Providing Micronutrients through Food-Based Solutions: A Key to Human and National Development[1,2]

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ABSTRACT To alleviate poverty in developing countries, economies must grow. Without the necessary investments in human capital, national economic growth may not lead to poverty alleviation and socioeconomic development, nor be sustainable. Economic growth that leads to poverty alleviation is fueled by the creative and physical capacities of people. The impact of micronutrient malnutrition is established early in life, leading to growth stunting, lower cognitive abilities, lethargy and poor attention, and greater severity and rates of infection. These effects limit educational progress, physical work capacity and life expectancy, thereby reducing individual lifetime productivity and the aggregate ability of the population to enhance its well-being and participate in national and global markets. The diets of the poor are largely cereal-based, monotonous and lacking in diversity and micronutrients. Animal source foods (ASF) have been an important factor in human evolution, a component of what was an historically diverse diet and an important source of micronutrients. Poverty and micronutrient malnutrition positively influence each other. This poverty micronutrient malnutrition (PMM) trap requires outside inputs to change the state of development in developing countries. Nutrition interventions have been excellent investments in development. More productive interaction between agricultural scientists and nutritionists, supported by a strong federal agenda for development, is needed to break the PMM trap. In the end, food is the means by which nutrients are delivered. Food-based approaches will require long-term commitments, but are more likely to be sustainable because they are part of a development process that leads to long-term economic growth. J. Nutr. 133: 3879S–3885S, 2003.

KEY WORDS: • *micronutrients* • *malnutrition* • *poverty* • *productivity* • *human capital* • *economic growth* • *animal source foods*

Although improving the welfare of human populations in developing countries has long been a goal of development efforts, two of the principal components of welfare—child development and nutritional status—rarely have emerged as explicit objectives. Martorell (1) summarizes a conceptual model of development that links economic growth to poverty reduction, improved nutrition and cognitive and physical development, which together generate increases in human capital. Increases in human capital then drive greater economic growth, which further fuels social sector investments in health, education and nutrition. In such a dynamic system the question for development agencies is where and how to intervene.

Development goals are usually narrowly defined in economic terms under the assumption that nutritional status is directly linked to income and that impacts from macroeconomic growth would trickle down and have a nutritional effect at the household and individual level. Beginning with priority setting processes in 1995, the Global Livestock Collaborative Research Support Program (GL-CRSP)[4] advocated a broader and more fundamental approach to development. We supported the premise that the foundation of development is people and that their cognitive and physical performance is ultimately what fuels national development. One of the major constraints to the development of human capital and capacities is the impact of loss of human potential, both physical and mental, due to poor childhood nutrition. With limited resources, the development

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[4] Abbreviations used: ASF, animal source foods; CRSP, Collaborative Research Support Program; DALY, disability-adjusted life years; FAO, Food and Agriculture Organization of the United Nations; GDP, gross domestic product; GL-CRSP, Global Livestock Collaborative Research Support Program; OECD, Organization for Economic Cooperation and Development; PMM, poverty micronutrient malnutrition.

community must make wise decisions in the allocation of resources. A substantial body of evidence now indicates that investments in nutrition programs are highly competitive with other development programs (2). When improving the cognitive and physical capacities of people becomes the explicit objective of development, optimal choices can be made to identify the best nutrition interventions.

Although agriculture's primary focus is the production of food, there exists a considerable disconnect between human nutrition and agricultural sciences in the development community. Recent advancements in our understanding of the nutritional needs of populations suggest that the integration of agriculture and human nutrition should be a major focus of future development strategies if human capital and capacity building are the objectives. One of the primary reasons for this lack of integration has been the compelling emphasis in international development on hunger as opposed to nutrition. Because development funds are so limited, the unfortunate growing need for disaster relief has compromised the ability to address long-term development goals. Such approaches have emphasized quantity of food over diet quality and nutritional balance. Greater awareness of the importance of micronutrients in child development and the refocus on human capital has been critical to the development of a more sophisticated concept of nutritional status and to a broader discussion of appropriate development interventions, which include a greater emphasis on agricultural and food-based solutions to malnutrition.

The goal of this paper is to describe the linkages between child nutrition, human capital, and national economic growth. Adequate nutrition, especially during fetal and child development, is a fundamental component of human development, and therefore, national economic development. This supplement examines the role of animal source foods (ASF) in this process, highlighting the recent study by the Child Nutrition Project of the GL-CRSP that shows the positive impact of ASF on children's cognitive and physical development. This supplement presents the papers from a conference entitled "Animal Source Foods and Nutrition in Developing Countries," organized by GL-CRSP and co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), Pond Dynamics/Aquaculture CRSP, Heifer International and Land O' Lakes.

Quantity and quality: finding the balance

Although challenges remain in meeting global energy needs, it is increasingly evident that dietary quality is one of the most current and pressing nutrition/health issues. The advances in food production, particularly in cereals, have made a major contribution by increasing the food supply. The proportion of hungry persons in most countries has declined since 1996. Between 1990 and 1992 and 1998–2000 the number of undernourished people decreased by 2.5 million/y, however six million children die annually due to undernutrition and 840 million are undernourished globally (3). As with the focus on protein-energy deficiency in the latter part of the last century, perceptions with respect to micronutrients have changed from a focus on clinical deficiencies, i.e., anemia, goiter and eye health, to that of the hidden consequences of inadequate nutrition that compromise immune function, cognitive development, physical growth, reproductive performance and work productivity (4).

The agricultural production paradigm of the 1960–1980s sought to alleviate widespread famine. The success of the "Green Revolution" was based on the ability of researchers to breed cereals with increased proportions of edible seed. The efficiency of that research and its high rates of return are testimony to the success that agricultural research can achieve. This success has maintained cereals as a cheap and available source of energy, but it has also decreased the dietary diversity of the world's poor (5). The growing dependence on cereals has aggravated the challenge of meeting individual micronutrient needs. Cereals provide far more energy and protein per capita in the developing world than does any other class of food. Although cereals satiate hunger and supply protein, the consumption of micronutrients actually decreases when cereals replace more nutrient-dense foods, such as meat and dairy products (6).

In many cases, cereals have replaced traditional crops that are higher in iron and other important micronutrients. In South Asia, where cereal production has increased more than four times since 1970, the production of pulses has actually declined ~20% (5). From 1970 to 1990, South Asia's population almost doubled and its per-capita energy intake increased due to cereal production, but iron intake declined and anemia increased (5). This growing dependence on cereals has increased the challenge of meeting micronutrient requirements. The refining of cereals removes the phytates that inhibit micronutrient absorption. However, as a result of milling and refining, the iron and zinc contents also fall, so the amount of micronutrients that are absorbed does not change. In contrast, meat products have bioavailable iron in the form of hemoglobin and cysteine-containing proteins that enhance the absorption of iron in the meal (6).

Human diets: an evolutionary perspective

Many historical studies suggest that human diets have diverged only recently from diets that were much more diverse (7,8). For example, Milton (9) builds a case that meat eating has been a fundamental characteristic of our evolutionary past, and has led to increases in the size of both the human body and brain. Studies of modern hunter gatherers (10) and Paleolithic evidence (7) indicate the importance of meat in the diets of preagricultural humans. The transition to agriculture that began 10,000 y ago was accompanied by a dietary change, resulting in the narrowing of diets, reduced consumption of meat and increased consumption of cereals. The archeological record reveals an accompanying decline in health and morbidity (11). Micronutrient intake throughout our evolutionary past exceeded current recommended intakes (7). Contemporary hunter gatherers derive on average 40–60% of their dietary energy from ASF (meat, milk and other products). These diets are noticeably low in cereals, but are rich in fruits and vegetables and micronutrients (7).

Based on results from the National Pilot Program study (conducted by Department of Biochemistry and Nutrition of the All India Institute of Hygiene and Public Health, Calcutta), present-day rural families in India have diets that are sufficient only in the "cereal" food category. In all regions, their diets lack diversity in terms of fruits and nuts and ASF, supplying only 20–90% of the Recommended Daily Allowances (RDA). In all but one region, diets lack sufficient amounts of green leafy vegetables, and 8–30% of all families are deficient in vitamin A (12). An underlying cause and fundamental constraint to solving the micronutrient deficiency problem is that nonstaple foods, particularly animal products, tend to be the foods richest in bioavailable micronutrients, which the poor in many developing countries desire to eat but cannot afford (13). Although this constraint is clearly pervasive, government policy, household behavior and education can also be direct and indirect barriers to increasing micronutrient intake, especially in children. Nonetheless, it has been argued that "as greater numbers of children survive, it becomes critical to pay closer attention to the strong relationship between nutritional status and children's ability to achieve optimal physical growth and psychological development" (14).

The global prevalence of micronutrient deficiencies

Widespread micronutrient malnutrition is well documented. Vitamin A deficiency, iodine deficiency disorders, and iron deficiency anemia are the most widely recognized, whereas the importance of zinc, vitamin B-12, folate and several other micronutrients warrants additional attention (15). Iron deficiency anemia is by far the greatest micronutrient problem affecting 2–3.5 billion people globally (15). In developing countries, 52% of pregnant women, 39% of children aged <4 y, and 48% of children aged 5–14 y are anemic (13). Despite some success in some regions from iodized salt campaigns, one third of the world's population is said to be at risk from goiter caused by iodine deficiency disorders (15). Globally, 740 million people are affected with goiter (15). Vitamin A deficiency is a major health problem in more than 60 countries. The World Health Organization Micronutrient Deficiency Information System (WHO-MDIS) (16) reported that in 1995, 29 million children aged <5 y had clinical vitamin A deficiency. Annually, 250,000–500,000 preschool children are estimated to go blind from this deficiency and about two-thirds of these children die within months of going blind (13). FAO data suggest that more than half of the world's population is at risk of low zinc intakes (correcting for phytate inhibition) (15). In Peru and Indonesia, studies have suggested that among pregnant and postpartum women, the prevalence of zinc deficiency was 60% and 24%, respectively (15). The Child Nutrition Project of the GL-CRSP found that intakes of vitamin B-6 and vitamin B-12 in young children and women of reproductive age in rural Kenya were below two thirds of the RDA (17).

Micronutrients: from human to national development

Micronutrient malnutrition adversely affects all attributes of individuals that determine their productive capacity. Micronutrient malnutrition leads to low birth weight (18), which has a negative effect on the trajectory of an individual's future lifetime productivity (1) through its impact on life expectancy (19), decreased work capacity (20) and higher rates of infection (18,21). As reviewed by Black in this supplement (22), cognitive capacity is impaired by micronutrient malnutrition (1,23,24). The impact of this loss on the educational achievement of children is augmented by lower attention span (25), increased lethargy (26) and delayed enrollment in and early drop out from school (27). "Education raises productivity in the market and in the household by enhancing information acquisition; it improves the ability to learn" (28). If one accepts the development model that identifies the individual as the primary unit in development, then it is evident that micronutrient malnutrition has a pervasive limiting effect on the creative and physical capacity of individuals and constrains national development and economic growth.

Micronutrients and human physical development. Growth is impaired by several micronutrient deficiencies, as explained by Rivera et al. in this supplement (29). Stunting is the most commonly measured indicator of micronutrient deficiencies (21,30,31). "Stunting has been shown to be cumulative and nonreversible and therefore provides an excellent measure of chronic malnutrition and its effects" (32). Rosado (33) found in a study of 337 Mexican school children that, among those receiving multiple micronutrients, linear growth increased significantly compared to those receiving placebos. In 2000, an estimated 182 million preschool children in developing countries (or 33% of children <5 y old) were stunted (<2 z-score height-for-age). The highest levels of stunting were estimated for Eastern Africa, where on average 48% of preschool children were affected, up from 47% 10 years previous. Stunting rates in other regions were similarly high, such as in South Central Asia, with 44% of preschoolers affected (34); Latin America, where in four of 11 countries surveyed, more than one-third of the children in school were stunted; and Peru and Guatemala where about half of the school-aged children showed inhibited growth symptoms (34). Stunting is symptomatic of a grave situation that also includes concurrent effects on organ systems and their functions. "Among the contemporaneous effects possibly predicted by growth failure are: low physical activity, impaired motor and mental development, lowered immunocompetence, greater severity of infections and increased case fatality rates and mortality" (1).

Two key aspects are central to understanding the links between growth failure and human capital (1). First, growth failure occurs primarily during intrauterine life and the first two or three years of life. Second, growth failure is associated with direct and indirect functional consequences that have profound economic implications. Although most growth failure occurs between 6 and 24 mo of age, early damage due to anemia, iodine deficiency and chronic malnutrition may only partially be reversed in later life (21). Micronutrient deficiencies among child-bearing women not only lead to low birth weights, they compromise the ability of those mothers to care for their families (18). Iron-deficiency anemia is the third leading cause of loss of disability-adjusted life years (DALY) for females aged 15–44 y worldwide (35), thereby further compromising the ability of many mothers to provide adequate nutrition for their children. As shown in Martorell et al. (36), stunting by age five leads to diminished height in adulthood. Small stature results in diminished lean body mass, strength and work capacity and may result in reduced productivity and income (37,38). There are intergenerational consequences as well. Infants born to small mothers have lower birth weights and are at a greater risk of dying (1).

Because of their high metabolic needs per unit weight and their developmental requirements, particularly for neurological development, it is vital that a child's diet be complemented with a diverse array of foods early in life. Nutrition early in life largely determines the cognitive potential through which education builds functional capacity. Physical growth is a strong predictor of overall nutritional status of populations (1). Chinese children 12–47 mo old had higher height-for-age scores when eating ≥3 food groups compared to those eating <3 food groups in their complementary diets at 12 mo of age (39). Among Kenyan children, dietary diversity was the strongest and most consistent predictor of anthropometric status (40). The early introduction of cereal-based complementary foods and decreased dietary diversity may have long-term negative effects (40).

Micronutrients, cognitive development and learning. A considerable body of evidence indicates the strong link between micronutrient nutrition and cognitive development (22), thereby indicating potentially negative implications for the educational achievement of affected children. Because they can potentially take only limited advantage of their educational exposure, children suffering from malnutrition will contribute only a portion of their potential to the economic development of their countries. Because education level (hopefully a surrogate for knowledge) is strongly linked to national economic growth (28), then loss of individual creative potential directly affects the long-term aggregate development trajectory of developing countries.

Micronutrients and immune response. Micronutrient malnutrition further impairs social and national development as it deprives societies of their true human potential by increasing their susceptibility to debilitating diseases. The health impacts of inadequate nutrition may be set in motion even before birth. For example, fetal undernutrition has been linked to chronic disease in adulthood (34). The relationship between micronutrient malnutrition and high childhood mortality rates is alarming. According to Pelletier el al. (19), 56% of the deaths of <5 y olds in developing countries is associated with malnutrition. Life expectancy, correlated with height, increases due to improved conditions in early childhood that can decrease the risk of health problems in later life (41). For example, improved human nutrition in England resulting from the industrial revolution was the main factor causing mortality rates to fall (41).

Inadequate nutrition may also play a role in increasing the virulence of infections. One group of authors concluded that deficient levels of nutrients may increase not only host susceptibility to infection, but also the virulence of the pathogen itself (21). Some studies have shown that micronutrient deficiencies compromise immune response to HIV, increase the rate of progression to AIDS and increase maternal-infant transmission (18). Micronutrient deficiencies may play important roles in causing and facilitating some cancers in that they cause DNA damage in the form of chromosome breaks or DNA oxidation (42).

Linking nutrition, education, wealth and economic growth. Nutrition is related to educational performance in a number of ways. According to Galor and Mayer (32) general health (and therefore nutrition as a major determinant of general health) affects the returns to education by: *1*) enabling the formation of human capital in the early years and throughout youth, which increases the efficiency of education; *2*) raising skilled and unskilled labor efficiency; and *3*) promoting longevity, itself influenced by early (nutritional) health, by lengthening the time during which education will yield returns. Weak health and poor nutrition among school-age children diminish their cognitive development either through physiological changes or by reducing their ability to participate in learning experiences, or both (27,43). Growth retardation is associated with a substantial reduction in mental capacity and adverse school performance, even in mild to moderate cases, and ultimately leads to reduced work productivity (21,25).

There is a great deal of evidence supporting the above conclusions. Findings from the Institute of Nutrition of Central America and Panama longitudinal study that followed individuals from childhood to adulthood indicate that nutritional interventions that improved growth rates in Guatemalan children also had important effects on height, fat-free mass, work capacity and intellectual performance (44). A study of over 3000 children in China found that children with lower height-for-age were consistently further behind in their expected school grade (45). Results indicate that the process of stunting, which results from prolonged nutritional deficiencies, may have persistent effects on cognitive development, which consequently compromises children's learning capabilities in school (32). Alba (30) examined the effects of preschool health and cognitive ability on eventual educational attainment. His results indicate that both preschool health status and preschool cognitive ability simultaneously and independently exert significant positive influences on educational attainment. A difference of one standard deviation in the *z*-score of height-for-age, accounts for 1.9–2.6 more years of school attendance (a significant predictor of national economic growth; see below). According to human capital theory, Maglen (46) maintains that there is a direct causal effect running from schooling to wages and this causality is due to increases in productivity that education confers on the more schooled workers. Galor and Mayer (32) also conclude that to achieve the greatest human capital investments, policies promoting education must be carefully complemented with policies that promote the satisfaction of basic needs and health. Addressing micronutrient malnutrition is one very important component of such investments.

Available estimates of the impact of cognitive achievement on wage rates in developing countries for urban Kenya and Tanzania (47), for Ghana (48) and in rural Pakistan (24) suggest that child nutrition/health and schooling act through cognitive achievement to significantly increase wages and economic productivity (24,49). Galor and Mayer (32) show that when families cannot supply their basic needs, (including but not limited to nutritional needs), their compromised health may give rise to a condition that does not disappear when funds are made available for education, but not for basic health needs. As a result, inadequate nutrition in children may lead to low levels of education and therefore to an intergenerational state of poverty.

Glewwe and Jacoby (50) found that children in low income countries often delay primary school enrollment as a rational response to early childhood malnutrition. The cost of the average delay is ~6% of an individual's lifetime wealth. These results indicate that early childhood nutrition interventions can lead to substantial increases in lifetime wealth. Recent empirical findings confirm a positive relationship between wages and academic achievement, as measured by test scores, in both developed (51,52) and developing countries (47). With the general tendency in many developing economies to move toward greater dependence on global markets, the economic impact of nutrition for poor people may increase with better incentives and rewards for greater productivity (24). This point is particularly relevant to the information revolution, in which cognitive capacity is critical for technical adaptations and competition in global markets. Based on these findings, if malnutrition does compromise school performance and school performance is an important determinant of individual economic productivity, then economic growth and improved nutrition can be mutually reinforcing (27).

Investment in education leads to the accumulation of human capital, which is key to sustained economic growth and increasing incomes (28). For example, the World Bank (28) found that differences in the educational level of the labor force explain ~20% of the differences in growth across states in Brazil. Arcand (53) shows that nutrition has substantial effects on economic growth both directly and indirectly through life expectancy and schooling. Barro (54) concluded from his study of the health and human capital of 100 countries observed from 1960 to 1990, that years of schooling at the secondary and postsecondary levels for males ≥25 y of age showed a significantly positive effect on economic growth. Sadly, his results also showed that female schooling was not significantly related to subsequent growth, but was indirectly important for overall economic development because there was a strong correlation with fertility rates. Studies from the World Bank in 1980 and 1981 claim that the average social real rate of return to primary schooling in low income countries is 24% (24). Their regression results show that the rate of return to schooling is

~5.9% for the population of young adults and adolescents in these studies.

Although the education systems of developing countries are often weak, they are one of the primary mechanisms available to nurture new ideas, build human capital and promote national capacity to participate in an increasingly information-oriented world. Primary education alone is the single largest contributor to growth in both the cross-country and cross-regional comparisons and the within-country analyses carried out to explain the East Asian "miracle" of development (28). A people-based development model integrates the physical and mental capacity of children with education to build national human capital. Because the educational systems in developing countries are often lacking resources, the educational outcome for students should be very sensitive to the degree to which children are able to capture the full intellectual potential of their schooling.

As with most demographic models, what happens early in life has a disproportionate impact on the outcome for the population. This means that the potential gains from nutritional interventions are great. For example, during the six years of the comprehensive *Nutrition and Child Development Project*, summing up all the potential productivity gains from reducing iodine and iron deficiency and stunting, Uganda would be expected to benefit from $54 million (on a present value basis) in productivity gains (2). The productivity gains and benefits over the six years of the project would include 237,000 lives saved, higher IQs for 210,000 newborn infants and healthier children. Such accomplishments would result in fewer grade repeaters, lower education costs and lower health expenditures (2).

Micronutrient sufficiency and national economic development. Malnutrition impacts national economic development in two ways (55). First, individual productivity is lost, thereby impacting directly on national productivity. Second, malnutrition places increased demands on social services and public revenues that indirectly absorb economic productivity. The estimates of the economic losses from malnutrition are: *1*) for human productivity, in the range of 10–15%; *2*) for gross domestic product (GDP), in the range of 5–10%; and *3*) for children's disability-adjusted life years, in the range of 20–25% (56). Economic productivity is compromised for those who need it most, the poor (56). The World Bank World Development Report 1993 estimates that deficiencies of vitamin A, iodine and iron alone could lower GDP in developing countries by as much as 5%, but addressing the deficiencies comprehensively would cost less than one-third of one percent of GDP (13).

As outlined in this paper, the link between health and micronutrient status and human capital has a major impact on national economic development. In response to this growing recognition, the history of development economics has shown a gradual shift from mathematical planning models to those models emphasizing people as the fundamental cause of development (48). Fogel (34) contributed greatly to this transition with his analysis of the industrial revolution in the United Kingdom in which he concludes: "Much of this gain was due to the improvement in human thermodynamic efficiency. The rate of converting human energy input into work output appears to have increased by 50% since 1789." Therefore, it is healthier, more productive populations that contribute to greater economic growth (49,53). Fogel (41) estimates that half of the economic growth of the United Kingdom after the industrial revolution was due to the increased capacity of its people and can be explained by nutrition's impact on human health and life expectancy. If creativity and working capacity were the forces behind the industrial revolution, then cognitive and intellectual capacity, as well as overall individual economic productivity will also be critical to national development in the information revolution.

Ways forward

The links between poverty and micronutrient malnutrition are clear. This connection extends from the level of the individual, to the community, and to the nation. The literature argues causality both ways: poverty creates micronutrient malnutrition and micronutrient malnutrition causes poverty. Perhaps it is best to describe this relationship as the PMM trap. The trap is a negative feedback cycle where the forces of one condition reinforce the other. To move out of this state, much like changing states of matter in the physical environment, requires outside inputs. There are many forces that create and keep people in this PMM trap. For most developing countries, agriculture is the largest sector of the economy and employs the majority of the work force. For that reason, making agriculture more efficient and integrating agricultural and human development is critical to both long-term economic growth and a transition to an industrial or information-based economy (57).

Because the poor spend a large proportion of their income on food, increasing production efficiency lowers food prices disproportionately and positively affects the poor. If the poor recognize the importance of micronutrients, they could use this increase in disposable income to increase the diversity of their diets and micronutrient intake. The problem, particularly for sub-Saharan Africa, occurs because the trade tariffs and subsidies that protect the domestic producers of the Organization for Economic Cooperation and Development (OECD) countries block the expansion of developing countries' agricultural systems (58). These subsidies represent more than the combined GDP of all sub-Saharan countries. Without access to those markets, how will their agricultural sectors develop, and how will transitions be made and poverty alleviated?

The way forward has many potential routes. These range from broad approaches directed at economic growth that reduces poverty, to targeted programs that supply micronutrients as a supplement. Supplement-based solutions have been widely used because of their apparent cost-effective system of micronutrient delivery, but questions remain as to their sustainability. Fortification, plant breeding, biotechnology, improved food processing and education all provide useful strategies to address the widespread problems of micronutrient deficiencies (6).

All of these approaches have a role in the development sequence to alleviate malnutrition. Food-based solutions, although perhaps most important, have received less attention than other approaches. Due in part to the apparent cost effectiveness of supplement-based interventions and the need for donors to show short-term impacts, food-based solutions have not been popular. They take time and are complex in that they require interdisciplinary approaches, but they are likely the most effective means of addressing the problem at its source, as indicated in this supplement. Most food-based approaches function in a market environment (unlike pill-based programs), where they succeed because the private sector adopts the technologies or information. In these cases, not only are micronutrients supplied, but their delivery becomes a more integral part of local economies. A development strategy that combines the comparative advantages of many approaches, appropriately tailored and sequenced, would seem a prudent strategy.

Educational campaigns that stress the importance of a diversified diet are also vital. Simply helping consumers to understand the interactions between products they ingest, such as iron inhibitors that occur in tea and coffee, could improve overall nutritional status. In a recent study in Nepal, only 38.1% of participants in a nutrition and gardening development project and 13.3% of controls (nonparticipants) were able to identify the cause of night blindness even though the condition is widely recognized in this region (59). Education that engages civil society in ways that encourage the public to be active participants in the demand for micronutrient adequacy—not just the "target" of imposed interventions—is a most effective way to intervene (4).

Two elements are lacking. First, for governments and donors to efficiently address the problem, those in nutrition and agricultural sciences must collaborate to develop an integrated conceptual model that provides a systematic mechanism to analyze food systems and determine the constraints that prevent the delivery of micronutrients to the individual. Such analysis should parallel other rapid appraisal techniques used in development and provide a framework to identify the most cost effective approaches to the delivery of nutrients. Second, and most important, there is not sufficient awareness at the level of policy makers in both developed and developing countries of the true costs of malnutrition. President Bush has made development and poverty alleviation one of the three pillars of the National Security Strategy, signaling for perhaps the first time that the clear link between international poverty and domestic security justifies a major increase in development assistance. It is time to reevaluate our approach in light of the emerging importance of the PMM trap and commit new funds to support new and integrated approaches. Clearly the evidence, outlined here and elsewhere (1,32,53), indicates that if the goal is to eliminate poverty, development must address the importance of nutrition in building human capital as the first and fundamental step to reducing poverty and creating a more productive and secure world.

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