HUNGER, SCIENCE, AND PUBLIC POLICY

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I. Introduction

Food touches everyone's daily life. Around the world some six billion people eat: usually regularly and often enjoyably. Food, an ineluctable element of life, has increasingly become a secure, unproblematic resource in human existence. At the end of the 20th century, however, millions remained hungry. Although these "hungry" persons represent a declining portion of the earth's population, their plight seems all the more dramatic when contrasted to the broader picture of a successful reduction of hunger and increased per capita food supplies during the last 100 years. Indeed this success has occurred, paradoxically, as the smallest portion of the world's population in the history of civilization is engaged in food production. Moreover, increased supplies have occurred under different policy thrusts—beginning as national government controls over farming and marketing greatly expanded during the first half of the 20th century, yet continuing also in the last ten years as government efforts to insure the stability and adequacy of food supplies have waned.

With the supply problem solved, hunger is an unnecessary scourge in the 21st century. Why should one of six people in the world, mostly in poor, developing countries, not get enough food to sustain a healthy life? Why do governments tolerate the results: high infant mortality, increased rates of illness, less energy, and lowered productivity? Hunger harms individuals, families, and the economy of countries around the world. And it denies individuals basic opportunities to appreciate simple pleasures of life, such as a beautiful sunset or a stroll with friends. Hunger remains, therefore, a major international public policy problem in spite of advances in science and technology that makes its elimination possible. Since a food shortage panic in 1970-1974, we have dramatically expanded our ability to harvest plentiful supplies of food, to distribute these quickly, and to identify where hunger exists or is impending. Indeed, our capacities in food production, distribution, and the identification of emerging needs for food have all improved from a century ago. In that era, when natural disasters and civil strife occurred, millions died in famines. Today, we can prevent such calamities, at least in principle.[1] Furthermore, we have the capacity to eliminate chronic under nutrition, the condition when people fail to get enough food to stay healthy. Some countries, such as China and Chile, did just that in the 1970-80s.

[1] A review of famines in Foster and Leathers (1999, pp. 2-6) documents the millions killed in the last century and the decline and elimination of this in the last fifty years. Exceptions are the times when perhaps a million died in Bangladesh in 1974 in a policy related famine (Sen, 1981) and an estimated two million who died in North Korea in the mid-1990s, due almost entirely to government policies that obfuscated the problem so that the government only turned very late to accepting international aid (Natsios, 2001).

We may ask: why should American college students, often bombarded with opportunities to eat, and more likely to suffer from bulimia or anorexia than the effects of kwashiorkor,[2] take note of this problem? Indeed, how can people in an academic setting even empathize with those experiencing undernourishment? Some students in colleges and universities have tried to relate to the issue of hunger, both locally and internationally. Organizations on campuses have raised funds for NGOs that fight hunger, such as Oxfam; others have participated in actions such as a "Fast for Hunger" day, not eating for a day and donating the money saved to an anti-hunger cause. Of course, the effects of not eating for a few days on energy, thinking, and health are outside the experience of most youth in college, even those in developing countries. Before suggesting students or others change their diets, either to gain insight or to save food for others (an idea seldom recommended anymore), we should explore how hunger operates in today's world, why it affects the life opportunities of virtually everyone, and how knowing more about hunger might affect our civic choices in support of various research and policy options.

The next section of this essay explores several topics to help the reader understand better why hunger persists in a world where food is abundant. First, hunger is defined, differentiating it from other food-related problems such as overeating, illnesses that interrupt digestion/use of food, and micro-nutrient deficiencies. These other problems, while important, point to different research and policy needs. For this paper the focus is principally on hunger or under nutrition in developing countries, while recognizing that its occurrence and sinister (primary and secondary) effects occur in virtually all countries. Indeed, even the US, the world's largest exporter of food, has been estimated to have 33 million of its population facing "food insecurity"—some of this number will be absolutely affected to the point of loss of life skills.[3] Second, the fundamental causes of hunger are reviewed. Next, the economic problem of an absence of entitlements to insure access to food is explored. This occurs as a "market failure" when depicted in economic terms. Overcoming this failure by public action takes us into a number of issues for which knowledge and research in the natural sciences are required. The section closes with a review of a wide array of links between hunger and science.

Sections III and IV provide more detailed discussions of just two of the areas—"cases"—where thinking about and developing public policies hunger require the "help" that

[2] Kwashiorkor is a tragic form of hunger that afflicts young children after they have been weaned and are unable to get enough nourishment from an "adult" food diet.
[3] The USDA has done a number of studies on U.S. food insecurity—based on surveys of when and how much people eat, finding it rises with unemployment and lack of access to programs such as food stamps (USDA, 2000). An estimate in the New York Times, February 23, 2003 contained the estimate of 33 million, noting how advocates of food stamps and food lunch programs were losing a battle to keep these tools of hunger prevention (NYT, p.4-4, 2003).

understandings of mathematics and science offer. These two case examples are meant to awaken interest in and appreciation of the ways in which the global problem of hunger depends upon science to provide tools and techniques that will break down existing barriers to its solution. Section III of this paper takes up the challenge of measuring who is hungry. This involves substantial mathematics and economics. Section IV engages biotechnology. New seeds, engineered using gene splicing techniques discovered by science, are thought to hold great promise in assisting poor, underfed farmers and countries to expand their food production (Conway, 1998; Paarlberg, 2001). Why have these genetic modifications not been universally endorsed?

In section V, I posit that science can serve hunger reduction only if policies are in place to fund what is needed from science, and to protect us from harm that science applied haphazardly or without appropriate safeguards, can bring. I discuss two principal reasons that justify society's providing the resources and attention needed to produce such policies. Why should we do the research, make the investments, and adopt the regulations that will help protect producer and consumer alike? I will argue that we should produce these policies because it is in the economic and the moral interest of virtually everyone to reduce hunger. Then, in the last section, I will suggest a few steps that would reduce the gap between what is possible and what now exists. Hunger reduction, I conclude, is a task in which science can and should play a powerful role.

II. The Hunger Problem

<u>Defining Hunger</u>

Hunger is a shortage of basic nutrients, calories, and proteins sufficient to lead a normal life. Many definitions exist as to where hunger begins, or how deficient in food a person must be to deserve to be labeled "food insecure."[4] These result in a variety of estimates of how many people are affected and how seriously. Hunger occurs when people feel the effect of being short of food. And food is essential to life. This problem is not the same as malnutrition, an even

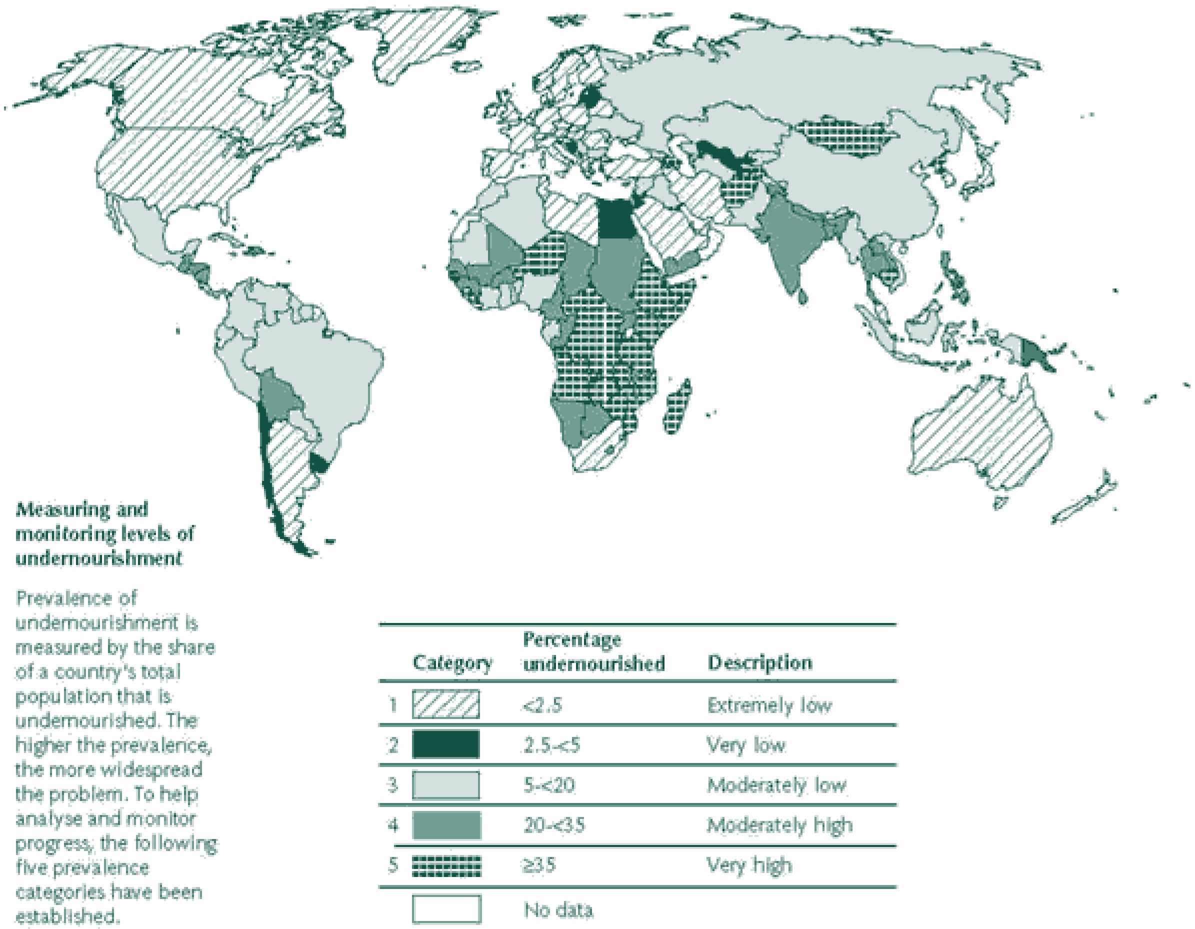
[4] Food insecurity is a term developed after the food crisis of 1974 to describe those who were vulnerable to hunger, either because they were not able to eat enough, or were facing that prospect. Usually people refer to these as either "chronic insecurity"—regularly eating too little to be healthy—or "acute insecurity"—eating so little that death will result shortly. Acute problems generate emergency responses, getting the most attention by the world's media, but only constitute the most visible and dramatic portion of the problem, much as the tip of an iceberg is a fraction of frozen water one sees. Famine actually grows from populations already vulnerable to or experiencing "chronic food insecurity" (or under nutrition).

broader term that includes people who overeat and hence are harmed by excessive weight, and people with micronutrient deficiencies (and suffer special problems, such as goiter).

As mentioned, estimates of who is hungry vary, as do arguments about the consequences of hunger. According to the UN's Food and Agriculture Organization (FAO) June 2002's mid-summit meeting, roughly 790 million were considered hungry in "developing countries" or LDCs. The FAO has provided data that allows estimates of hunger for the map depicted in Figure 1, which displays countries of the world according to how seriously affected by undernourishment each nation is.

FIGURE 1

The prevalence of undernourishment in the world



Source: FAO, 2002. Data is derived from averages of years 1997-1999.

There is much evidence that food security has not improved in the last few years.[5] Thus, to the FAO estimates for LDC [in 1997-1999], I would add another 75 to 120 million who are substantially undernourished in transition countries such as CIS (Russia and other former states of the USSR) and East European states, and in wealthy countries of the Organization for Economic Cooperation and Development (OECD), that includes the US, Europe, and Japan. The FAO has lower estimates for these areas than I suggest here and does not report estimates for OECD. So we should add to the FAO estimate of nearly 800 million as hungry in LDCs, those affected by hunger in other countries, the increases in LDC food insecurity (owing to growing unemployment), and a rise in near-famines (post 9/11) in Afghanistan, Southern

[5] According to recent studies by the International Food Policy Research Institute, the decline in hunger has slowed or reversed in many LDCs, especially in Africa, while new estimates among OECD states suggest growing numbers of "hungry" people, especially among migrants and chronically poor populations (IFPRI, 2003; USDA, 2003)

Africa, and Ethiopia. In 2003, a third of the population in some of these countries face starvation without food assistance from external donors. A reasonable estimate for world hunger, then, is that one billion—or one of every six—people on the earth faces hunger.[6] As we will see later, however, by changing an assumption or two, this number can be doubled or halved.

So we can have two pictures. In the one we just reviewed, a billion people are affected. : In another one, trends in portions of the world's populace who face hunger are favorable. As Table 1 indicates, the projections are for fewer people and a much smaller proportion of most regions' populations to be food insecure or hungry (i.e., estimated to be receiving twenty percent or fewer calories per day than the minimum level of needed caloric intake).

In either case the question remains: why should hunger still be such a problem for so many people and societies, given the capacity of modern technology and transport to feed everyone easily? Moreover, and deeply troubling, in the face of overall trends that seem favorable, why should hunger problems be growing in Africa and parts of South Asia?

Table 1: *Chronic under nutrition in developing regions of the world, 1969-2010. Estimates and projections in millions of persons (percentage of total population in parenthesis).*

	1969-71	1979-81	1990-92	2010 – projected
Sub-Saharan Africa	103 (38%)	148 (41%)	215 (43%)	164 (30%)
East Asia and Southeast Asia	476 (41%)	379 (27%)	269 (16%)	123 (6%)
South Asia	238 (33%)	303 (34%)	255 (22%)	200 (12%)
Other Developing Regions	101 (22%)	75 (13%)	101 (14%)	93 (9%)
Developing Regions Total	918 (35%)	906 (28%)	839 (21%)	680 (12%)

We can begin to answer these questions most satisfactorily by looking at the major trends in how (and where) the world has achieved increased food production and consumption. For this growth to have occurred in the face of expanding population and deterioration in environmental and water resources must deepen our appreciation of the power of technical innovation. Not only is the world food-abundant for the first time in history, but it is also largely free of famine. Where famine has occurred (that is where people have died directly or indirectly as a result of

[6] This number should be compared with the FAO estimates for 1998-2000 of 790 undernourished in developing countries, 11 million in "industrialized countries," and 30 million in "transitional" ones [FAO, 2002A].

lack of food), the causes can be traced to factors other than inadequate food production. In the 1990s and since, famine has been the product of internal war and civil strife and/or corruption and bad government policies. While weather aberrations can make things worse in some cases, it was "human-made" disasters that created the food shortages in the last decade in Liberia, Mozambique, North Korea, and Central America. In most cases, emergency humanitarian assistance responded to avert the worst elements of disaster. Floods in Bangladesh and Central America in 1998, for example, which undercut local food production, led to dramatic inflows of food and other rescue/recovery resources sent by the international community. Shocks to production and economic well-being in Indonesia in 1997-98 were quickly counterbalanced by loans for importing substantial amounts of rice. All these rescue efforts, however, did nothing to reach the poor in many countries. Poor rural dwellers in the US, Brazil, and India still suffer the consequences of hunger and still await some solution.

TABLE 2

Per capita dietary energy supply

Region	**1969-71**	**1979-81**	**1990-92**	**1996-98**	**1997-99**
	(kcal per day)				
WORLD	**2 410**	**2 540**	**2 700**	**2 780**	**2 800**
Developed countries	**3 130**	**3 220**	**3 270**	**3 240**	**3 230**
Transition economies	**3 320**	**3 390**	**3 160**	**2 890**	**2 910**
Developing countries	**2 110**	**2 300**	**2 520**	**2 650**	**2 680**
Latin America and the Caribbean	2 470	2 700	2 710	2 810	2 820
Near East and North Africa	2 360	2 820	2 980	2 970	3 010
Sub-Saharan Africa	2 100	2 070	2 120	2 200	2 190
East and Southeast Asia	2 010	2 320	2 640	2 850	2 920
South Asia	2 060	2 070	2 310	2 420	2 400

Source: FAO.

Achieving food security means ensuring that sufficient food is available, that supplies are relatively stable, and that those in need of food can obtain it. Over the years, governments, with support from FAO, the World Food Programme (WFP) and other development agencies, have addressed food security and its related elements in many ways. The coming challenge is enormous, however. With the world's population continuing to grow—about two billion more people are expected by the year 2025—the unconscionable gap between those who are hungry and those who are not will worsen unless very determined and well-targeted actions are taken to improve food security (FAO, 2002A).

<u>What causes hunger?</u>

Hunger has many causes and consequences—ones that challenge us to understand the dynamics of human food systems and to devise strategies to alleviate hunger. Answers advanced by scientific work have been invaluable in developing better options for farmers and more effective policies for governments. Considerable debate exists, however, as to what kind and how much science should be used in coming years. Food production and consumption patterns have altered considerably with new technology and urbanization. These developments have spurred opposition to "food technology" by advocates of more natural or organic foods, and opponents of large, industrialized farm and processing operations.

Production strategies have become controversial. Answers about whether to help people grow more food or to better insure transfers of the food that is now produced are not simple. Moreover, the answers vary by context and the presumed cause(s) of the hunger. Hunger reduction requires a variety of context-specific changes in production, marketing, and distribution policies. Research by a number of agencies, national and international, including IFPRI, the World Bank and the FAO affirms this point.

Complicating efforts to address hunger is the shift in the last decade whereby hunger has become conflated with poverty. Hence, some see hunger reduction as concurrent with the poverty reduction. . In short, the belief is that poverty alleviation is the principal task and the best path to reduce hunger. This a dominant view expressed in the strategies of the World Bank and OECD countries expressed in their goals to reduce poverty by half between 1995 and 2015. However, the work and policies to address hunger that will actually help produce more food, or will get the food to those in need, requires more than market-based or poverty-eliminating employment schemes. Poverty reducing strategies such as micro-financing, export-led growth, targeted training and employment schemes *will* assist the poor acquire food, especially in urban areas.. They *will not*, however, directly attack the "market failure" that hunger entails.

<u>Why is hunger a global "bad," reflecting what economists call a market failure</u>?

Those who regularly eat Big Macs or sushi may query what burden they face from the other people's hunger. Harm from hunger refers in the first instance to bad outcomes for those who experience too little nutrition—too few proteins, calories, and related dietary items—in order to lead healthy, productive lives. Alan Berg has shown that even the most basic sources of human satisfaction, i.e., friendship, the beauty of nature, the joys of exercise, and play, are barred to people distracted and weakened by hunger (Berg, 1973). But hunger causes not only individual personal suffering, it has costs for others, as well. Two important considerations that affect everyone command our attention to hunger. The first is moral; the second is the economic effects of "negative externalities."[7]

Morality arises from obligations people recognize or simply feel as part of their being human. How many people could pass someone truly starving and do nothing while having the means to do so? What kind of social fabric would such an absence of obligation to others produce? The very existence of hunger is an affront to norms of human dignity that provide the trust and freedom that allow modern industrialized and interdependent societies to function. Philosophers, theologians, and psychologists all discern that human dignity rests on some common shared obligations among people. In a world with ample food, ignoring the inequality of such a basic human need threatens the moral rectitude of anyone aware of the problem. Failing to fulfill the moral duty of hunger alleviation corrodes cultural and individual sensitivities. Thus, a moral concern arises, going beyond the physiological importance of food and its impact on individual health, because food is important to people's general quality of life.[8]

The second rationale for treating hunger as a general problem, affecting more than those immediately harmed, is, as noted above, the economic point that hunger reduces the productivity of an entire society, as well as its trading partners. In the first instance, we can measure the

[7] Other critiques of those enjoying "modern" and ample food include the loss of quality and nutrition, as well as desirable ways of life. For example, see Eric Schlosser, Fast Food Nation (2002). Michael Pollan critiques the relationship of people and plants and adds the concern over new genetically modified plants, such Bt potatoes in Botany of Desire (2001).

[8] A related point about the importance of food to human physiology arises from the positive benefits of having ample food to eat. When food supplies have become readily available, dramatic changes have occurred in the very physical characteristics of a people. The boom in post-World War II Japan, for instance, was characterized not only by rapid economic growth rates, but also in rapid average size growth of the Japanese people. Ample food supplies during childhood can account for differences in height and weight of 10 to 30 percent. The physical features of Japanese age cohorts born in the 1950s compared with those of the 1920s and 1930s illustrate the striking difference that nutrition can make. We can say the market fails when there remain large numbers of people throughout the world deprived of these benefits. Indeed, improved nutrition both reduces the demand for a family to have many children, as childhood death rates drop, but also extends the years for childbearing. Of course, if eating habits lead to excessive intake, abundant and cheap food can lead to bad outcomes in excessive weight and negative health, as in more heart attacks and higher rates of diabetes, as studies in the US and Egypt have pointed out.

healthcare costs of hunger—family members or health professionals drawn away from other tasks, medical costs of care diverted to those made ill by hunger, to which may be added the costs of medical supplies. In addition, for a family or country, there are goods forfeited because of the work not done by those weakened by under nutrition. Thus, there are some quite practical, economic reasons for reducing hunger. Doing so will add net wealth to the world, and expand opportunities widely for a more secure and encouraging international economy. For both moral and economic reasons hunger alleviation has become an accepted goal for most countries and the international community. Insufficient and unreliable food supplies, therefore, operate as a major constraint on the development of humanity, leading both to fewer resources from productive activity and to a threat to basic human values.

For these two reasons, we can call hunger a "bad." Today this “bad” challenges the existing policies of people and countries with abundant resources. Rich countries, therefore, as suggested by these two reasons, have cause to expand efforts to reduce hunger in poorer countries.

Applied science, itself a more developed asset within richer countries, moreover, offers the potential for advances geared especially to ways that will supply more food for the needy. Overall, from rich countries’ perspectives ending hunger elsewhere is justified. Particularly sensible is the use of public money for research and the application of “optimizing” efforts that seek to overcome the negative effects of continuing hunger, especially: lowered productivity and increased illness (both mentioned already). Moreover, there are several “bad” side-effects of hunger that can be reduced at the same time as well: illegal migration, political uprisings, and the spread of disease.[9] The material interest calculus alone, therefore, justifies public policy to end hunger since the economic gains outweigh the costs of hunger reduction for these wealthier states.

World policies on such trans-national matters as food and hunger are framed in larger multi-national meetings and conferences. These meetings adopt “approaches” to solve world problems and these approaches also vary over time. OECD (developed, industrial) countries have held a number of meetings in the last decade to set policy guidelines for poverty and hunger reduction world-wide. One hundred eighty countries, both rich and poor, came together at The World Food Summit of 1996, and its follow up 5 years later in June, 2002. In these meetings

[9] The World Food Summit “Plus 5” in June, 2002 noted the work on these additional afflictions and motivations (political will) for improved food security (FAO (2002B, pp. 31-56).

and the resulting policy proposals, the final documents emphasized a private-sector, market-oriented policy approach. These current policy orientations and their attendant goals have displaced an earlier supply management approach to hunger/food problems best exemplified in goals and policies adopted at the World Food Conference of 1974.

As suggested earlier, the theme emerging in these newer policy documents is that *poverty* and not food scarcity is the core problem, and that *governments are the culprits* not the solution to market failures such as hunger. This outlook, generally referred to as "neo-liberal," is contentious; it has been criticized by NGO advocates who point to the failure of this hunger-reduction approach to secure targets and gains proclaimed, and by professional economists who believe the anti-government critique of neo-liberalism is excessive. The prescriptions for public and private sector action that follow from the current neo-liberal diagnosis tend to overlook, among other items, the key role now possible for science to identify the hungry, to develop crops that will especially address their needs, and to uncover insights about how nutrition affects health and intellect that could be incorporated in policies being developed and adopted.

Figure 2 sketches (on the next page) some differences that occurred in global efforts to address hunger as reflected in different outcomes at the two major meetings held in Rome of this topic. Note the differences that reflect the current shift to minimal government action and reliance on market forces as a framework to address hunger.[10]

[10] The different outcomes in 1974 and 1996 reflect changes in both material circumstances and in dominant interpretations of the hunger problem. In the earlier period, the world experienced severe economic shocks. Weather-induced shortages in agriculture production disrupted markets. Rapid change in inputs, such as oil dependent fertilizer and machinery use, combined with weather to induce panic in world food markets in 1973-74. There are other historical examples: overproduction of food led to agriculture depressions in the 1920s. This, in turn, was an important ingredient in the great world-wide recession of the 1930s. During the 30s many farmers became insolvent, stopped growing crops, and even destroyed supplies while millions in cities found their access to food diminished. This phenomenon was more widely visible in advanced industrial countries. In the 1972-75 era, shortages of marketable food led to a panic in markets, with a doubling and tripling of key commodity prices.

Figure 2: Shifting Perspectives on the Hunger Problem and Policies to Alleviate It

	World Food Conference (1974)	**World Food Summit (1996)**
Time Horizon	Ten years	Twenty years
Focus	Narrow	Diffuse
Trend Appraisal	Unfavorable	Favorable
Causes to be Addressed	Low food production, Poverty, Violence	Instability, Access/income of poor countries, Farmers
Need for International Collaborative Action	High	Low
Institutional Recommendations	Agreements: To create an international security stock; To establish higher food aid guarantees; To increase funds for public international food research; To establish a fund for poor farmers; and To create a global policy co-ordination organization.	None. And no discussion of the decline in international public institutions.
Institutional Outcomes	Follow-up: Created WFC and IFAD (UN organizations in Rome); Strengthened CGIAR, WFP, CFA, Food Aid convention; Failed to create a stock holding agreement, but spurred unilateral strategies.	Follow-up: Created no new organizations; Internal shifts in existing institutions (e.g., The World Bank) occurred, reducing attention to food security

Analyses of causes and solutions, philosophical orientations, and resulting policies have profound influences on the nations of the world where hunger is a critical fact of life and a substantial contributor to morbidity and premature mortality. These "orientations" influence hunger everywhere, including rich countries, such as the US, that have hunger. Recent USDA studies suggested that hunger has grown in the last decade in the US, and is especially high in states where people eschew food stamps and have growing unemployment. (Oregon, for example, was estimated to have 5% of its population facing hunger at least once a month, according to a study done in 2000).

In rich and poor countries alike, public policy can create favorable conditions for voluntary organizations to help in hunger alleviation. However, in poor countries, both direct and private sector efforts are inadequate on their own, hence the rationale for international assistance. Indeed, some argue that the principal cause of poverty and hunger is failures by national governments in poor countries. These failures include: weak authority, distorted regulatory frameworks, and insufficient redistribution (i.e., getting "donated" food to the people who need it). This diagnosis does not provide policy prescriptions to deal with state failure, however. What incentives are there to achieve prescriptions for public sector reform regarding hunger reduction? Overcoming failures in states—ones within which much of world hunger occurs—will require actions by rich countries and international agencies to reshape the incentives and practices of national institutions. This is a "political" issue, to be sure, but not one without scientific dimensions.

Where does science come in?

Addressing hunger requires understanding a wide range of factors that affect the production and consumption of food. What follows is a greatly abridged catalogue of some scientific and mathematical disciplines and the "ways of knowing" that each represents. The knowledge produced or potentially produced in each of these areas—and more, for this is hardly an exclusive list—is needed for solving the hunger problem. :

- *Mathematics* offers models for calculations to estimate hunger. Mathematics helps us measure things and plot their probable directions. (In Section III, We'll explore some of the efforts to use statistics and mathematics to estimate who is hungry—both the number and distribution.)
- *Bio-Chemistry* helps us explore how health/illness patterns operate (including the key role of potable water and the absence of parasites and worms), as well as people's fuel-burning rates. Food contains complex materials that our bodies need for life. Food can also contain dangerous toxins—adding reasons for policy-makers to use science to set safety standards for foods, as well as to explore foods for potential use as medicine.
- *Neuro-science* helps us to understand how inadequate nutrition, especially in children before the age of five, leads to permanent loss of cognitive skills. The loss of capacity among underweight babies and undernourished youngsters frames a science debate over how much loss occurs, and whether it can be restored. The bulk of the evidence shows

that food insecurity in early years is very damaging to height, intelligence, and long-term health; and that the damages are largely irreversible.

- *Agronomy* focuses on soil quality, conservation, and water issues; it is especially crucial to understanding the threat to land of poor farming and the promise and risk of new genetically engineered crops. Soil science, water management, and other concerns about the needs and effects of various crops require complex understanding of what makes plants grow.
- *Nutrition* is critically important for identifying values in various foods and resolving issues of vegetarianism vs. grain foods as useful for individual diets and/or global needs. We often are encouraged to eat less fatty foods, for example. The rationale for this and numerous other recommendations are the continual subject of scientific study. Announcement of nutrition policy by health or agricultural authorities is also subject to considerable political influence by various producers and manufacturers. Nutrition science helps us sort out and test the validity of these often competing claims.
- *Meteorology/geology/geography* help map deficiencies and vulnerabilities for people and agriculture around the world; often aiding in early warning of shortfalls as well as problems such as desertification and deforestation that are growing problems in Africa and Asia where there is heavy population pressure for "harvesting" natural resources and little environmental protection over them. Geography is important both for predicting where new agricultural development might safely and productively occur, and areas where it is unwise. These disciplines also help explain and forecast where logistical barriers exist. These forecasts are essential to overcoming the condition where there is ample food in some areas of the world while shortages exist elsewhere. Climate change forecasts also pinpoint areas likely to be more or less suitable for agriculture. For example, rainfall patterns and temperatures are expected to make tropical areas even more vulnerable while improving growing conditions in some regions, such as Canada. Such forecasts affect policy, even though their development may be years away. Hunger policy mostly draws on the kinds of answers experts can give to immediate issues, such as, will tube wells produce water, and, if so, will that water production be reliable enough so that sufficient food can be grown and sold to pay for both the costs of wells and the labor of people who engage in farming?
- *Sociology/Population Scienc*e, mixed with economics, helps us understand the dynamics of population, food supply, and demands for food. For example, different age groups need different caloric intakes, and good nutrition extends both child-bearing years and child survival, just as good nutrition reduces infant mortality. Thus, ending hunger can lead to short-term higher population and increased demand for food. Equally, millions of

people migrate as a result of food shortages or loss of income from farming. Demand for food changes as population profiles shift (very old people eat less; but they also work less and are more a net burden on a group's supplies). How all this relates to food production and public policies can be explored within the disciplines of sociology and population science.

- *Economics and Political Science* help us explore and explain issues of distribution, trade-offs, property rights, market and state failures, public goods, and other factors that affect who gets what to eat. Recent studies of food insecurity in Africa have identified the failure of states to provide basic public goods as the most fundamental problem for food insecurity. In dozens of African states there are ample resources for growing food to feed everyone well. And there is sufficient capacity to also grow cash crops for export. Many of these opportunities have been unrealized thanks to the personal insecurity of farmers, the absence of maintained transportation systems, and the ability of predators to steal or tax production. Why is this and what can be done about it? are questions these social science disciplines can help answer.

Hunger, like HIV disease with which it shares some significant causal and national boundaries, is a remarkably complex, large, unsolved public problem. It won't be understood solely through the lens of only one discipline or framework. It certainly won't be overcome without the scientific knowledge gestured to in the foregoing paragraphs. In the next two sections of this paper, I will explore at greater depth two issues, one of measurement ("how do we know who is hungry?"), and the other relating to technological solutions to hunger ("do we want the solutions applied science is offering us?"). The first reviews a wide range of strategies for counting and shows how the choices we make about how and what to count will greatly affect the results we ultimately get. The second issue is more modern. It suggests how advances in applied science become themselves the "public policy problems" that we need additional scientific knowledge to understand and, ultimately use in connection with the policies we adopt. In one sense, the problem "caused" by science ironically requires science for its (even provisional) resolution.

III. Measuring Who Is Hungry

It's relatively common to find estimates in the news media of hunger and the number of people facing starvation for one reason or another. In February 2003, for example, it was reported that the UN estimated that in six African countries a total of 38 million were facing starvation unless they received emergency food aid (Africa Recovery, 2003, pp. 3-4). Where do such numbers come from? Are these and other estimates of hunger and food insecurity consistent with one another? Are they based on "facts"?

The numbers of people declared at risk owing to their being short of food often vary depending on their source. Earlier I noted how world estimates of chronic food insecurity ranged from 300 million to over one billion people. The same is true within countries.

In Brazil, for example, in the fall of 2002, newly elected President "Lulu" launched "Zero Hunger," a campaign to end under nutrition in about 25 million people. These people represent about 14% of Brazil's population of 175 million (New York Times, January 4, 2003). Because Brazil has one of the world highest levels of income inequality (with a gini coefficient of .60), hunger is a serious problem. Relying on the large inequalities in income, hunger estimates for Brazil regularly propose that a large number of very poor people suffer from under nutrition. Lulu's campaign, however, faltered shortly after beginning. It turns out that only a fraction of the poor are hungry in Brazil and that it is hard to reach them with government programs. Indeed, it turns out that the very poor in better off countries, such as Brazil or Mexico, have less under nourishment than estimates suggest. So while Brazil does have an alarmingly high portion of its people living in poverty, the portion of undernourished people is far fewer than predicted. While still substantial, targeting hunger in Brazil, which is ten times richer per capita than poor African states, such as Ethiopia and Tanzania, is not a simple task, nor one for a party apparatus to carry out. Where poverty creates much larger vulnerabilities to food insecurity (see map), the hunger alleviation strategies can work more readily.

The difficult questions in making estimates, and then developing policy from them, involve both the estimates and the policy trade-offs considered. Estimates relying on inequality must vary as countries have different wealth, allowing us to take into account *Engel's Law* (that shows how impoverished people spend very large fractions of their income on food). The tough policy question then becomes, what is a country's principal goal: to reach those who are both poor and hungry and provide relief, or to use those resources to open up opportunities for all the poor to jobs, income, and "entitlements?" The latter policy is usually favored by economists since it may alleviate immediate hunger (for those for whom it is a problem) and also overcome glaring inequalities in a country. The political support for such a program, however, may be lower and its economic costs to the government may be higher. Moreover, such a policy may transfer resources to those who are much better off as much or more than it does to those who are truly unable to get enough to eat.

Let's take one example. In a recent study of the Middle East and North Africa, the International Food Policy Research Institute (IFPRI) measured household food insecurity. Not surprisingly it was closely related to poverty, with highest levels of both undernourishment and poverty in rural areas. Further, food insecurity and poverty were most concentrated within Iraq, Sudan, and Yemen. Overall, however, 25% of the area's population was seen as poor, while only 7% were labeled undernourished. This study concluded that the key to increased national and household-level food security, therefore, was to follow policy that was "pro-poor" in achieving national economic growth. This led to recommendations for export-oriented, labor-intensive sectors being given attention over the agricultural sector. The authors suggest that that National food self-sufficiency policies should be subordinate to the "pro-poor growth goal"(Lofgren and Richards, 2003).

Food subsidies for imports, or targeted food distribution, or propping up local production were considered poor choices to tackle hunger compared to efforts to raise incomes of the poor generally. Such policy trade-offs do not just compete for scarce resources. They are also at logger-heads with one another. Economists favor market-based access to food and subsidies to help the poor gain skills or access to credit. However, the solutions proposed will have only the remotest chance of alleviating hunger for those who are both poor and hungry. Indeed, here we can see how a policy choice emanating from a "theory" linking poverty and hunger will probably result in no alleviation of hunger for the rural, agricultural poor because it is not targeted to them, and they will have least access to the employment options created by a "self-sufficient" food strategy.

Basically, then, we see from these examples quoted above, that there are a variety of estimates for those suffering from hunger. The cases of different countries help us understand how varieties of estimations occur because of different strategies of measuring. In Brazil and the Middle East, officials have used household income estimates. In the US, the estimates are derived from survey responses about behavior. During African emergencies, the figures are reached by means of special reporting teams of UN and NGO officials who physically examine supplies and current nutritional status of people in parts of countries where famine conditions have been proclaimed.

The estimates that I use most often, as do most writers on the topic of hunger, are the global or national figures constructed from statistical models using basic data on average caloric availability and levels of inequality of access to food in each country. FAO and IFPRI are the principal organizations that rely on this approach. Most other international agencies, NGOs, and independent scholars rely on FAO and IFPRI figures, as we can recognize from the earlier tables in this background paper. Still we need to be able to defend estimates we use. Beyond that, we are confronted with many non-comparable and dissimilar estimates of who experiences how much hunger, and where. How can we make sense of these variations in numbers? A recent symposium by the FAO clarified five approaches that I will describe below.

Five Approaches to Measuring Hunger

The five methods reviewed recently by the FAO are: (1) a standard method for measuring undernourishment achieved by combining information from food balance sheets and household income and expenditure surveys; (2) other methods for measuring food insecurity using household income and expenditure survey data; (3) methods for measuring adequacy of dietary intake based on individual intake surveys; (4) methods for measuring child nutritional status based on anthropometric surveys; and (5) qualitative methods for measuring people's *perception* of food insecurity and hunger. The first three compare dietary energy availability (or intakes) with energy needs. The fourth measures nutritional outcomes and the fifth measures people's perceptions of hunger. I will comment briefly on each of these and then discuss the FAO approach because it involves some interesting statistical issues.[11]

The first method, on which I elaborate later, is FAO's standard "national" method. It involves the estimation of a distribution function of dietary energy consumption on a per-person basis. The mean of this distribution refers to the usual food consumption level and is estimated by the daily dietary energy supply per capita for a country, derived from its food balance sheet (averaged over three years). The variance, as measured by the coefficient of variation, is derived on the basis of food consumption or income data from household income and expenditure surveys. The proportion of undernourished people in the total population is defined as that part of this distribution that is likely to lie below a minimum energy requirement level for the country. This minimum, where possible, is derived by taking into account the sex and age distribution of the country's population, assuming the minimum acceptable body weight for given height for all sex-age groups, and predicting light activity levels for adults.

A second method, also using household income as a measure, estimates hunger by combing the most representative household income and expenditure surveys in each of those countries where surveys have been done and are available. The data from such surveys allow each household's average food consumption and energy intake to be calculated, since they typically ask respondents to recall their consumption of food items over a reference period, e.g. the previous week. The proportion of households in a country whose energy intakes fall below a minimum energy level can then be calculated.

A third strategy for estimation is food intake surveys. The surveys measure actual food intake at the individual level. The modalities for data collection include taking a dietary history, administering a food frequency questionnaire, recording weights of foods consumed, asking

[11] These are discussed in The Sixth World Survey (FAO, 1996), pp. 91-150, and in a June, 2002 symposium (FAO, 2002C). The five methods discussed here are drawn directly from the symposium proceedings.

respondents to recall what they ate in the previous 24 hours, or analyzing the chemical and nutrient content of diets. The results from these surveys are then compared with "dietary energy requirements" and yield a statistic for the proportion of the population with deficient energy intakes. Alas, in countries where hunger is most likely to be a major problem, few such national surveys of individual dietary intakes are undertaken; they require considerable human and financial resources.

A fourth alternative to measuring hunger is to use information from "nutritional outcomes." Under-nutrition is said to exist when individuals' anthropometric measurements, for example, their weight for height, fall below international reference standards. Poor growth in infants and children, as well as underweight in adults, may be the consequence of both inadequate food intake and poor absorption of food caused by other factors, such as infections, parasites, and other conditions. Such anthropometric surveys are carried out in many developing countries. From these, when proper survey techniques are used, estimates can be made of the proportion of all persons in the country who fall below established cutoffs and who, therefore, are considered to be under-nourished or food insecure.

A fifth method involves the use of sociological surveys. This strategy, not likely to give results similar to the ones achieved by the other methods described, rests on the view that hunger is as much a social as a biological problem. People who lack the means to acquire sufficient food may regard themselves as hungry, even if there are no clinically recognizable signs of inadequate nutrition. Furthermore, even if they are not currently hungry, they may have a well-founded fear of future deprivation. Qualitative or 'self-assessment' indicators of food insecurity have been developed to attempt to capture these dimensions. The US uses such an approach. While the results of this technique are well correlated with other measures of hunger, the estimates of who is hungry are often higher than results from the other methods. That is why a figure such as 33 million hungry in the US is established by this survey method, but would not be replicated by using inequality of household income and average caloric availability techniques used in the first approach. Basically such social survey estimates are used in developed countries. The FAO has supported efforts to extend their use to developing countries.

The final point I wish to stress in this section on measuring hunger is the variation that can occur within even one method. Let's use the first method mentioned above to illustrate how difficulties or different judgments in assumptions will affect the results. Here is a simplified version of the analysis used by the FAO: A statistician at the FAO calculates for each country a national food balance sheet—what is produced, traded, fed to livestock, wasted, stored. Then, by definition, since it is what is left, we can assume that this is the food actually consumed by people. This amount of food, converted into calories, is then divided by the population of the country. That calculation gives us the national average caloric intake (that can be further estimated to be the caloric intake per day). Next, using indicators of "inequality," the FAO estimates how many people in the country are below some basic minimum caloric intake—usually searching for the estimated number who are 20% below an intake level required to satisfy the basic metabolic rate and also sustain steady life without activity.[12] The FAO summarizes this method with more details on its web page (www.FAO.org).

The difficulty of this method is how exactly to estimate inequality. In ideal cases, the FAO uses national household surveys, in which a representative sample of households is asked to describe how much money they typically spend on food each week. The FAO then calculates how many calories worth of food these expenditures can purchase. Unfortunately, these data are not readily available for many countries. For many statisticians, there exists a basic and common underlying concept for inequality called the "gini coefficient." Ranging from zero (no inequality) to one (single family gets everything), it is the most commonly used indicator of inequality. This coefficient corresponds to what is called a "Lorenz curve," a graphical representation of the distribution of any item among a population: income, education, or food intake. These distributions, since they often are causally related, are also similar among countries. So income distribution is related to, but not exactly the same, as food distribution. Since the poor typically spend a greater percentage of their income on food than do the rich, however, the inequality in food will be different than income inequality (which may be the measure with which an analyst must begin).

Using this approach, a statistician could estimate the number of hungry people in any country today, or over time, using information on total average calories available, the metabolic demands of the climate, and the inequality in that country. For every country, the FAO has a figure for the total per capita calorie supply. If you were to look at how such a number was composed, however, you would find that different countries get calories in different percentages from basic foods. Hence, rich countries get their total per capita calories much more from meat, fruits and dairy products, while poor countries derive their calories largely from cereals and starches. These differences conform to *Bennett's law* (that proposes that the wealthier a country is, the lower the percentage of starchy staples in the average diet). You can also see how *Engel's law*, relating to how wealthier people spend a smaller fraction of their income on food, also works to affect levels of under-nutrition and hunger. Thus, the various estimates of hunger you encounter may be based on different strategies for measuring.

Hence, an important scientific task for the world is make progress in deciding how best to make policy. Should it be made from estimates based on the direct counting of people arriving at refugee camps? Or should it be made on measures of weight, height, and other physical features,

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[12] In *The World Food Problem* (1999), pp. 67 – 73, Foster and Leathers describe how the FAO uses *food balance sheets* to estimate the level of *food insecurity*, or hunger.

or on inferences from aggregate measures of food in a country and its inequality, or on some subjective measures derived from interviews with people (as in the US)?

Using national statistics is almost always the most common method employed to make comparisons among large groups of countries. These statistics are accessible to any student interested in exploring or advancing an argument about the "facts" of hunger. They are also the least compelling! Given the caveats about how one counts determines the results one gets, it is worth considering how well these measuring strategies really serve us in deriving helpful estimates of who is hungry and where the hungry people live. Without persuasive, well-trusted estimates, governments and NGOs have been and will continue to be slow to commit resources. Rather, they often wait until direct evidence of starvation is physically present. By then, harm has irreversibly occurred.

IV. Using Biotechnology to Solve the Hunger Problem

One obvious solution to hunger is to produce more food. Prices would fall even further, and access to food by the poor would be easier. Moreover, if the extra food could actually be produced by people who are currently poor farmers, themselves suffering from hunger, then the results would be even better. Thanks to advances in biology and related sciences, we now have the ability to use biotechnology to design crops that could help a great deal, provided they were able to overcome the constraints faced by farmers in low-potential areas—mentioned earlier as places with poor soil, erratic rainfall, year-round threats from pests, and climates not conducive to agriculture. Achieving higher rates of food production is the historical solution to hunger, one pushed for the last fifty years by United Nations agencies and several foundations.[13] It promises to help the world's poorer countries to produce more food, and/or crops to lift the income of "hungry" farmers through sale of their production. In this way, it is theorized, a good portion of the hunger problem would be solved.

While there are dozens of proposals as to how increasing production might occur, the most dramatic changes in the last 30 years have come from the "Green Revolution" technology that allowed much higher yields for any given crop or plot of land by using new seeds that plant biologists developed. These hybrid and dwarf varieties of rice, wheat, maize and other crops are credited with some of the miracle solutions to hunger in China, India, and elsewhere in Asia. These crops are troublesome, however, because they are less drought-resistant, require

[13] The CGIAR system has promoted this strenuously; Gordon Conway lays out a prudent case for biotechnology, used with caution, alleviating both poor yields and environmental losses among poor farmers (Conway, 1998).

considerable fertilizer as well as other chemical inputs such as pesticide and herbicide sprays. The result has been greater harm to the environment.

In the last decade, a second wave, or the "Green, Green Revolution," has been described. In this phase, genetically modified seeds could be employed that reduced vulnerabilities to insects or weather, thus extending the revolution in productivity to more farmers while lessening harm to the environment (Pardy, 2002; Per Pinstrup-Andersen, 2001).

As seeds for genetically-modified (GM) crops were first introduced in the early 1990s, the private ownership of the patents for these seeds raised concerns. These included a question about how dependent farmers using these seeds would become on the seed producers and the crops they produced. Other concerns were raised about the likely unavailability of these crops to the world's poorest farmers (NRC, 2002, p. 241). International property rights (IPR) agreements were enhanced by the inauguration of the World Trade Organization (WTO) in 1995. This gave rise to concerns about the distribution of GM seeds. In retrospect, however, the problems with patents and ownership did not prove to be a major factor in slowing the spread of GM crops. Indeed, in a few countries there has been significant growth in the cultivation of GM crops, most notably Bt cotton, but also soy, rice and tomatoes.[14] On the other hand, India, Indonesia, Japan, Brazil, Kenya and other countries have prevented or halted introduction of GM crops. Nevertheless, some commentators estimate that the arrival of GM seeds in these countries is inevitable, or that it is already occurring clandestinely. In any event, IPR restrictions by private international companies have proved no barrier to using the power of biotechnology for the poorer countries. Firms, led by the Monsanto Company, have shown a willingness to extend GM crop technologies into developing countries whether or not the receiving country offers IPR guarantees. For example, all four of the private companies holding patents on the technologies used in Golden Rice (a GM strain high in a crucial nutrient—vitamin A) have agreed to make seed use available to developing countries on a royalty-free basis. Having fought for IPR protection, these firms seem ready to waive that protection in LDCs in return for increased seed use.

Hence, the slowdown in dissemination and use of genetically modified seeds is not a result of concerns for patent protection, but of concerns about safety. There has been a slowdown, and even a moratorium on bio-safety and food safety approvals. The bio-safety caution rests on the fact that GM crops are often developed quickly. This is one of the more positive, yet risky, aspects of GM technology. The timeframe of GM development—as well as

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[14] David Barboza (2003) reviews recent developments in Asia, where China, India, and Malaysia and Japan are spending billions on government studies of biotechnology applications. He reports that the area planted by GM crops grew in 2002 from 2001 by 40% in China, 50% in South Africa, and around 10% in Argentina, Canada and the US.

the fact that this is “new” technology—leads to concerns about possible unknown bio-safety hazards. What happens if crops are released before proper testing has been carried out to determine if they will produce detrimental environmental side-effects? What happens if the new organisms contain traits that, when released into the environment, prove to be harmful? And for food safety, how would we know if the crops (or the animals that ingest the crops) are safe, especially if eaten? Will we be eating “Frankenfoods” (the name some commentators have given to this phenomenon)? Will GM organisms spawn super weeds and bugs that develop resistance to the new genetically engineered plant features? Or worse, will the protein that makes a new seed attractive migrate into some other plant that is not wanted and then will that “new” plant become a monster plant, one hard to eradicate?

In light of these and many other concerns, scientists worldwide have acknowledged the need for caution while more careful testing is done. In 2002, United States’ National Academy of Sciences noted the need to have more careful monitoring of GM crops to enable appropriate data collection so that actual risks would be able to be identified (NAS, 2002).

Screening GM crops, case by case, for biological safety risks is a routine national policy function in all wealthy countries. This case-by-case screening practice has now been established in most important developing countries, as well. In Europe, however, thanks to strong consumer pressure urged by NGOs fearing unnatural food and perhaps by trade concerns as well, new approvals of GM varieties were frozen in 1998. This prompted other countries such as Brazil, Kenya, and Japan to also slow approvals. As of 2003, it was not yet legal for farmers to grow GM crops in most of the developing world. National bio-safety screening systems, even those in place and functioning, are producing very few approvals of GM crops for commercial planting. Caution in Europe has also led to a stringent regime for labeling and tracing all GM foods, a plan the US opposes, but which may be followed by many countries as the safest path toward using new technology and preserving prospects of trade. Indeed, the US, in May 2003, decided to challenge the European ban on new GM seeds and products and its new risk precautions, including required labeling and tracing of GM products. Europe’s regime is deeply resented by many American farmers and has been labeled “immoral” by the US Trade Representative.[15]

One labels food for a number of reasons; safety concerns can be reduced if consumers can choose crops that are certified “organic” or admitted as containing GM components. Where there is evidence of a harmful component, however, preventing harm is usually addressed by banning certain foods or setting limits on permissible levels of harmful ingredients. Labeling has less stringent and broader purposes.

[15] Elizabeth Becker (2003) suggests this reluctance was a reflection of complex factors, including some respect for differences in European consumer preferences and a reluctance to antagonize Europe further during a period of coalition seeking for allies to stand against Iraq.

In the developing nations of Asia, governments have approved production only of fiber crops. None has approved GM food or feed crops. The only significant bio-safety approvals yet given in Asia are for an industrial crop, Bt cotton, which has been released previously to farmers in China, Indonesia, and, in 2002, in India. In Africa and the Middle East, only the government of South Africa has yet approved the commercial growing of any GM crops (Bt cotton and Bt maize). In South America, the government of Argentina was quick to go ahead with several important GM food and feed crop approvals in the mid-1990s (specifically soybeans, maize, and cotton). Then, after 1999, Argentina imposed an effective freeze on new approvals (so as to avoid losses in export sales to Europe). In several other important agricultural states in the region, including Brazil and Chile, no official GM crop approvals have yet been granted.

At least once in recent years, a state has refused food aid in the form of genetically modified corn. In 2002, Zambia rejected Bt corn food aid in the midst of a dire food shortage. The rejection wasn't caused primarily by a fear that the corn would be harmful to those who ingested it. Rather, the main cause for rejecting the corn related to fear that the corn might be planted and cross-pollinate. That could then lead to future Zambia corn production having Bt in it. There was concern that this might be a safety risk, but even more a concern that, in good years when production of Zambian corn would be available for export, the market for Bt "tainted" corn in Europe would be closed.

A key element in the debate over GM crops is whether there are scientifically demonstrated bio-safety or food safety risks. In some developed countries, the absence of clarity and scientific consensus on this point fuels the reluctance to plant GM crops. In developing countries, however, where designer seeds hold the greatest promise of lifting constraints on production (overcoming the limitations of poor soils and high pest infestations), bio-safety concerns have not been the key factor slowing official approval. Instead, the slowdown has come from factors such as weak bureaucratic and technical capacity, donor-induced caution, legal and political opposition from domestic and international NGOs, and, most of all, as in the case of Zambia just discussed, fear of lost export sales. None of these is technically a bio-safety concern. However, the most convenient way for officials to address these concerns has been, quite often, to slow down the bio-safety approval process (Paarlberg, 2001; Pardy, 2002). Thus, a potential boon for increasing production in areas populated by some of the world's most vulnerable people is held up.

Science can help sort out the issue of whether GM forms of biotechnology can produce a new, environmentally favorable farm revolution. It can address better issues of bio-safety and insuring biodiversity (threatened by possible negative effects of monoculture, if seed use becomes widespread and dominant, driving out older varietals). At mid-year 2003, a number of both rich and poor nations continue to freeze GM crop approvals. As noted, some of the policies are based on political and economic calculations, including a desire to keep trade options available. But the "for public consumption" argument or justification is often based on bio-safety.

Consider the case of how such international pressures affected Argentina. As has been previously mentioned, this country was at first aggressive in its approval of planting GM soybeans and corn. More recently, however, Argentina's officials have held back from approving any GM food and feed varieties if they are not yet approved by regulators in the EU whose own moratorium on additional GM crops for commercial production inside the EU began in 1998. One result is that a considerable quantity of biotechnology crops from Argentina make their way into Brazil and are then exported (as Brazilian crops). Thus, instead of science settling or at least clarifying an issue, the crops of "unknown" safety are being distributed anyway. So it is trade concerns and not health concerns that have held up the spread of GM crops, as many other countries followed the European ban with ones of their own, or at least with suspensions of approvals.

This circumstance has led advocates of production strategies for solving hunger to fear that prospective gains coming from improved technology, offering more environmentally safe options, will not accrue to poor farmers in currently poor, food-insecure countries (Per-Pinstrup Andersen (2003). The concerns of critics (Pollan, 2001) have been translated into cautionary rules and restrictive policies. This, in turn, has made it less attractive to farmers, and hence to private researchers whose "research products" need a promise of profitable markets. Funding for public research, which might develop crops for poorer farmers regardless of the crops' apparent "profitability" for the developer and which would be subject to careful scrutiny regarding safety issues, remains meager and declining. The result is that the promise of bio-technology may be held hostage to protests by rich country consumers. These consumers are not people who are not hungry. They may be less interested in a scientific risk analysis, than they are in preventing monoculture and new crops that would take the place and lack the appeal of older ones. This resistance leads to a hold-up. GM growth has slowed since 2000. And, as I have been arguing, this slow rate of growth is more the product of economic anxiety about potential consumer fears and costly extra regulation, than an actual finding of a bio-safety or food safety risk. Fear and high safety standards for GM crops are enough to make a country pause and consider its steps carefully.

Just last year in Canada, which, like the US adopted GM quickly, the chair of the Wheat Board estimated that the first major exporting country to begin planting GM wheat could immediately lose one third of its foreign customer base (Raine, 2002). Under pressure from frightened wheat growers, Monsanto announced last year that it was pushing back the commercialization of its new GM wheat varieties in the United States until at least 2005.

In summary, the current stalemate holding back the introduction of new GM crops is the absence of government approvals worldwide. This, in turn, can be attributed to discord within and between various realms of science and public policy. How is it that science can be divided and can lead to a policy stalemate? Basically, scientists lack sufficient knowledge in order to assess GM risks to the degree requested by skeptics. Thus, while international trade interests polarize political leaders, many consumers, worried by alarms set off by some scientists, have become averse to the use of DNA recombinant technology in foods. People seem inclined to think that tampering with DNA is generally a dangerous idea. They see DNA as the basis for their own lives and they regard a scientist's power over and intervention in life's DNA make-up as scary (Nottingham, 1998). We can see, therefore three areas of this controversy in which science has a role. These are diagramed below in Figure 3.

Figure 3: Approaches used in analyzing GM policy

Domain	Science	Social Science	Civic Engagement
Field	Biology	Economics	Media, Personal Exchanges
Theoretical Tools	Statistics	Models and Experiments	Cultural Beliefs
Objective	Risk Assessment	Risk Management	Risk Avoidance and Informed Choices

I suggest these three categories of policy shapers in order to distinguish the crucial role that science can and must play in all three. As policy-makers look to the biological research and statistical assessments published by scientists, they want to rely on these to discern the relative risk of using certain GM varieties, often in comparison with traditionally developed varieties. However, scientific research on GM crops so far has not proved to be an objective measure upon which to base policy decisions for two reasons. First, scientific researchers have formed no consensus on the issue of risks in spite of many studies that detect none. Because, however, several studies have claimed to demonstrate significant bio-safety risk from particular GMOs, scientists are more cautious regarding transgenic crops than a decade ago. Second, although most GMO research has indicated GMO safety, the research projects that have been done has been, for the most part, paid for by the very same private companies that produce GM seeds. Therefore, many are skeptical of the objectivity of these studies. Critics wonder whether the companies have done all of the relevant studies and disclosed all of the important information. Critics also question whether we have had enough experience and time to work with GM organisms in order to form a reliable conclusion on bio-safety.

One policy solution would be to put more resources into public sector research, and to use this both for assessing safety and for increasing inducements for biotechnology to favor poor farmers, and perhaps consumers. Currently, the advantages of GM crops are almost entirely directed to the producers, usually those already rather well-off, who plant them.

While the standard answer—the one I just noted— to this problem has been to request further research, we must be aware that, at best, such research provides only an "assessment" of the risk—that is, it will give us probabilities of various bad effects being associated with the potential benefits (see Figure 3). This approach is common for scientific assessment of building materials and codes, new medicines, as well as GMOs. For GMOs, however, given the newness of the technology and the range of unknowns, the question becomes at what point will there be enough research to be sure the assessment is correct? What level of uncertainty about the risk is tolerable?

Here is where science and civic concerns of public policy meet. Adoption and use of any technology involves taking some risk. Thus, a basic problem in shaping bio-safety-based policy for GMOs is that controlled scientific experimentation is good for demonstrating the presence of specifically hypothesized risks, but no amount of experimentation can demonstrate the ***absence of all risk***. There will always be an Nth hypothetical risk not yet tested for, or an Nth year of hypothetically risky exposure.

These issues—and the controversies and debates surrounding them—have found an institutional home in the major international bodies. The most cautious approach is imbedded in the Convention on Biological Diversity (CBD) that emerged from the Environmental Summit of 1992. To shape GM regulation, the CBD drafted the Cartagena Protocol, known as the CP. The CP is nominally intended to protect biological diversity within GM importing countries, yet it is an agreement that focuses almost entirely on trade (on the "trans-boundary movement" of living GMs, known as LMOs). Because the CBD originally emerged from negotiations launched by the United Nations Environment Programme (UNEP), it was primarily representatives of national environment ministries, rather than by trade ministries, science and technology ministries, or agricultural ministries, who negotiated the 2000 CBP. In part, because of its emphasis on the natural environment, and to limit opposition from major industries using biogenetic technology, the Cartegna Protocol explicitly excludes governance of trade in pharmaceuticals for human use. The Protocol's focus is on bio-safety rather than on human safety and on living organisms and foods rather than products that have no effect on the environment, such as drugs.

The assumption behind the CP was that poor countries lacking bio-safety capacity within their borders would need stronger means to stop potentially dangerous LMO movements into their countries at the border. The terms of the CP were originally drafted to resemble the Basel Convention on trans-boundary movement of hazardous wastes (Gupta 2000). Under the CBP, just as under the Basel Convention, importing countries are offered generous options for blocking or requiring labels on trans-boundary product movements. Under an Advance Informed Agreement (AIA) procedure in the CP, governments that import LMOs intended for "environmental release" for the first time (e.g., GM seeds or GM plant materials) are permitted to require prior notifications from exporters regarding bio-safety.

In contrast to this approach, the WTO has committees on trade issues that take the view that only where science establishes a risk can barriers be established. The assumption is that if the risk has not been established scientifically, then no cautionary protections need apply. The committee on Technical Barriers to Trade (TBT) and the Committee on Sanitary and Phytosanitary Safety measures (SPS) are mandated to review and rule on what policies national governments can legitimately follow in blocking imports. In general, these groups in WTO favor the US approach that has treated GM more or less the same as conventional hybrid varieties and approved most when no health risk was found in normal trials. Basically, this approach assumes safety until evidence proves otherwise. Thus, it is probable that the WTO would rule against precautionary measures as a barrier to trade. Indeed, since the US requested (May, 2003) a WTO dispute panel to investigate and rule on the issue on whether EU regulations are in violation of WTO rules, political friction over GM has increased.[16] Hence, we have two competing orientations regarding the role science should play (as a "gatekeeper" of safety, or a post-facto analyst of risk). It has been suggested that these conflicts should be resolved and the dual roles reconciled by some third body, such as Codex Alimentarius, a largely scientific panel that was designated by the WTO after 1995 to determine what were safe food standards for use in SPS deliberations. Over the next few years, this dispute will command major attention, and demand considerable scientific inquiry.

[16] US Trade Representative Zoellick, in support of prohibiting European Union precautionary rules that inhibited the use of biotechnology-created crops, proclaimed: "People around the world have been eating biotech food for years. Biotech food helps nourish the world's hungry population, offers better health and nutrition, and protects the environment." Europe's Trade Commissioner Pascal Lamy shot back: The EU's regulatory system for GAOs is in line with WTO rules; it is clear, transparent, and non-discriminatory." The EU Commission called the US's action "legally unwarranted, economically unfounded, and politically unhelpful."

So we have the WTO with its “prove the risk” approach and the CBD that, while it endorses scientific risk assessment, also endorses “the precautionary approach” under conditions of scientific uncertainty, and the Codex Alimentarius with its blend of scientific and harmonization of law expertise. In the body of the Cartegna Protocol text that the CBD helped shape, it states repeatedly (in Articles 10 and 11) that “lack of scientific certainty due to insufficient relevant scientific information and knowledge” should not prevent states from taking precautionary import actions against live, or potentially alive, as with un-milled seed, genetically modified organisms (CP/ CBD 2000).

Thus, the debate among and within the three orientations shaping policy, as outlined above—scientific, economic, and cultural—creates a complex situation. The situation is produced in varying degrees inside each of the three international bodies discussed. On the one hand, science alone is inadequate for policy making. Nor can those with a short-term economic stake in disseminating a product determine its safety. On the other hand, relegating policy only to satisfy preferences of consumers, or popular opinion and superstition, threatens human progress, blocking avenues for bettering people’s lives.

Is there a way to reduce the “Luddite” quality of reaction to GM products, while meeting legitimate safety and cultural concerns? I believe a sustainable and global governance outcome will have to emerge, one that takes into account these differences among all three of the groups of interests reflected in Figure 3. GM regulation has become a global problem. Various participants should ask: how can ethical and “enlightened” self-interested calculations reach a regulatory outcome that respective states can agree upon and then adopt into national regulation? Since the tension between gaining GMO benefits and protecting against its uncertain risks has no easy solution from science or any deductive processes, international public agencies, such as the CBD, WTO and, especially, the Codex Alimentarius set up by the FAO and WHO, will be challenged to negotiate bargains among competing claims and stakeholders relying on advances and knowledgeable appraisals from science.

Note that this debate suggests that international agencies must play a role in shaping sustainable world-wide regulatory regime norms. For guidance in this complex area of international policy and regulation, we can turn to existing organizations and procedures for policy coordination. Guidelines for creating a regime exist in a variety of locations: the WTO 1995 agreement, the 2000 Cartagena Protocol, and national decisions on regulatory policy in various countries whose influence on production and sales world wide is significant. National policies are crucial as anchors, barriers and examples. A mixture of diffusion and amendment of national policies must occur as part of a global “solution.” An effective transnational regime rests on the capacity of national or regional entities to enforce policy; concurrently it builds on the greater sensitivity to the competing demands individual states experience (Hopkins, 1996; Cerny, 2001; Braman, 2002).

Practices that blend different positions, as suggested above, is needed for achieving gains. This will allow GM with acceptable levels of safety. In Canada, for example, regulation has moved to include in its formulation concerns of producers, distributors and consumers (Einsiedel, 2002). Labeling offers many advantages, but in itself does not resolve questions of safety. I suggest this Canadian approach has a greater prospect of sustainability than ones developed largely at the demand of consumers, as in Europe, or producers, as in the US. Given the two competing solutions currently promoted by national and international agencies—the rather permissive solution in the US and the more restrictive and precautionary alternative in the EU—the challenge for science and policy will be to create a coherent regime that is not only able to satisfy strongly conflicting interests, but also to create it within the existing complex maze of multiple international institutions.

Besides safety concerns, there is at least one other aspect of GM technology to address by suitable regulation. This is developing seeds for crops that will help discourage land degradation caused when poor, desperate farmers try to till marginal soil. Often poor farmers, otherwise excellent stewards of nature, face no choice but to farm in areas vulnerable to erosion. Deforestation, land degradation from shifting slash and burn cultivation, and salinization from improper irrigation are toughest to combat when such outcomes result from practices linked to the fate of marginalized peoples. Often they occur in situations where insecure populations have little stake in the stewardship of vulnerable land. Growing income inequality and shrinking of government safety nets are other factors that can account for food production and farming practices that carry with them harmful secondary effects. While the vast story of the contemporary world is improved food security, the people remaining insecure face more complex obstacles to resolving their vulnerability. So the irony on food production is that the poor are destroying "nature" fastest, and the rich are holding back new crop technologies that will do little to help their economies or hunger problems, but could do much to help improve the diets and lives of people in Africa and elsewhere with improved varieties of yams, cassava, plantain, as well as traditionally traded food crops.

Scientific knowledge may have gotten the world into some of these new dilemmas. It is clear that scientific knowledge, combined with new transnational institutions designed to weigh and evaluate a welter of competing interests and claims, will be necessary for us to resolve them.

V. Hunger and Policy: What Good Would Eliminating Hunger Do?

We have reviewed the current debate over what priority hunger should have in contrast to poverty alleviation. As I have noted, for many analysts, poverty is the root cause of hunger. They would argue that programs that send food to those facing hunger are mere palliatives. Moreover, they claim that emphasizing food production will lead to social distortions and lower incomes. They contend that letting the market decide what jobs and income those living in hunger can best achieve is the way to end their hunger.

I have emphasized in this paper, however, a view that we must know a good deal more about hunger and its distribution and effects before deciding such an issue of how to give priority for donations and investments from those who are well off, as in OECD countries, to poor countries, or even for food distributions within a country that finds hunger morally unacceptable and has the means to essentially eliminate this condition.

Science can help us sort out this debate and give some clearer understanding of the benefits of eliminating hunger. We know that those experiencing inadequate nutrition are harmed—physically, economically, morally. But what about those who are well fed already? Do they gain anything from hunger reduction by others? I would say emphatically, "yes!" First, there are the broadest consequences to consider. Reducing the threat of hunger can change people's use of time, their risk-aversion, and the political and economic action they can enjoy. Consider how food availability has been linked by scientists to how governments and societies flourish or flounder (Diamond, 1997). In general, the more precarious and minimal the food supply, the more critical food intake becomes. Historically, securing food was an essential activity for hunting and gathering bands and peasant societies. Virtually all other activities revolved around it. Where people lived, their housing style, their plans for travel, recreation, procreation, and indeed, the very distribution of wealth and status among them were all intimately and directly tied to the exigencies of food procurement and distribution. Enforcing rules that served the aim of food security was a dominant feature of government.[2]

This is hardly surprising. When deprived only of one or two meals, people in contemporary societies, as in earlier primitive societies, immediately feel discomfort. An experiment with volunteers in the United States revealed that seemingly average Americans, when deprived of food for a few days, underwent dramatic changes. They became hostile, lazy and melancholic; furthermore, food became the dominant focus of their attention. They dreamed of food, thought constantly of eating, and their efforts to engage in other activities were continually interrupted by overriding psychological and physiological concerns to secure food (Keys, et al., 1950). Little wonder that in periods of general food insecurity, such as during

World War II or 1973-75, governments dramatically increase their attention and action in food matters.[3]

Increasing caloric intake to a minimum needed for health is important, not only for meeting physical human needs, but also for symbolic, cultural, economic, and political purposes. It is not surprising, therefore, that shortages produce anxiety and insecurity. When the reality, or even the prospect, of hunger arises at various levels of human organization—household, national, and international—it does so in relation to that unit's "adaptive capacity." Where households, the state, or the international system are threatened with a shortfall of food, fairly drastic and dramatic adjustments can occur.

Ultimately, food insecurity is a national-level problem. It occurs in countries that experience variations in production or inadequate production to meet consumption needs. Either such countries cannot smooth out production variability through domestic carry-over, or have a population whose consumption habits regularly exceed absolute production capacity, or lack adequate internal mechanisms for reallocating domestic food supplies. In such situations, household level actions, at least in the short run, put pressures on national governments that, in turn, must approach international markets, either for commercial or concessional food imports. In these situations, especially in countries with weak foreign exchange positions, food aid is the most helpful short-term remedy. Another way of saying this is that food security must ultimately be secured at the national level. If it is not, an international safety net of food aid is required.

The norms and expectations governing world food system participants' activities are complex, layered, and evolutionary. They reflect, at any given time, among other things, an understanding of what state action is appropriate to manage food systems and more specifically, what is required to reduce hunger. The role of the public sector has shifted substantially over the last several centuries. A state unable to prevent hunger within its domain, fails a rather practical test for success or failure. Hence, as we think of delivering food to those most in need within a country, the focus is on direct distribution of the food or food access (food stamps, food for work jobs). To get food to the hungry in foreign nations, we must consider international transfers of food, since it is in the poorest countries where hunger is greatest and whose governments are least able to cope with the crisis of food shortage and distribution. In spite of dramatically increased needs in several parts of the world, in the last decade, food aid supplies have dwindled from 15 to 8-10 million tons. The resources dedicated to helping countries with rural production and food supplies from major assistance agencies such as the World Bank and USAID have also dwindled. So while we have seen how important food is to human life and political stability, food aid it is not attracting levels of support in the last decade as it did in earlier times.

Food aid in the early years of the 21st Century has gone principally to areas where civic violence or mis-guided policy has led to serious short-falls. Although India has the largest population deemed food insecure (and thus might seem to be a good candidate for receiving food aid), it has made enormous strives in two decades to contain its problem and has even offered to donate wheat surpluses as food aid in 2002. Brazil in January, 2003 announced a massive program to reach the millions of its poorest population and achieve food security. Both these countries have substantial food shortages in certain sectors, but they also have capacities to solve their problems domestically and will be aided by external policies that promote trade and growth. It is Afghanistan, North Korea, the Democratic Republic of the Congo, Sudan, Ethiopia and several countries of Southern Africa to which the largest and most immediate need to transfer food from surplus to food-short populations exist. The failure of these countries' governments to deal with internal problems and persisting policies that have destroyed land and incentives arethe biggest causes of the food problem. However, food is still needed to avert famine and prevent death., To move the food from those who have it to those who need it requires a complex understanding of transportation systems and the engineering of shipments to the targeted peoples. Here is where knowledge of engineering and geography can really help.

The World Food Program (WFP) and others who provide food aid undertake work that calls upon extensive skills in engineering and logistics. For example, the logistical challenge of complex emergency operations may cost two to five times the value of the food, and involve knowledge of ship capacity, optimal storage and routing techniques, as well as simply coping with rugged terrain, as in Ethiopia and Afghanistan. As WFP was drawn into emergency peacekeeping tasks in the 1990s, its logistical experts managed details for these unforeseeable crises that invariably attend getting food to difficult locations. Among UN agencies, it had the expertise, information, and experience to oversee off-loading, storage and in-country transportation. It was accustomed to doing this with its own vehicles when local private haulers were unavailable. Emergency operations, however, entail a more rapid draw-down of physical resources, such as vehicles. With heavy use over treacherous roads, equipment life during emergencies is abnormally short. Food also has to be coordinated with other items and the cost of this assistance undercuts the longer-term policy goal of sustainable food security by a population, since funds spent on engineering and transport disappear from investments in research or farm inputs. This is the price paid to ensure that food and relief supplies (water, clothing, tents) reached distant areas.

Does it matter? Is it worth eliminating hunger? As I have said, I think the clear answer on moral, prudential, and political grounds is yes. I have also suggested that there are many ways—some that are sometimes in conflict with one another—to achieve food security. It is also clear, I hope, how much we must depend on scientific knowledge, engineering know-how, complex political skills, respect for the circumstances of others, refined moral sensibilities, and a commitment to justice, and just plain hard work to reach the goal of providing food security for all.

VI. How Can Science Serve Policy?

Underlying public policy, with its authoritative prescriptions, are presumptions about causes and effects that are rooted in science. Policy enjoins people to act in specified ways. Enforcement can employ coercion, but this is weakest at the locations where solutions to hunger are most needed from policy: at the international level and in states with little human capital to staff a government. One way to overcome this weakness is by global norms that become almost self-enforcing. Relying on science helps. It legitimates policy. The centrality of scientific knowledge applied to policy-relevant scientific questions is what most strongly distinguishes public policy in the modern era from policy in pre-modern eras in which superstition, tradition, and narrow individual preferences held sway over policy.

Today, as hunger becomes a global problem, it is increasingly possible to craft a global public policy on hunger. A global hunger policy, for example, like nuclear non-proliferation or ocean pollution policy, is embedded in a variety of instruments from treaties to ad hoc working groups. The scope, adequacy, and effectiveness of any set of policies will vary with circumstances and the level of authoritative commitment among the principal agents entrusted to carry out the policy. In the case of growing more food with GM or providing more food through entitlement programs such as food stamps, governance has had shortcomings, and science offers important information for policy improvement.

Two gaps exist between recommendations to address hunger and practical steps to implement recommendations. First, we do not know how to overcome state failures within whose borders hunger is a permitted result. Agencies with a mandate to reduce hunger need to know what measures will actually encourage changes in state performance, changes crucial to fulfilling this goal. This requires analysis. The knowledge gap on state construction calls for research on what incentives will work to achieve desired reforms in state behavior.

A second gap exists between the responsibility and resources of international institutions. Efforts to fight hunger in poor countries, whether bilateral or multilateral, are limited by this gap. These agencies lack the tools relevant to overcoming the state failures now blocking hunger reduction. This resource and institutional capacity gap requires altering the outlook and working ties of agencies to reduce mismatches between goals and means.

One example may help illustrate how science could help close these gaps. We look at the case of GM crops. As discussed in section V, science can reduce ambiguity over risk. Science can also help shape technology that would lift the environmental constraints on those poor countries and farmers whose food production is so low and where poverty and dependency on food aid and other assistance, especially in emergencies, has thwarted efforts to reduce hunger. While no panacea, the marriage of science and policy through research and sensible regulation holds great promise.

Responsibility for food security–that is preventing and or ending hunger—once the basic province of individual states has moved to the international level thanks to globalization. At this level, however we are moving away from inter-government management arrangements developed in the 1970s toward more purely "market" reliance. While trade barriers for agriculture grew substantially in the 1930s, they have begun to fall. Farm policies in the US and Europe, on the other hand, have moved away from offering incentives that could help farmers in poor countries and the hungry people of Africa and Asia toward insuring income for domestic production. While this occasionally blocks trade, it mostly distorts world prices and the situation for farmers outside the subsidized areas of rich-country policies. Instead of helping people in such countries, global market opening policies combined with protection practices in OECD countries, most notoriously in areas such as sugar and citrus, have made poor countries and the rural poor living there worse off.

This conclusion is reflected in a recent FAO pronouncement (2002D):

> Progress in reducing world hunger has virtually come to a halt. As a result of hunger, millions of people, including 6 million children under the age of five, die each year. Between 1990-92 and 1998-2000, the number of undernourished people decreased by barely 2.5 million per year and in most regions the number of undernourished people may be actually growing.

Can science help end hunger? In many ways it already has. The social commitment and the resulting public policy for this goal, however, are weak. Much more can be done to use existing and potential new scientific knowledge. The debate about welfare reforms undercuts social programs to transfer to those in need. The debate about dependency and exploitation makes food transfers to the poor countries so controversial that neither donor nor recipient countries celebrate such transactions except for the most dire of emergencies. And the debate about "Frankenfoods" and environmental monsters coming from transgenic crops slows the investment and use of this new technology.

All in all, reducing hunger is an anachronistic challenge for the 21st century. Mechanisms to accomplish this exist, but their use is impeded by other priorities, or in dire cases by localized conflict that creates acute hunger while blocking international aid, as in Afghanistan, Sierre Leone, and Angola in recent years.

What is needed to change this? Heroic rhetoric has proved to be no solution. Nor is "political will" (usually called for by advocates for the hungry) lacking. Those who set priorities and control resources simply do not understand that hunger is a serious problem. Understanding that hunger carries high shared costs and lost opportunities, is crucial. Scientific knowledge is essential to achieving this understanding. Once the benefits to all from hunger alleviation are recognized the anachronism of hunger may indeed become history.

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