- Sequencing of the human genome.
- Bioinformatics.
- Genomic sequencing of major infectious diseases.

Targeted drug design: In human health, there has been a significant impact of the new molecular technologies on drug design. It is now possible to look at many more new targets for drugs. Where there were about 500 drug targets worldwide, a few years ago, today we can identify over 3,000–10,000 potential targets. Increasingly it will be possible to target new drugs to individuals. Also, greater efficiencies in developing new drugs means that diseases important in tropical environments and emerging economies will be able to be targeted for drug development. These include diseases such as malaria and tuberculosis (TB).

Biotechnology offers several means of improving human health by enabling:

- Early detection of diseases and susceptible individuals.
- Gene therapy for specific cases (still at the experimental stage).

International experiences

Several drugs have been donated to developing countries through the World Health Organization (WHO) and have proved effective (e.g. drugs against leprosy, malaria and liver fluke). There is now a move toward drug price differentiation in different markets. The industry is looking at some new modalities, particularly public/private sector partnerships and other international initiatives such as those on polio and malaria.

In the human health field, one important factor is the high cost of developing a new pharmaceutical, estimated at US$800 million. Much of this is the regulatory cost. This highlights the need for drugs for "orphan" diseases that are important in developing countries but for which the global market is limited. Such orphans need to be "adopted" either through public investment; or through some public/private sector partnerships; or through legislation that provides tax or other incentives for private investments in orphan drugs.

Research consortia are particularly needed for research on genome mapping of parasites and their vectors. An example of this is the TIGR and ILRI collaboration in mapping the *Theileria parva* genome, which is identifying new targets for vaccine development against East Coast Fever in Africa.

National institutes and regional networks enable progress in human health care. Multinational companies can help developing countries by funding research centres located in developing countries. Such centres could provide the leverage for the exponential increase in biological knowledge. One such partnership is the newly established Novartis Center of Tropical Diseases in Singapore that will focus on developing improved means for the control of TB and malaria.

There is an opportunity for more public/private partnerships and also learning lessons of cross-sector collaboration. The medical sector has been successful in developing effective programmes, such as those on polio and smallpox, leading towards the eradication of these diseases.

Three main factors are relevant in order to develop an effective cooperation at the international level:

- The mobilization of research groups in the South working in collaboration with major research institutes based in industrial countries, and providing stable funding for these groups. This approach could make possible the development of new therapeutic drugs and vaccines designed specifically for diseases important in developing countries.

- Technology transfer as a gateway to new and promising economic development in those countries where a level of entrepreneurship is already able to promote and produce innovations. Initiatives should be taken for personal skills enhancements and learning opportunities.
- Public awareness has to be promoted to balance risks and opportunities. Each country needs to balance the benefits and the hazards of biotechnology; recognizing ethical concerns and supporting the public and individuals in making informed choices.

Future actions

Priority areas for further actions in the health sector are to strengthen:

- The development and evaluation of new vaccines for infectious diseases prevalent in the developing countries.
- New diagnostic methods that are cost effective, rapid and reliable.
- Differential pricing of drugs and diagnostics between North and South, so that they are more accessible to poor people.

Food, Agriculture and the Environment

Major challenges

The major challenges to be addressed are reducing global poverty, providing food security and reducing agriculture's ecological footprints. At least 1.2 billion people live on less that US$1 per day, over 800 million people are hungry and a further 2 billion people are malnourished, unable to access sufficient nutritious food at affordable prices.

Agriculture treads heavily in the environment. Various species of flora and fauna are lost as their habitats are converted to agricultural uses. Crop cultivation, livestock production and forestry put pressure on national resources. For example, it takes 2 tons of water to produce 1 kg of rice. Land and water for agriculture are becoming increasingly scarce. Intensification not extensification of agriculture, and increasing its efficiency, are needed to reduce pressure on land and other national resources.

Climate change will affect tropical agriculture adversely. A report from the International Panel on Climate Change indicates that surface temperature could rise 5.8^{o}C over the next 100 years.

Agriculture is the foundation of many economies, and agricultural research helps to develop new crop and farming technologies that can unleash economic growth, boost incomes, increase per capita availability of food, reduce food prices, and help conserve the environment.

Role of science

Science has been a key contributor to development and provided the foundation of the "Green Revolution" that was based on the development of high yielding varieties of rice and wheat. The "Green Revolution" led to a profound transformation of agriculture and helped avert a Malthusian spectre of famine. It bypassed Africa, however, where average cereal yields are 1 ton/ha compared to nearly 3 ton/ha now achieved by Asian farmers.

Agricultural research has helped to feed more people than ever before. Productivity has doubled: in 1961, the world used l.4 billion ha of land for food grain production; in 1998, 1.5 billion ha was used to produce twice the amount of food grains.

In the transition from the "Green Revolution" to the "Gene Revolution" we are witnessing a revolution in biological science made possible by the coming together of molecular science, computers, and relational databases. This revolution has been termed "Promethean Science", in recognition of its potential risks and benefits (Serageldin and Persley, 2000).

Whole genomes, including the human genome, have been sequenced at breathtaking speed. In plants, genomics is offering increased understanding of the structure and function of plant genes. It is enabling some of the more difficult traits such as drought tolerance to be addressed, which were difficult to handle through conventional breeding. New scientific developments in proteomics and metabolomics are giving greater understanding of the biochemical pathways in plants and how these may be manipulated to improve the nutritional content of food (Persley *et al*., 2002).

Modern science is an expensive endeavour. In 1998, 22 OECD countries spent more on research and development than the total economic output of the world's 61 poorest countries (the low-income countries, excluding China and India). Investment in science is heavily concentrated in the North.

Agricultural biotechnology: an overview of issues

In 2002, the area planted to transgenic crops was approximately 58 million ha in 16 countries (James, 2002). Four countries (USA, Argentina, Canada and China) accounted for 99% of the area, and the principal GM crops cultivated commercially were soybean, maize, cotton and canola.

Despite all the major private sector investments in agricultural R&D (US$8-10 billion annually, 80% of which is in the USA), public sector agricultural research is still dominant in developing countries where it accounts for more than 60% of agricultural R&D.

The institutional environment has changed: the changing roles of private and public sector research in the North, an explosion in investment levels, heavy concentration of investments in an ever smaller number of multinational corporations (life sciences or seed companies that increasingly dominate the scene), and the growing importance of proprietary science, with IPR regimes being used by companies to protect their investments and maximize returns. These investments are targeted at northern ecologies and crops that are commercially important there.

Biotechnology research also needs to be oriented to crops grown and consumed by the poor, and to their ecologies. New technologies must target the special needs and agro-ecological niches of small farmer production systems of the South. Specifically, such research must address the problems and constraints faced by small farmers by way of abiotic stresses (drought, heat, floods, salinity) and biotic stresses (pests, pathogens).

In the Consultative Group on International Agricultural Research (CGIAR), the United Nations Food and Agriculture Organization (FAO), and elsewhere in the science and development communities, people are keenly conscious of the need to create better links between the world of science and the poor, ensuring that knowledge remains a public good, and modern science is brought to bear on specific problems of poor farmers and consumers.

Developing country experiences

In the food and agricultural sector, there are structural problems in storage, transport, marketing, distribution, and land allocation. For example, many of the best lands in sub-Saharan Africa are committed to cash crops.

The challenge is to provide structural, scientific, and financial support to realize scientific advances of developing and industrial countries. Most importantly, we need changes in attitudes of governments. There needs to be a shift in priorities and increased support for agriculture and agricultural research. The voices of agricultural community are often not organized, not expressed, and so not heard.

North America, Europe and Asia all have had one or multiple “green revolutions” to increase the productivity of agriculture. Africa has had none. We need demand driven biotechnological innovations to create a green revolution in Africa. These innovations must address the needs of the African terrain (e.g. drought resistance) and African crops (cassava, bananas, sweet potatoes).

A particularly interesting example is the work by the Kenyan Agricultural Research Institute (KARI) and CABI Biosciences on bacterial wilt in Kenya. This research makes use of seed plot systems combined with sophisticated scientific discoveries to control disease on potatoes (see Smith *et al.*, Chapter 11, this volume).

Biotechnology that is designed to cater to local needs can help in transition from subsistence farming to entrepreneurial farming. Case studies from several countries in Africa, Asia, South America, the Middle East and North Africa illustrate that science can be very effective in solving well-defined problems, when linked with locally-devised delivery systems (Persley and MacIntyre, 2002).

International experiences

Mobilizing biosciences to address the problems of poverty and hunger cannot be achieved by relying on private sector investments alone. There is a need for additional investments from governments, foundations and international agencies. There is also a need for renewal of key institutions, such as CGIAR, and increased public funding of "public goods" research.

The trend in decreasing support for agriculture by the World Bank at a time when it could and should be leading the application of new technologies to practical purposes in the field is being addressed.

Technology donations alone are not the answer. Developing countries want to partner in the production of new products and ensure that they are adapted to their particular circumstances. Success stories in South Africa and Egypt about the applications of biotechnology suggest that government support can be decisive. Conditions conducive to business development are needed to attract investment. These include political stability, an effective regulatory framework and functioning infrastructure.

New plants for poor people

How do we safely use the advances in molecular technology to create the plants and other products that society needs?

There is an abundance of new information about plants as a result of advances in fundamental research (genomics, proteomics and metabolomics). For example, expressed sequence tags (ESTs) for 120 plant species have been completed or nearly completed. The complete genome sequence for *Arabidopsis* and rice are now publicly available.

The problem is that these advances in fundamental research have not been adequately linked to strategic and applied research; we need to achieve greater synergy between fundamental and applied research; and we need to use this combined research effort to produce the plants that are desperately needed in the developing countries. This synergy is illustrated in the area of plant breeding, where strong plant breeding programs are essential to capture the benefits of the discovery of the structure and functioning of genes through genomics.

There is also a need to have more agricultural "start ups" in the developing world, small companies that help ensure that the results of research are taken through to product development and delivery. This is increasing important as the pubic sector withdraws from areas such as extension services and near market research.

Information is available to create value through input traits (insect, bacteria resistance, drought tolerance) and output traits (greater nutritional or health value, such as increased folate in rice to combat spina bifida), which could lead to the development of new plants targeted at the needs of poor people.

There are encouraging examples of research and innovations such as:

- Research at the World Fish Center in Malaysia has produced knowledge that can be applied to achieve fast growth in fish such as Nile tilapia (see Gardiner *et al.*, Chapter 9, this volume).
- Research into salinity management in mangroves has produced promising results; scientists are now seeking to apply lessons learned from mangroves to plants cultivated in saline and arid conditions.
- TIGR/ILRI collaboration on sequencing *Theileria parva* parasite shows promise towards developing a vaccine to protect cattle against East Coast fever in Africa; and international collaboration on trypanosomiasis (see Murphy *et al*., Chapter 15, this volume).

The bottom line is that there is a need for a network of public institutions and private companies and governmental support for science and technology in developing countries to transform new knowledge into practical realities.

Environmental Issues

Broadly, the first wave of genetically modified crops, which are in commercial use, address production traits; the second wave, which are mainly under development, address quality and nutritional traits; and the third wave address complex stress response traits and novel products able to be produced in plants. The scientific basis for dealing with each of these groups of traits is increasingly complex (Persley *et al.*, 2002).

The production traits targeted in the first wave of transgenic crop varieties specifically addressed the economic and environmental costs of chemical management in large-scale agriculture.

The most widely cultivated transgenic crops in emerging economies are herbicide tolerant soybean in Argentina and insect tolerant cotton in China. The cultivation of Bt cotton in China, by some 5 million small holders is leading to substantial reductions in pesticide use and other economic benefits, which have been documented by Pray *et al.*, (2002).

Risk assessment issues

The issues to be assessed when considering the potential impact of genetically modified plants and other living modified organisms (LMOs) on the environment include:

- Gene flow issues, in terms of frequency and any resulting environmental impacts.
- Any increased risks of plants becoming weeds or invasive species.
- Any potential toxic effects on non-target species.

- Changes in land/water use, or other indirect environmental effects due to changing agricultural practices resulting from the use of new genetic technologies.

Regulatory systems that address food safety and environmental risks of LMOs need to be science-based, transparent, involve community participation and be able to undertake case-by-case assessments of the risks and benefits of particular technologies and novel products (Persley, 2003).

Ethical Issues

In seeking to bring clarity, reason and some perspective to the ethical debate, the following factors are critical for constructive discourse:

- *Respect for all and by all:* There should be trust, consent and truth-telling by all parties, including those of different persuasions as to the risks and benefits of biotechnology.
- *Justice and fairness:* Who is exposed to risks by the introduction of gene technologies? Who benefits most? Who is in control? Is the process fair?
- *Responsibilities:* There is an obligation to preserve the environment, avoid harming others, and accountability should be paramount.
- *Benefits:* There is a responsibility to provide nutrition, clean water, health care, and choice to all by way of new technologies and other means.
- *Faith and ethics* is very much the concern of the faith communities, and future debates should engage more theological inputs.
- *Framing the questions* is important, for example so as to separate matters of uncertainty from those of risk.

Emerging Issues

Policy and institutional issues

More attention is needed to develop the policy and institutional framework necessary to enable science to function safely, effectively, and efficiently. This framework must include:

- Innovative intellectual property regimes that reward both owners of traditional knowledge and discoverers of new inventions.
- An enabling environment to foster local private sector development, since local businesses are essential vehicles for technology development and delivery, in all countries.

- Effective and affordable regulatory regimes for gene technology, and other new technologies. The regulatory environment needs to be designed for the particular environment that it has to work in, taking account of local concerns and current institutional arrangements.

Public–private partnerships

Case studies from developing countries and international experience give some fascinating insights into successful public–private partnerships. These could form the basis for further initiatives, based on the maturation of several examples in Egypt and elsewhere.

The lessons learned over the past decade or more need to be distilled and used as a basis for designing further initiatives to accelerate private–public partnerships. New opportunities should be drawn to the attention of potential investors, public and private.

Investments

Two key elements are necessary for success – people and money:

- *Human resources:* Insufficient attention is being paid to human resource development, at all levels from primary school onwards, to ensure that developing countries have the capacity to access and use new scientific developments to address specific problems.
- *Financial support:* Continuity of financial support is essential for R&D. It is difficult to do successful research if the money tap keeps turning on and off.

The Way Ahead

Foresight: understanding tomorrow's science and technology

The issues of science and society tomorrow may be very different to those that consume our attention today. We need to find ways to show more foresight on the benefits and risks of emerging scientific discoveries, and how to mobilize them more effectively and with a greater sense of urgency in the War on Poverty. Being poor is a terrifying and life-threatening experience itself.

For example, concerns about biosafety and regulation of *interspecific* gene transfers may be overtaken by new discoveries in plant genomics, which suggest that it is the regulation of genes *within* a particular plant species that may provide more effective ways of controlling resistance to diseases and tolerance to environmental stress.

Articulating the problems: health/agriculture/environmental synergies

Experience across the sectors of human and animal health, agriculture and the environment should be better shared. The international health sector has been successful in promoting well-defined initiatives/consortia for tackling specific diseases (HIV/AIDS, TB, malaria), with substantial and innovative private business involvement and investment. The food and agriculture sector with its overriding aim of environmentally sustainable development has been less successful in articulating the needs, and how the pieces of the jigsaw, some of which may be new technologies, will fit together in the environment to improve the livelihoods of poor people. Sharing experience about specific initiatives in the three sectors may assist in developing more effective national and international programmes in the future.

Developing the research agenda to inform choices on health and environmental safety of living modified organisms

The issues of debate on the safety of living modified organisms (LMOs) for human consumption and their risks to the environment need to be investigated with scientific rigour and independence. Research agenda need to be developed to answer the key questions, indeed to say where science can help resolve some of these issues. For example, on the issue of the impact of LMOs on biodiversity:

- What are the researchable issues?
- What ecological experiments need to be done?
- Where should these experiments be done?
- Can commonly agreed principles and methodologies for assessing the impact of specific biotechnology applications on biodiversity be developed and broadly agreed by the scientific community?

Human resources

Human resource issues are critical, especially in relation to the need for institutional and financial support of scientists in their home countries, so that they can do the world-class research of which they are capable. If this is not available, the best and the brightest will move to where they can pursue their scientific careers, and this will often be in the North.

Access to information

Access to information is crucial, and difficult in many ways. There may be an important role here for the Bibliotheca Alexandrina, in real and virtual modes (e.g. facilitating electronic access to scientific journals).

Agenda for Action

Biotechnology is one of an array of development techniques that can help tackle the intertwined problems of hunger, poverty and environmental degradation – but that potential is unrealized and unfulfilled. The obstacles to the effective mobilization of this tool (economic, legal and institutional barriers) can and must be overcome. A new compact between North and South, public and private, international, regional and national, is needed.

Biotechnology has raised many concerns – intellectual property rights, biosafety, ethical, social and environmental. But we must remember that only some of these are amenable to scientific intervention. Others are matters for decision on social and ethical consideration.

The debate has often been misguided, polarized, and has shed more heat than light. More worrisome is the growing anti-science sentiment that runs the risk of preventing the new technologies from reaching the farmers, or giving them the choice as to select those new technologies which meet their needs.

The voices and concerns of these farmers must be heard – poverty is multidimensional: lack of food, assets, technologies, extension services, voice, and, increasingly, knowledge.

New technology must be mobilized for improving the human condition, keeping in view the need for safety, ethics and equity (such as benefit sharing amongst inventors, holders of genetic resources and owners of indigenous knowledge).

Knowledge and partnerships are keys to success – whether in agricultural research, sustainable development, or poverty reduction.

The results of these Alexandria Dialogues, developed with the traditions of independence, scientific rigour, and the values of science, will be widely disseminated to decision makers and to society. These dialogues could become important agenda-setting fora to mobilize additional national and international scientific and financial resources for Science and the Poor.

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