Biotechnology and Food Security

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Preface

Food security consists of three major components: availability (associated with production and trade); accessibility (associated with income and wealth); and utilization (associated with health and nutrition) (Asenso-Okyere, Benneh and Tims, 1997). While there seems to be a consensus among analysts that current global food production is adequate to avoid widespread famine and malnutrition, the overall positive trends disguise the disparities in production and distribution of food between regions. The disparities are described by Rosegrant, Agcaoili-Sombilla and Perez (1995) as a two-tiered system of food security, in which rich and rapidly growing economies enjoy abundant, affordable food supplies, while poor, slow-growing countries suffer from food scarcity and malnutrition. This means that the food security problem is, in the main, not one of shortage but of imbalance and distribution.

Another aspect of food security is sustainability. The concerns are: "can food production continue to keep up with demand in generations to come?" and "is the prosperity of the current generation at the expense of the future?" Some analysts believe that the rapid growth in agricultural production in the last few decades has occurred at great environmental cost (Anderson, 1994). That is, over-exploitation has resulted in natural resources being depleted and the environment being damaged. Indeed, the greater intensity of use of land and water resources and chemicals has created problems such as soil salinization, soil erosion, water pollution, pest resistance, etc. As a result, there are signs of declining rates of growth in yields. For example, it has been shown that the average annual growth rate of paddy rice yield in the world declined from 2.42 percent in 1974-82 to 1.78 percent in 1982-90. The corresponding figures were 2.62 and 1.66 percent for Asia and 4 and 1.6 percent for China. Similar results were found for other crops, including wheat, maize, sorghum and other coarse grains.

Similarly, externalities from agricultural production, and related environmental or "green" issues such as climate change, preservation

of wilderness areas and biodiversity, animal welfare and food safety, have received increasing attention in the discussion of agricultural policy in recent years. These concerns suggest that sustainable food security is not only about meeting the increasing and changing demand for food now, but about protecting the environment for future generations. Whether and how this is to be achieved depends on a number of economic, social and political factors, both at the national and international levels. Socioeconomic factors with potentially significant effects on future developments in the world food situation include: population and income growth, demographic changes and urbanization on the demand side, as well as technological change and productivity growth on the supply side. Therefore, future agricultural production and productivity growth depend on, among others, a combination of agricultural, environmental, trade and macroeconomic policies at the global level.

Although food security issues are multi-faceted, the discussion here focuses on food availability and production in Asia and the Pacific as a first step towards resolving such issues. Particular attention is paid to the role of investment and agricultural productivity in meeting the challenge of sustainable food security.

The present book has been designed to outline the basic and fundamental aspects of biotechnology to be understood in its right perspective.

—Editor

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Industrial Biotechnology

Industrial biotechnology (known mainly in Europe as white biotechnology) is the application of biotechnology for industrial purposes, including manufacturing, alternative energy (or "bioenergy"), and biomaterials. It includes the practice of using cells or components of cells like enzymes to generate industrially useful products. *The Economist* speculated (as cited in the *Economist* article listed in the "References" section) industrial biotechnology might significantly impact the chemical industry. *The Economist* also suggested it can enable economies to become less dependent on fossil fuels.

The industrial biotechnology community generally accepts an informal divide between industrial and pharmaceutical biotechnology. An example would be that of companies growing fungus to produce antibiotics, e.g. penicillin from the penicillium fungi. One view holds that this is industrial production; the other viewpoint is that it would not strictly lie within the domain of pure industrial production, given its inclusion within medical biotechnology.

This may be better understood by calling to mind the classification by the U.S. biotechnology lobby group, Biotechnology Industry Organization (BIO) of three "waves" of biotechnology. The first wave, Green Biotechnology, refers to agricultural biotechnology. The second wave, Red Biotechnology, refers to pharmaceutical and medical biotechnology. The third wave, White Biotechnology, refers to industrial biotechnology. In actuality, each of the waves may overlap each of the others. Industrial biotechnology, particularly the development of large-scale bioenergy refineries, will likely involve dedicated genetically modified crops as well as the large-scale bioprocessing and fermentation as is used in some pharmaceutical production.

Industrial Biotechnology and Climate Change

Climate change effects on the developing country populations and its relation to industrial biotechnology present an opportunity of setting a foundation for a transition to and industrial economy via mitigation options set about in the Kyoto protocol. The relationship between industrial biotechnology and climate change cuts across three major spheres of climate change science and policy: impacts, mitigation, and adaptation. The impacts of a changing climate on agriculture and land use will affect the availability of biomass as well as food production. Developing country populations will suffer disproportionately, especially since some of the regions that may be most negatively affected are located in small island states and in already impoverished areas of sub-Saharan Africa. With respect to mitigation, the expansion of industrial biotechnology can offer new opportunities for fossil fuel substitution and carbon sequestration. If genetic modification is employed, the linkages to both mitigation and adaptation would be even more direct. A given crop might be adjusted so as to yield better characteristics for energy production (e.g. more fibre, faster growth, less lignin). With respect to adaptation, varieties might be developed that require less water or are otherwise more suited to the new climate. Biomass and industrial biotechnology can address GHG emissions while at the same time providing a more sustainable foundation for the developing world's transition from an agrarian to an industrial economy.

Novel implementation platforms and identification of existing technologies that are under-utilised or inefficiently utilised will generally be preferred to developing new technologies, particularly in smaller and/or poorer developing countries.

The following options could be considered:

- Improving the efficiency of biomass to energy conversion (e.g. advanced cogeneration, biomass gasification)
- Creating biomass resource options from agricultural or process wastes
- Use of agricultural or process wastes as inputs to industrial processes
- Substitution for products made from fossil sources (e.g. fertilisers, bio-plastics).

The above options tend to have medium-to-large economies-of-scale. Alternatively, in the context of poverty reduction in rural areas,

there may be a preference for options aimed at expanding energy services (e.g. biogas for cooking) and/or creating income-generating opportunities (e.g. small-scale agro-industrial plants). At the same time, smaller-scale options with many end-users require more effort for replication and dissemination, and thus entail higher transaction costs. Detailed analysis of impacts, adaptation, and enhanced sequestration are quite complicated and beyond the scope of this report. Mitigation options through the Kyoto mechanisms (Emissions Trading, Joint Implementation, and CDM) are of greatest near-term interest, not only because of the opportunities to obtain financial support, but also because expanded platforms for industrial biotechnology can address long-term sustainable development goals at the same time that they offer greenhouse gas (GHG) emission reductions.

Since only Annex 1 parties have Kyoto obligations, Emissions Trading and JI are only indirectly related to developing country crediting via the linkages from GHG credits that are generated.

Industrial or white biotechnology uses enzymes and micro-organisms to make bio-based products in sectors such as chemicals, food and feed, detergents, paper and pulp, textiles and bioenergy (such as biofuels or biogas). In doing so, biotechnology uses renewable raw materials and is one of the most promising, innovative approaches towards lowering greenhouse gas emissions.

The application of industrial biotechnology has been proven to make quite significant contributions towards mitigating the impacts of climate change in these and other sectors. In addition to environmental benefits, biotechnology can improve industry performance and product value and, as the technology develops and matures, white biotechnology will yield more viable solutions for our environment. These innovative solutions bring added benefits for both our climate and our economy.

Industrial biotechnology is based on renewable resources, can save energy in production processes, and can significantly reduce CO_2 emissions. The impact that biotechnology has on industry is confirmed by scientific studies and reports, such as the OECD's report on the application of biotechnology to industrial sustainability and, most recently, by the World Wide Fund for Nature (WWF) report on the potential of industrial biotechnology to cut CO_2 emissions and help build a greener economy.

The WWF report concludes that the full climate change mitigation potential of biotechnology processes and bio-based products ranges from between one billion and 2.5 billion tons CO_2 equivalent per year by 2030. This represents more than Germany's total reported emissions in 1990. Many low-carbon technologies are already available, and future innovations offer greater potential. Forward-thinking companies have already discovered the potential of biotechnology to cut greenhouse gas emissions. However, in order to fully realise the potential of biotechnology it will be critical that international policy creates a fully supportive biotechnology legislative framework.

Pharmacogenomics

Pharmacogenomics is the branch of pharmacology which deals with the influence of genetic variation on drug response in patients by correlating gene expression or single-nucleotide polymorphisms with a drug's efficacy or toxicity. By doing so, pharmacogenomics aims to develop rational means to optimise drug therapy, with respect to the patients' genotype, to ensure maximum efficacy with minimal adverse effects. Such approaches promise the advent of "personalized medicine"; in which drugs and drug combinations are optimized for each individual's unique genetic makeup.

Pharmacogenomics is the whole genome application of pharmacogenetics, which examines the single gene interactions with drugs. Pharmacogenomics is being used for all critical illnesses like cancer, cardio vascular disorders, HIV, tuberculosis, asthma, and diabetes.

In cancer treatment, pharmacogenomics tests are used to identify which patient will have toxicity from commonly used cancer drugs and identify which patient will not respond to commonly used cancer drug. Over the last couple of years, pharmacogenomics is also known as companion diagnostics, meaning tests being bundled with drugs. Two good examples are K-ras test with cituximab and EGFR test with Gefitinib.

In cardio vascular disorders, the main concern is response to drugs including warfarin, clopidogrel, beta blockers, and statins.

Pharmaceutical Products

Most traditional pharmaceutical drugs are relatively simple molecules that have been found primarily through trial and error to treat the symptoms of a disease or illness. Biopharmaceuticals are

large biological molecules known as proteins and these usually target the underlying mechanisms and pathways of a malady (but not always, as is the case with using insulin to treat type 1 diabetes mellitus, as that treatment merely addresses the symptoms of the disease, not the underlying cause which is autoimmunity); it is a relatively young industry. They can deal with targets in humans that may not be accessible with traditional medicines. A patient typically is dosed with a small molecule *via* a tablet while a large molecule is typically injected.

Small molecules are manufactured by chemistry but larger molecules are created by living cells such as those found in the human body: for example, bacteria cells, yeast cells, animal or plant cells.

Modern biotechnology is often associated with the use of genetically altered microorganisms such as *E. coli* or yeast for the production of substances like synthetic insulin or antibiotics. It can also refer to transgenic animals or transgenic plants, such as Bt corn. Genetically altered mammalian cells, such as Chinese Hamster Ovary (CHO) cells, are also used to manufacture certain pharmaceuticals.

Another promising new biotechnology application is the development of plant-made pharmaceuticals. Biotechnology is also commonly associated with landmark breakthroughs in new medical therapies to treat hepatitis B, hepatitis C, cancers, arthritis, haemophilia, bone fractures, multiple sclerosis, and cardiovascular disorders. The biotechnology industry has also been instrumental in developing molecular diagnostic devices that can be used to define the target patient population for a given biopharmaceutical. Herceptin, for example, was the first drug approved for use with a matching diagnostic test and is used to treat breast cancer in women whose cancer cells express the protein HER2.

Modern biotechnology can be used to manufacture existing medicines relatively easily and cheaply. The first genetically engineered products were medicines designed to treat human diseases. To cite one example, in 1978 Genentech developed synthetic humanized insulin by joining its gene with a plasmid vector inserted into the bacterium *Escherichia coli*. Insulin, widely used for the treatment of diabetes, was previously extracted from the pancreas of abattoir animals (cattle and/or pigs).

The resulting genetically engineered bacterium enabled the production of vast quantities of synthetic human insulin at relatively low cost. According to a 2003 study undertaken by the International

Diabetes Federation (IDF) on the access to and availability of insulin in its member countries, synthetic 'human' insulin is considerably more expensive in most countries where both synthetic 'human' and animal insulin are commercially available: e.g. within European countries the average price of synthetic 'human' insulin was twice as high as the price of pork insulin. Yet in its position statement, the IDF writes that "there is no overwhelming evidence to prefer one species of insulin over another" and "[modern, highly purified] animal insulins remain a perfectly acceptable alternative.

Modern biotechnology has evolved, making it possible to produce more easily and relatively cheaply human growth hormone, clotting factors for hemophiliacs, fertility drugs, erythropoietin and other drugs. Most drugs today are based on about 500 molecular targets. Genomic knowledge of the genes involved in diseases, disease pathways, and drug-response sites are expected to lead to the discovery of thousands more new targets.

Genetic Testing

Genetic Testing : Gene tests (also called DNA-based tests), the newest and most sophisticated of the techniques used to test for genetic disorders, involve direct examination of the DNA molecule itself. Other genetic tests include biochemical tests for such gene products as enzymes and other proteins and for microscopic examination of stained or fluorescent chromosomes. Genetic tests are used for several reasons, including:

- carrier screening, which involves identifying unaffected individuals who carry one copy of a gene for a disease that requires two copies for the disease to be expressed
- preimplantation genetic diagnosis
- prenatal diagnostic testing
- newborn screening
- presymptomatic testing for predicting adult-onset disorders such as Huntington's disease
- presymptomatic testing for estimating the risk of developing adult-onset cancers and Alzheimer's disease
- confirmational diagnosis of a symptomatic individual
- forensic/identity testing.

Genetic testing allows the genetic diagnosis of vulnerabilities to inherited diseases, and can also be used to determine a child's paternity

(genetic father) or a person's ancestry. Normally, every person carries two copies of every gene (with the exception of genes related to sex-linked traits, which are only inherited from the mother by males), one inherited from their mother, one inherited from their father.

The human genome is believed to contain around 20,000 - 25,000 genes. In addition to studying chromosomes to the level of individual genes, genetic testing in a broader sense includes biochemical tests for the possible presence of genetic diseases, or mutant forms of genes associated with increased risk of developing genetic disorders.

Genetic testing identifies changes in chromosomes, genes, or proteins. Most of the time, testing is used to find changes that are associated with inherited disorders. The results of a genetic test can confirm or rule out a suspected genetic condition or help determine a person's chance of developing or passing on a genetic disorder. Several hundred genetic tests are currently in use, and more are being developed.

Since genetic testing may open up ethical or psychological problems, genetic testing is often accompanied by genetic counselling.

Types

Genetic testing is "the analysis of, chromosomes (DNA), proteins, and certain metabolites in order to detect heritable disease-related genotypes, mutations, phenotypes, or karyotypes for clinical purposes." It can provide information about a person's genes and chromosomes throughout life. Available types of testing include:

- *Newborn Screening:* Newborn screening is used just after birth to identify genetic disorders that can be treated early in life. The routine testing of infants for certain disorders is the most widespread use of genetic testing—millions of babies are tested each year in the United States. All states currently test infants for phenylketonuria (a genetic disorder that causes mental illness if left untreated) and congenital hypothyroidism (a disorder of the thyroid gland).
- *Diagnostic Testing:* Diagnostic testing is used to diagnose or rule out a specific genetic or chromosomal condition. In many cases, genetic testing is used to confirm a diagnosis when a particular condition is suspected based on physical mutations and symptoms. Diagnostic testing can be performed at any time during a person's life, but is not available for all genes

or all genetic conditions. The results of a diagnostic test can influence a person's choices about health care and the management of the disease.

- *Carrier Testing:* Carrier testing is used to identify people who carry one copy of a gene mutation that, when present in two copies, causes a genetic disorder. This type of testing is offered to individuals who have a family history of a genetic disorder and to people in ethnic groups with an increased risk of specific genetic conditions. If both parents are tested, the test can provide information about a couple's risk of having a child with a genetic condition.
- *Prenatal Testing:* Prenatal testing is used to detect changes in a fetus's genes or chromosomes before birth. This type of testing is offered to couples with an increased risk of having a baby with a genetic or chromosomal disorder. In some cases, prenatal testing can lessen a couple's uncertainty or help them decide whether to abort the pregnancy. It cannot identify all possible inherited disorders and birth defects, however.
- *Preimplantation Genetic Diagnosis:* Genetic testing procedures that are performed on human embryos prior to the implantation as part of an in vitro fertilization procedure.
- *Predictive and Presymptomatic Testing:* Predictive and presymptomatic types of testing are used to detect gene mutations associated with disorders that appear after birth, often later in life. These tests can be helpful to people who have a family member with a genetic disorder, but who have no features of the disorder themselves at the time of testing. Predictive testing can identify mutations that increase a person's chances of developing disorders with a genetic basis, such as certain types of cancer. For example, an individual with a mutation in *BRCA1* has a 65% cumulative risk of breast cancer. Presymptomatic testing can determine whether a person will develop a genetic disorder, such as hemochromatosis (an iron overload disorder), before any signs or symptoms appear. The results of predictive and presymptomatic testing can provide information about a person's risk of developing a specific disorder and help with making decisions about medical care.
- *Forensic Testing:* Forensic testing uses DNA sequences to identify an individual for legal purposes. Unlike the tests described above, forensic testing is not used to detect gene

mutations associated with disease. This type of testing can identify crime or catastrophe victims, rule out or implicate a crime suspect, or establish biological relationships between people (for example, paternity).

- *Parental Testing:* This type of genetic test uses special DNA markers to identify the same or similar inheritance patterns between related individuals. Based on the fact that we all inherit half of our DNA from the father, and half from the mother, DNA scientists test individuals to find the match of DNA sequences at some highly differential markers to draw the conclusion of relatedness.
- *Research Testing:* Research testing includes finding unknown genes, learning how genes work and advancing our understanding of genetic conditions. The results of testing done as part of a research study are usually not available to patients or their healthcare providers.
- *Pharmacogenomics:* Type of genetic testing that determines the influence of genetic variation on drug response.

Medical Procedure

Genetic testing is often done as part of a genetic consultation and as of mid-2008 there were more than 1,200 clinically applicable genetic tests available. Once a person decides to proceed with genetic testing, a medical geneticist, genetic counsellor, primary care doctor, or specialist can order the test after obtaining informed consent. Genetic tests are performed on a sample of blood, hair, skin, amniotic fluid (the fluid that surrounds a fetus during pregnancy), or other tissue. For example, a medical procedure called a buccal smear uses a small brush or cotton swab to collect a sample of cells from the inside surface of the cheek.

Alternatively, a small amount of saline mouthwash may be swished in the mouth to collect the cells. The sample is sent to a laboratory where technicians look for specific changes in chromosomes, DNA, or proteins, depending on the suspected disorder. The laboratory reports the test results in writing to a person's doctor or genetic counsellor. Routine newborn screening tests are done on a small blood sample obtained by pricking the baby's heel with a lancet.

Interpreting Results

The results of genetic tests are not always straightforward, which often makes them challenging to interpret and explain. When