

Malnutrition, Poverty and Intellectual Development

Research into childhood nutrition reveals that a poor diet influences mental development in more ways than expected. Other aspects of poverty exacerbate the effects

by J. Larry Brown and Ernesto Pollitt

The prevalence of malnutrition in children is staggering. Globally, nearly 195 million children younger than five years are undernourished. Malnutrition is most obvious in the developing countries, where the condition often takes severe forms; images of emaciated bodies in famine-struck or war-torn regions are tragically familiar. Yet milder forms are more common, especially in developed nations. Indeed, in 1992 an estimated 12 million American children consumed diets that were significantly below the recommended allowances of nutrients established by the National Academy of Sciences.

Undernutrition triggers an array of health problems in children, many of which can become chronic. It can lead to extreme weight loss, stunted growth, weakened resistance to infection and, in the worst cases, early death. The effects can be particularly devastating in the first few years of life, when the body is growing rapidly and the need for calories and nutrients is greatest.

Inadequate nutrition can also disrupt cognition—although in different ways than were previously assumed. At one time, underfeeding in childhood was thought to hinder mental development solely by producing permanent, structural damage to the brain. More recent work, however, indicates that malnutrition can impair the intellect by other means as well. Furthermore, even in cases where the brain's hardware is damaged, some of the injury may be reversible. These new findings have important implications for policies aimed at bolstering achievement among underprivileged children.

Scientists first investigated the link between malnutrition and mental performance early in this century, but the subject did not attract serious attention until decades later. In the 1960s increasing evidence of undernutrition in indus-

trial nations, including the U.S., along with continuing concern about severe malnutrition in developing countries, prompted researchers to examine the lasting effects of food deprivation. A number of studies in Latin America, Africa and the U.S. reported that on intelligence tests children with a history of malnutrition attained lower scores than children of similar social and economic status who were properly nourished. These surveys had various experimental limitations that made them inconclusive, but later research has firmly established that undernutrition in early life can limit long-term intellectual development.

Worry over Brain Damage

For many years, scientists considered the connection between nutrition and intellectual development to be straightforward. They assumed that poor nutrition was primarily a worry from conception to age two, when the brain grows to roughly 80 percent of its adult size. In this critical period, any degree of malnutrition was thought to halt the normal development of the brain and thereby to inflict severe, lasting damage.

Gradually, though, investigators recognized that the main-effect model, as we have termed this view, was too simplistic. For instance, the emphasis on

HEALTHY BREAKFAST provided to schoolchildren helps them avoid malnutrition and its attendant problems. A growing consensus indicates that meeting nutritional requirements throughout childhood is essential to full intellectual development. The program providing food to this kindergarten in Central Falls, R.I., is funded by the National School Breakfast Program.



STEVEN LEHMAN SABA

the first two years of life proved somewhat misguided. Brain growth in that period is not always terminated irreversibly in undernourished children. Rather it may be put on hold temporarily; if diet improves by age three or so, growth of the brain may continue at close to a normal pace. Conversely, injury to the brain can occur even when a child suffers malnutrition after the first two years of life—a sign that providing adequate nutrition throughout childhood is important to cognitive development. Focusing exclusively on the first two years of life is thus inadequate.

Furthermore, although severe underfeeding in infancy can certainly lead to irreparable cognitive deficits, as the

main-effect model predicts, the model cannot fully account for intellectual impairment stemming from more moderate malnutrition. This flaw became apparent in the 1960s, when researchers showed that mildly undernourished children from middle- or upper-income families (whose nutrient deficits stemmed from medical conditions) did not suffer the same intellectual troubles as did mildly underfed children in impoverished communities. If poor nutrition impaired cognition only by structurally altering the brain, the two groups should have performed alike. Something else had to be at work as well. In other words, factors such as income, education and other aspects of the environ-

ment could apparently protect children against the harmful effects of a poor diet or could exacerbate the insult of malnutrition.

No Energy to Learn

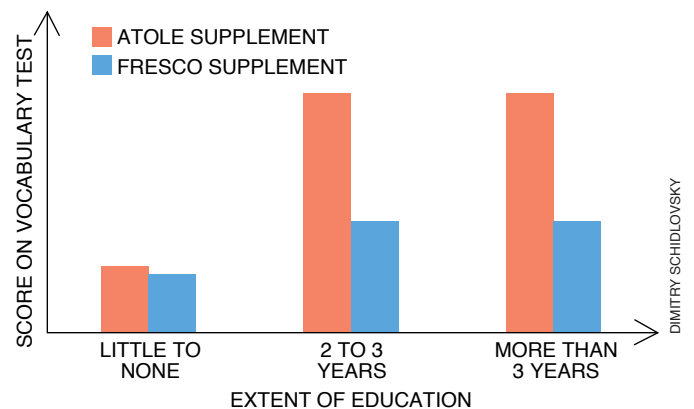
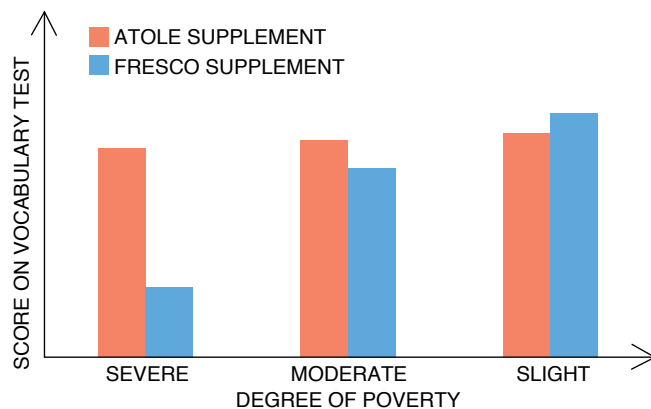
In the 1970s research by David A. Levitsky and Richard H. Barnes of Cornell University helped to clarify how malnutrition might hinder cognitive development in ways other than injuring the brain. Levitsky and Barnes studied rodents to examine the effects of malnutrition. Levitsky concluded that the malnourished animals performed less well on tests of mental ability, such as maze running, not because they suf-



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Effects of Poverty and Malnutrition: The Guatemalan Project

In a project carried out by the Institute of Nutrition of Central America and Panama, children and young adults in Guatemala who had received nutritional supplements in infancy were studied to assess the influence of early diet and poverty on later intellectual development. Subjects, including the boys at the right, were given a battery of cognitive tests. Individuals who regularly consumed a highly nutritious supplement called Atole before the age of two performed at about the same level on most tests, such as tests of vocabulary skills, regardless of economic status (*bottom left*). But the performance of those given a less nutritious supplement called Fresco varied with poverty level. Evidently, good nutrition early in life can help counteract the destructive effects of poverty on intellectual development. Among individuals who had more than two years of formal education, those who consumed Atole scored significantly higher than those who received Fresco (*bottom right*)—an indication that poor nutrition in infancy can subsequently undermine the benefits of schooling. —E.P.



ferred brain damage but mostly because, lacking energy, they essentially withdrew from contact with their peers and the objects in their environment. In addition, mothers coddled the less mobile infants, further hindering their growth and independence.

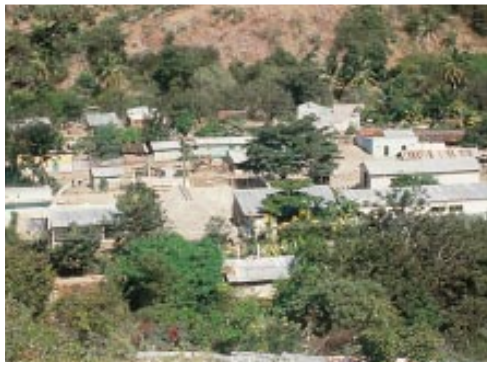
By extrapolation, the findings implied that cognitive disability in undernourished children might stem in part from reduced interaction with other people and with their surroundings. This fundamental shift in understanding produced increased optimism about the prospects for remediation; if decreased social interaction was partly at fault for cognitive impairment, then social and

intellectual remediation could presumably help make up for deficits in the youngsters' experiences.

Although the new ideas were compelling, scientists did not have much human evidence to buttress the changing views. A recent study by one of us (Pollitt) and several collaborators adds strong support to the notion that malnutrition affects intellectual development in part by compromising many different aspects of a child's development. The research also provides added insight into how poor diet and economic adversities during childhood combine to impede intellectual functioning later in life. Pollitt's collabora-

tors included Reynaldo Martorell of Emory University, Kathleen S. Gorman of the University of Vermont, Patrice L. Engle of California Polytechnic State University and Juan A. Rivera of the Institute of Nutrition of Central America and Panama.

The project was an extensive follow-up of Guatemalan children who were studied by other scientists many years earlier. In 1969 the Institute of Nutrition of Central America and Panama, with the help of various U.S. government agencies and private foundations, began a massive effort to examine the value of nutritional supplements in preventing the health problems of malnutrition. For



GUATEMALAN VILLAGE (above) was one of four towns where children and pregnant women received nutritional supplements.



PHOTOGRAPHS BY MARGARITA DE MARTINEZ/INCAP

COGNITIVE TESTS given as part of the Guatemalan project assessed the participants' abilities in areas such as vocabulary, reading comprehension, general knowledge and arithmetic.

eight years, residents of four villages in Guatemala received one of two nutritional supplements. When this phase of the study was being planned, researchers felt that protein was the most important nutrient missing from diets in developing countries. Therefore, project workers looked specifically at how children would respond to added protein in their diets. The mothers and children in two of the villages received a high-protein supplement called Atole (the Guatemalan name for a hot maize gruel). Inhabitants of the other two villages—who constituted the control group—received Fresco, a sweet, fruit-flavored drink, which contained no pro-

tein. Both supplements provided vitamins and minerals as well as calories; Fresco provided a third the calories of Atole.

When the study began, all pregnant women, and all children under the age of seven in the villages, were invited to participate. During the course of the study, children under seven who moved into the villages and women who became pregnant were also asked to join the project. More than 2,000 children and mothers participated between 1969 and 1977. Regular medical exams of the children revealed that both supplements improved the health of the participants, but Atole performed more impressively. For instance, in all four villages, the rate of infant mortality decreased. But in the villages that received Atole, infant mortality decreased 69 percent, whereas in villages receiving Fresco, the rate went down by just 24 percent. Also, only Atole improved growth rates in children under three.

Gains in Guatemala

In the follow-up study, carried out in 1988 and 1989, Pollitt and his colleagues visited the villages to assess how these early nutritional supplements affected intellectual development over the long term. More than 70 percent of the original participants—by then, ranging in age from 11 to 27 years old—agreed to take part in the follow-up. In particular, the team's analysis concentrated on the group of roughly 600 people who were exposed to Atole or Fresco both prenatally and for at least two years after birth. These adolescents and young adults took literacy, vocabulary and reading comprehension tests, a general knowledge exam, an arithmetic test and a standard nonverbal intelligence test. The researchers then determined how education and economic status (measured by house quality, father's occupation and mother's education) correlated with test scores.

The subjects who received Atole in early life performed significantly better on most tests of cognition than those who received Fresco. The strongest effects of Atole were observed among those at the low end of the social and economic ladder: these children performed as well as the more privileged children in their villages [see box on these two pages]. Atole thus served as a kind of social equalizer, helping children from low-income families achieve at the same level as their slightly more economically advantaged peers within the village. But the children of this study all lived in extreme poverty and did not perform at the same level as,

say, a child from a middle-income household in a more prosperous area of Guatemala. Hence, adequate nutrition by itself could not fully compensate for the negative effects of poverty on intellectual growth.

In addition, Atole appeared to have increased the advantage of education. With every additional year of schooling, the differences in achievement between the adolescents who received Atole and those who consumed Fresco increased. This result indicates that poor nutrition can essentially negate some typical benefits of education. In separate but related studies, Pollitt and his collaborators, working in Peru, and Sally Grantham-McGregor of the University of the West Indies, working in Jamaica, have demonstrated that learning capabilities are affected by how recently one has eaten. So breakfast every day before school is indeed important, particularly among children at risk for undernutrition.

The better long-term effects in the Atole group can largely be explained by the differences in the children's motor skills, physical growth, and social and emotional development. The youngsters who received Fresco in their early life suffered more physical disadvantages—a slower rate of growth and a slower rate of recovery from infection, for example—compared with those who received Atole. Because development was hindered, these children also learned to crawl and walk slightly later on average than the infants who received Atole. Pollitt and his colleagues speculate that for the infants who took Fresco, this limitation delayed the acquisition of the cognitive skills that children develop when they explore their social and physical environment.

Furthermore, because these undernourished toddlers remained small for their age, adults might have tended to treat them as if they were younger than their actual age. Such a response would very likely slow cognitive development, if the toddlers were not challenged—to talk, for instance—in the same way that other children their age were. Children who consumed Atole, in contrast, avoided malnutrition, grew up faster and were presumably exposed to more challenges in their social environment. Of course, the results do not rule out the possibility that the Fresco recipients may have suffered some degree of brain damage that impeded their later functioning. The findings, however, imply that additional factors, such as the child's social environment, played a major role as well.

The results in Guatemala are also consistent with the prevailing understanding of the interactions between poor

nutrition, poverty and education. Nutritional supplements combat the effects of poverty, but only somewhat. A well-nourished child may be better able to explore the environment, but an impoverished community may offer little to investigate. And although schools can provide much of the stimulation children need, early malnutrition can undermine the overall value of education. Most important, this study demonstrates that poor nutrition in early childhood can continue to hinder intellectual performance into adulthood.

Because the early planners of the Guatemalan study chose to examine protein, these results emphasize protein's importance to intellectual growth. The supplements also included calories, vitamins and minerals; consequently, their role should be taken into account, but

the arrangement of this particular study makes isolating the effects difficult.

Other work links essential vitamins and minerals to mental ability. For example, in one study in West Java, Pollitt and his colleagues showed a close association between iron-deficiency anemia (the most common consequence of malnutrition) and poor mental and motor skills in children. The researchers gave iron supplements to babies between 12 and 18 months old who were suffering from iron-deficiency anemia. The mineral significantly improved the infants' scores on mental and motor skills tests. Sadly, children with iron-deficiency anemia are more susceptible to lead poisoning, which produces its own set of neurological disorders that interfere with proper cognition. Consequently, poor children face a double

jeopardy: they are more likely to be anemic and more likely to live where lead poisoning is widespread.

Correcting and Preventing Impairment

Studies such as the one in Guatemala have prompted many scholars, including one of us (Brown), to suggest that when the social and economic aspects of a child's environment cannot be easily changed, providing adequate nutrition during infancy and later will at least lessen the cognitive deficits engendered by poverty. Nutritional supplements cannot by themselves reverse the long-term adverse effects of earlier undernutrition, however. The ideal would be to provide additional support, such as tutoring, opportunities to develop new social skills and guidance

Avoiding Malnutrition

Opinions on what constitutes malnutrition—and recommendations for avoiding the problem—have been refined over time. Early studies considered lack of protein to be the most troubling deficiency in the diets of underfed children, especially in developing countries. Ingested protein is broken down into amino acids, which are then



RODICA PRATO

DIETARY requirements for children can be met by eating several servings a day from each of five food categories.

recycled to build the specific proteins needed by the individual at any given time. Proteins form many structural elements of the body and carry out most cellular processes. By the 1970s, though, investigators had begun to worry about calories, too. When faced with a lack of calories, the body breaks down amino acids for energy instead of using them to make new proteins.

In more recent years, nutrition research has emphasized that shortages of vitamins and minerals—particularly vitamin A, iodine and iron—contribute to significant health problems. Vitamin A is important for good vision, bone growth, tooth development and resistance to infection. Iodine, which tends to be scarce in developing countries, is needed for proper operation of the central nervous system. Iron is a constituent of hemoglobin, which transports oxygen to tissues. Iron also helps the body fight infections; levels of the mineral are low in diets of many poor children in the U.S. Hence, most investigators now believe malnutrition is best avoided by a diet that supplies enough protein, calories, vitamins and minerals to ensure normal growth. Some standard guidelines for optimal nutrition in children are listed below. —J.L.B.

FOOD CATEGORY	SERVINGS PER DAY	SERVING SIZE*		
		AGE 1 TO 3 YEARS	4 TO 6 YEARS	7 TO 10 YEARS
WHOLE-GRAIN OR ENRICHED BREADS, CEREALS, RICE, PASTA	6 OR MORE	1/2 SLICE BREAD OR 1/4 CUP RICE OR NOODLES	1 SLICE BREAD OR 1/2 CUP RICE OR NOODLES	1 TO 2 SLICES BREAD OR 1/2 TO 1 CUP RICE OR NOODLES
VEGETABLES	3 OR MORE	2 TO 4 TBSP OR 1/2 CUP JUICE	1/4 TO 1/2 CUP OR 1/2 CUP JUICE	1/2 TO 3/4 CUP OR 1/2 CUP JUICE
FRUITS	2 OR MORE	2 TO 4 TBSP OR 1/2 CUP JUICE	1/4 TO 1/2 CUP OR 1/2 CUP JUICE	1/2 TO 3/4 CUP OR 1/2 CUP JUICE
LEAN MEATS, FISH, POULTRY, EGGS, NUTS, BEANS	2 OR MORE	1 TO 2 OZ	1 TO 2 OZ	2 TO 3 OZ
MILK AND CHEESE	3 TO 4	1/2 TO 3/4 CUP MILK OR 1/2 TO 3/4 OZ CHEESE	3/4 CUP MILK OR 3/4 OZ CHEESE	3/4 TO 1 CUP MILK OR 3/4 TO 1 OZ CHEESE

* Data from "Growth and Nutrient Requirements of Children." P. M. Queen and R. R. Henry in *Pediatric Nutrition*, edited by R. J. Grand et al. Butterworth, 1987

LISA BURNETT

Old Theory

MALNUTRITION

BRAIN DAMAGE

DELAYED
INTELLECTUAL
DEVELOPMENT

New Theory

BRAIN DAMAGE
(SOMETIMES REVERSIBLE)

LETHARGY AND
WITHDRAWAL

MINIMAL
EXPLORATION
OF ENVIRONMENT

MALNUTRITION

ILLNESS

DELAYED DEVELOPMENT
OF MOTOR SKILLS SUCH
AS CRAWLING AND WALKING

LOWERED
EXPECTATIONS
OF CHILD FROM
ADULTS BECAUSE
CHILD APPEARS
YOUNG

DELAYED
INTELLECTUAL
DEVELOPMENT

DELAYED PHYSICAL
GROWTH

POVERTY

LACK OF EDUCATIONAL
AND MEDICAL RESOURCES

DIMITRY SCHIDLOVSKY

MALNUTRITION HINDERS COGNITIVE ABILITIES through several interacting routes, according to recent research. Early models of malnutrition considered cognitive deficiencies to result only from damage to the brain (*top*). Now scientists also believe (*bottom*) that malnutrition alters intellectual de-

velopment by interfering with overall health as well as the child's energy level, rate of motor development and rate of growth. In addition, low economic status can exacerbate all these factors, placing impoverished children at particular risk for cognitive impairment later in life.

from an involved parent or another concerned adult. Recent studies have shown that enriched education programs for children in economically impoverished communities can often ameliorate some of the problems associated with previous malnutrition.

To have the best chance at being useful, such intervention should be comprehensive and sustained. Most undernourished children face persistent challenges that can exacerbate the effects of underfeeding. They frequently live in areas with substandard schools and

with little or no medical care. Their parents are often unemployed or work for very low wages. And the children may suffer from illnesses that sap energy needed for the tasks of learning.

On balance, it seems clear that prevention of malnutrition among young children remains the best policy—not only on moral grounds but on economic ones as well. The U.S., for example, invests billions of dollars in education, yet much of this money goes to waste when children appear at the school door intellectually crippled from undernutri-

tion. The immediate expense of nutrition programs and broader interventions should be considered a critical investment in the future. Malnutrition alters educational preparedness and, later, workforce productivity, making it an unacceptable risk for its victims as well as for a nation's strength and competitiveness. Steps taken today to combat malnutrition and its intellectual effects can go a long way toward improving the quality of life—and productivity—of large segments of a population and thus of society as a whole.

The Authors

J. LARRY BROWN and ERNESTO POLLITT have collaborated for several years on the policy implications of childhood nutrition. Brown, director of the Center on Hunger, Poverty and Nutrition Policy at Tufts University, is also professor of nutrition and health policy at the School of Nutrition Science and Policy and at the School of Medicine. Pollitt is professor of human development in the department of pediatrics at the School of Medicine at the University of California, Davis, and is also a member of the Program of International Nutrition.

Further Reading

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THE EFFECTS OF IMPROVED NUTRITION IN EARLY CHILDHOOD: THE INSTITUTE OF NUTRITION OF CENTRAL AMERICA AND PANAMA (INCAP) FOLLOW-UP STUDY. Edited by Reynaldo Martorell and Nevin S. Scrimshaw. Supplement to *Journal of Nutrition*, Vol. 125, No. 4S; April 1995.
THE RELATIONSHIP BETWEEN UNDERNUTRITION AND BEHAVIORAL DEVELOPMENT IN CHILDREN. Edited by Ernesto Pollitt. Supplement to *Journal of Nutrition*, Vol. 125, No. 8S; August 1995.