Part 4 The Way Ahead

The Human Genome Project is providing a major impetus to understanding the genetic basis of life. It is, for example, resulting in the early identification of predisposition to genetic diseases, such as cystic fibrosis and breast cancer, leading to earlier detection and better treatments. The applications of modern science are strongest in health care where they offer new hope to patients with AIDS, genetically inherited diseases, diabetes, influenza, and some forms of cancer. Biotechnology-based processes are now used routinely in the production of many new medicines, diagnostics, and medical therapies.

These new developments are underpinning important new international health initiatives, such as the the children's vaccine initiative. This will be the basis of further international health initiatives as new order vaccines and therapeutics are developed. The important initiatives in the health sector, such as the "Roll Back Malaria Campaign," are being sponsored by the World Health Organization, the World Bank, and private foundations. These initiatives are mobilizing expertise and financial resources of governments, international agencies, private foundations, and the pharmaceutical industry. They are expected to lead to major improvements in human health over the next decades.

Modern science offers the potential for similar major contributions to improving food security and nutrition of the poor. However, the large private sector investments in modern bioscience are directed at traits of interest to producers and consumers in industrial countries. The current debate over the value of these new products is also largely dominated by the perspectives of civil society in industrial countries. The potential value of modern science in producing food for the poor will not be realized without major additional efforts involving all stakeholders, including civil society, small-scale farmers, urban consumers, and governments in developing countries.

The need to produce sufficient food for the world's population is urgent, compelling, and complementary to improving human health.

About 73 million people will be added to the world's population every year from now until 2020. Much of this population growth will occur in the cities of the developing world. Meeting world food needs requires increases in production and productivity, and matching these to dietary changes, including the rapidly increasing demands for livestock and fish as sources of protein. Demand for meat in the developing world is projected to double between 1995 and 2020.

World grain production will need to increase by 40 percent by 2020, while the increases in crop yields have been plateauing. Neither meat nor cereals production in the developing world is keeping pace with demand, and imports are increasing (Pinstrup-Andersen, Pandya-Lorch, and Rosegrant 1999).

Under this scenario, food insecurity and malnutrition will persist to 2020 and beyond. The International Food Policy Research Institute predicts that, without significant new developments in increasing productivity, 135 million children under 5 years of age will be malnourished in 2020, a decrease of only 15 percent on 1995. Approximately 77 percent of these children will live in Africa and South Asia.

The most promising approaches to increasing productivity on small-scale farms are agro-ecological approaches, albeit recognizing the potential role of modern biotechnology, and the use of modern information technology and precision farming. It will require the successful integration of these three approaches to achieve the full potential of modern science and ensure the necessary increases in production while conserving the natural resource base.

The initial applications of modern biotechnology to commercial agriculture have resulted in new genetically improved varieties of maize, cotton, rapeseed, soybean, and potato. These were grown on 40 million hectares worldwide in 1999, increasing from 1.5 million hectares in 1996. Fifteen percent of the area is in emerging economies of Argentina, China, Mexico and South Africa. There are also applications to livestock and fish, largely related to the production of more productive strains of commercially important species and the development of useful diagnostics and vaccines.

Several emerging economies are making major investments of human and financial resources in biotechnology with the aim of using these new developments in science to improve food security and reduce poverty. They include Argentina, Brazil, Mexico, China, India, Thailand, Kenya, and South Africa, amongst others (Persley and Lantin 2000).

However. the major research and development efforts of the private sector in biotechnology have been directed at opportunities for introducing traits useful to producers and consumers in the markets in industrial countries. This is where bioscience companies hope to recoup their investments. Initial research and development has concentrated on production traits such as insect resistance. More recent emphasis is on products with improved nutritional qualities.

It is the responsibility of civil society and governments, at the national and international level, to ensure that developing countries consider the benefits and risks of the use of modern science. All stakeholders need to assess the potential benefits and risks of new technologies to reduce food insecurity and poverty. This will require communicating about the role of science in development. It will require also mobilizing the expertise and resources of both the public and private sector nationally and internationally to address the specific problems that damage human health, constrain agricultural productivity and threaten the environment. New approaches that mobilize both public and private resources and involve nongovernmental bodies are needed if poor people are not to be bypassed by the revolutions in science and information technology.

This strategy of using modern science as a component of the overall policy to foster sustainable economic development, reduce inequities, and improve the livelihoods and well being of the poor, will require good governance and political skills and leadership of a high order, and new polices and actions by governments (Persley 1999; www.ifpri.org).

Food for the Poor

To achieve the required productivity increases in crop and livestock production to keep pace with population growth, there is a need for a major global effort on *Food for the Poor*. Its purpose would be:

> *To mobilize the new developments in science and technology to increase the productivity of the world's twelve major food crops, five species of livestock, and fish, that provide 95 percent of the food in the developing world.*

Several actions are urgently required to accomplish this, the most important of which are:

1. *Plant and Animal Genomes*: Ensure that the descriptions of genomes of the agriculturally important species are mapped and that this information is put in the public domain, able to be used by scientists worldwide to generate improved crop varieties and livestock breeds adapted to local ecosystems, and useful biological products. The species are: banana, cassava, maize (corn), groundnut, millets, oil crops, potato, rice, sorghum, soybean, sweet potato, wheat; cattle, sheep, goats, pigs, chickens; and fish species.

2. *Identify Traits for the Poor*: Identify the genes conferring traits that are important to poor producers in marginal environments. It is likely that research will show that some of these are governed by genes that are conserved (shared) across species (for example drought tolerance in cereals). This knowledge would greatly accelerate breeding for these difficult traits, increase the productivity of major food crops and livestock in the tropics, and enhance their ability to be more productive in difficult environments.

3. *Conserve and Characterize Genetic Resources*: Maintain and characterize the farm animal and plant genetic resources of the world's major agricultural species. The largest in vitro collections of plant genetic resources are held in trust for the international community by the CGIAR centers. A recent review commissioned by the CGIAR Technical Advisory Committee suggests that it will require US$70 million to upgrade the present plant collections, and thereafter US$8 million per year to maintain them. Additional investments are required to collect, characterize, and conserve farm animal genetic resources (see FAO 1999). The in vitro and in vivo collections of plant and animal genetic resources, and the biological information pertaining to them, are a vast but underutilized resource for genetic studies and the identification of useful traits.

4. *Access Enabling Technologies*: Obtaining access to key enabling technologies in agricultural biotechnology, many of which are proprietary technologies held by the private sector, is key to the successful applications of biotechnology in the developing world. It will enable the characterization and application of useful genetic information for crop and livestock improvement and the control of the pests, parasites, and pathogens that affect them. The economic concentration of agricultural biotechnology is a real issue that affects the potential beneficial use of new biotechnologies on the problems of poor farmers and consumers in developing countries.

5. *Establish Alliances of the Caring:* A concerted international effort is needed to establish a new compact between the public and private sectors of the industrial and developing countries, so that the new developments in genetics and biotechnology are able to be used more effectively to increase agricultural productivity in a sustainable way. This could, for example, involve a Food for the Poor initiative, whereby a trust fund is created with public and private donations, to conserve and characterize phenotypically and genetically the genetic resources of the world's major agriculture species in perpetuity.

New and nontraditional partnerships amongst public and private sector organizations are needed to make best use of all available resources involving farmers' associations, nongovernmental organizations, governments, and private sector organizations. Some alliances could be formalized into specific research consortia that address specific constraints and are financed to achieve agreed outputs.

6. *Increase Investments in Agriculture*: Significant additional investments by the public and the private sectors are required if agricultural productivity is to increase in the developing world in an environmentally sustainable way.

7. *Provide Incentives for Private Sector Participation*: Incentives are needed to encourage the national and international private sector to address the problems of agriculture in developing countries. These incentives may include improving the enabling environment for agribusiness in developing countries, providing financial incentives for research and development on orphan commodities, and incentives for entrepreneurs to establish bio-based businesses in developing countries, as a source of technology, job creation, and wealth.

8. *Mobilize the Global Scientific Community to Address the Problems of Food for the Poor*: The CGIAR centers presently spend about US$25–35 million each year on agricultural biotechnology, out of a total budget for all the CGIAR centers of US$340 million. These investments are impressive but insufficient by themselves. The CGIAR centers are also the custodians of the world's largest in vitro collections of plant genetic resources. The CGIAR centers and the national agricultural research systems are the repository of a vast array of knowledge of the biology of the world's major food crops, livestock, fish, and tree species, and their associated pests and pathogens. The CGIAR centers operate long-standing crop improvement programs and international testing programs, located throughout the world's major ecosystems. In combination, these scientific, biological, and financial resources are a powerful platform. However, the agricultural research efforts in the developing world now need to be mobilized with the global scientific community in new and imaginative ways, if a quantum leap is to be made in producing food for the poor by 2020.

It is here that the newly created Global Forum for Agricultural Research must be seen as an important new vector for bringing about the necessary collaboration amongst farmers, producer and consumer organizations, public and private companies, nongovernmental organizations, national agricultural research systems, advanced research organizations and international agricultural research institutes, including the CGIAR centers.

9. *Identify Desired Outputs*: Innovations that will be required to contribute to improved food security and to create wealth in the poorer regions of the world include:

- Improved genotypes and better agricultural practices to ensure sustainable increases in productivity of the world's agriculturally important commodities.
- New biological products, such as vaccines, biocontrol agents, and diagnostics, for the control of major endemic diseases of crops and livestock. Illustrative priority species, constraints, and targets on which additional research is urgently needed are shown in Box 7.

Development of these outputs will require marshalling and directing financial and scientific resources in new ways, both nationally and internationally. This will have profound implications for the CGIAR if it is to recognize and respond to these challenges with the appropriate strategy and tactics. Note, however, that whatever research and development work is being advocated on the genetic side must be seen, along with other crop, livestock and fish productivity work, within the context of improved agroecological, socioeconomic and gender-sensitive approaches.

10. *Challenge to the CGIAR:* The CGIAR has a challenge to invest in and mobilize the necessary human, financial, and bio-

Box 7 Illustrative examples of some priority constraints able to be addressed through biotechnology

Commodity	*Constraint*	*Regions*
Crops		
Banana/plantain	Black Sigatoka disease	Global
Cassava	Cassava mosaic virus	Africa
Maize	Apomixis (all cereals)	Global
	Quality protein maize	
	Drought	l
Millets	Blast resistance	Africa/South Asia
	Photoperiod response	Global
Sorghum	Drought, heat tolerance	Africa/South Asia
Rice	Blast, submergence	Global
	Vitamin A content	
	Yield potential	
Wheat	Heat tolerance	Africa/Asia
	Drought/salinity tolerance	
Livestock		
Cattle	Trypanosomosis	Global
	East coast fever	Africa
Sheep	Heat tolerance, helminths	Global
Goats	Helminths	Global
Chicken	Newcastle virus	Global
Pigs	Viral diseases	Global

logical resources to address the production and sustainability problems of agriculture in new and exciting ways. This will require the CGIAR to:

- Invest more, and with a greater sense of urgency, in science to solve problems, marshalling the new in-depth understanding of the agroecological issues with the new opportunities of modern genetics and biotechnology
- Build on traditional strengths in breeding, biology, and genetic resources
- Analyze, interpret, and make more accessible its wealth of biological data, using new tools in biotechnology and information technology
- Access new skills in the global scientific community to achieve new goals
- Form new strategic (in addition to project-specific) alliances to achieve common objectives
- Create more flexible and innovative institutional arrangements that cut across traditional Center boundaries
- Provide financial incentives for innovation and reward success.

Epilogue

Prometheus changed the world forever when he unleashed the forces of innovation and creativity. The Promethean scholars of today seek to use the new discoveries in molecular biology and genetics to understand and protect the natural world and to improve the productivity of agricultural systems. These developments are being driven by the scientific and industrial wealth of the industrial world. It is here that the early benefits of biotechnology are accruing. It is also where the debate as to the wisdom of using modern biotechnology at all is fiercest.

Modern biotechnology offers promise to increase the productivity of the agriculturally important species in developing countries. However this is unlikely to happen in time if present trends continue. The development of relevant and appropriately fine-tuned applications in developing countries will be hampered by a lack of access to the necessary scientific and financial resources. This means that the potential of the human and natural resources of the developing countries will not be fully realized and the world will be a poorer place.

The present economic concentration of investment, science, and infrastructure in industrial countries and the lack of access to the resulting technologies are major impediments to the successful applications of modern biotechnology to the global problems of the Age, namely the need to guarantee food security to all people and to create wealth for the presently poor people and countries.

Creativity in finding solutions to these policy and institutional impediments to innovation are as important and challenging as new scientific discoveries, if the promises of Promethean science are to be realized. Even more, the ability to link the findings and techniques of the new biological and genetic sciences within a framework that respects the agro-ecology of smallholder farming systems, and integrating all of that with the wisdom of the farmers themselves is the key to where a better future for all lies.