MALNUTRITION AND SOCIAL DEVELOPMENT: A COMMENTARY

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CHAPTER I

INTRODUCTION

This investigation is concern primarily with the state of knowledge on malnutrition, hunger, and behavior. This area of interest has recently became the major focus of the research efforts of social scientists who contend that the changes in the habits of eating, poverty, and hunger have an important impact on the social development of the individual and his role in society. An attempt is made in this research to point out the pertinent research finding and indicate what correlations may exist between behavior and malnutrition.

Nutrition is one of the most pervasive factors influencing growth, development, and health. It is, in fact, central to child development.

It has long been recognized that nutritional deficiencies, either of individual nutrients or of total food intake, retard physical growth and delay sexual maturation. Similarly, malnutrition and infection work synergistically and may leave in their wake permanent growth retardation and increased susceptibility to disease. More recently, we have been concerned with the possible relationship between malnutrition
and retarded behavioral development. Although this relationship appears causal and clear cut in some areas, information is considerably less direct and more complex in others. What do we know? What remains unresolved? And what does it mean in terms of planning programs for the children of America?

Definition of Terms

Before embarking on a review of this complicated subject, we must define several terms. The first is "malnutrition" itself. Malnutrition is the state of impaired functional ability or development caused by an inadequate intake of essential nutrients or calories to provide for long-term needs. Malnutrition results in specific symptoms or conditions, such as anemia, goiter, vitamin deficiencies, or growth retardation. It may be subdivided into "severe" and "moderate" categories.

Severe malnutrition refers to marasmus or kwashiorkor, each of which results from prolonged protein and/or caloric restriction in early childhood. Marasmus is caused by inadequate food intake, particularly of calories, from birth or shortly thereafter. It is manifested in tissue wasting and severe growth retardation. Most often, marasmus occurs in infants when breast-feeding is prematurely terminated and substitutes for mother's milk are not available or are nutritionally inadequate. Marasmus is more common in urban than in

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rural areas of the world. Kwashiorkor results from inadequate protein intake and occurs when the child changes from breast or bottle milk to foods high in starch but low in protein. It, too, produces extensive growth retardation plus water retention (edema), skin ulcers, and changes in the color of the hair to red or blonde. Both marasmus and kwashiorkor lead to early death if untreated.

A much larger percentage of the world's children suffer from what is being called "moderate malnutrition" or chronic undernutrition, which occurs when both quantity and quality of food intake are restricted. Although not death-threatening, as is severe malnutrition, the morbidity rate is high; the child grows at a much slower rate than normal and is more susceptible to such childhood diseases as measles, diarrhea, or pneumonia. The specific clinical nutritional disorders include anemia, rickets, and goiter. Most nutritional problems reported in U. S. children appear to fall in the "moderate" category.¹

Hunger is the psychologic and physiologic state resulting when there is unsufficient food to meet immediate energy needs. It is easily and immediately relieved with food, whereas malnutrition requires prolonged rehabilitation and may leave lasting effects. Hunger and malnutrition are not synonymous, although they are clearly interrelated.

Review of the Literature

Severe Malnutrition

Most of the data on malnutrition and mental development come from studies utilizing severe dietary restrictions in animals, as a means both to heighten measurable consequences and to duplicate protein-calorie malnutrition seen in man. Maternal nutritional deprivation sufficient to produce low-birth-weight infants has also been demonstrated with experimental animals. These data have been amply reviewed in recent reports.¹ Only a summary of pertinent points and newer findings is included here.

Animal studies. Restricted intake of either calories or protein slows growth rates. Depending on the age at which deprivation and rehabilitation occur, the effect on total body weight may or may not be permanent. There are also differential effects on the body organs. Although the brain and central nervous system apparently are relatively spared, moderately severe early nutritional deprivation, sufficient to

restrict physical growth by 40 to 50 percent in animals, significantly reduces brain size and the number of brain cells and alters lipid and enzyme organization. Maternal malnutrition during pregnancy also decreases the number of brain cells in the infant. A combination of prenatal and early postnatal malnutrition has a cumulatively greater effect than either alone. It is pertinent to note that neuronal development is maximal during the later periods of gestation in the rat, with glial and myelination occurring somewhat later during the suckling period. Recent reports suggest that maternal malnutrition during gestation primarily affects the cerebrum and that the other areas of the brain are relatively unaffected; postnatal caloric restriction in rats has its greatest effect on the cerebellum and on neuromotor development.¹ If these findings are confirmed in man, the differences in structural impact could have important consequences in terms of behavior.

Behavioral alterations are seen in rats and other species subjected to prenatal and/or postnatal dietary restric-

tion. These effects include reduced exploratory behavior and problem-solving ability, apathy, and heightened irritability.¹ Several studies indicate that the behavioral consequences of maternal dietary restriction may carry over to the second successive generation, even when the offspring have been adequately nourished. It is not yet clear whether these effects are due to (a) "nutritional imprinting" of genetic material, as suggested by Munro and Armendares and co-workers; (b) mediation by means of endocrine changes, as theorized by Zamenhof et al.; or (c) animal correlates for the presumably more complex interrelation between short maternal stature, prematurity, perinatal mortality, and mental retardation.²

Human brain development. The rat is not an ideal model for studying prenatal and perinatal nutritional problems in man, unless the investigator is cognizant of the relative stage of development of the central nervous system. The conditions necessary for permanent neurologic changes in


the rat, e.g., 40 percent restriction of weight gain, are rarely seen in man, except, perhaps, in early marasmus or in "failure-to-thrive." The head circumference and brain size of the failure-to-thrive child are reduced, particularly in populations where women are chronically undernourished. Children who have died of marasmus during the first year of life have significantly fewer brain cells compared with normal children; surprisingly, these findings are comparable to the data on rats.

The neurologic consequences of gross growth retardation or of nutritionally induced dwarfism appear to be permanent in animals and, probably, in man. This is supported by the studies on children hospitalized for marasmus, kwashiorkor, or failure-to-thrive. These have been summarized and interpreted by Read, Klein et., Pollitt, and Cravioto, DeLicardie, and Birch.\(^1\) The impact of nutritional deprivation is related to its severity and the age at onset. In line with this, marasmus appear to be more detrimental to behavioral development than kwashiorkor, probably because marasmus occurs earlier. Cravioto and co-workers have variously described the critical period as being under six months of age or as an "untreated epi-

sode... longer than four months, particularly during the first few months of life," whereas Hertzig et al. state that severe malnutrition requiring hospitalization at any time during the first two years of life will have equally adverse effects. Maternal malnutrition during pregnancy apparently increases the deleterious effects of malnutrition on growth, neurologic development, and behavior. A challenging observation is that of Stein and co-workers who have followed the children of women who were pregnant during the Dutch famine of World War II. They report little or no effect of this relatively brief period of severe restriction on adult performance. Maternal reserves may have protected the fetuses; on the other hand, social-environmental factors were closely related to adult performance.

Dobbing reports that there are two relatively distinct periods in the multiplication of human brain cells. The first occurs in the second trimester of pregnancy during which there is a rapid increase in the number of neuronal cells; the second period extends through the first two years


2Dobbing, "Lasting deficits and distortion."
of life and is characterized primarily by glial cell development and synaptic formation. The processes of dendritic growth, arborization, and establishment of synaptic connections that occur during the second period probably are more important to human mental performance than is neuronal number. Furthermore, neuronal multiplication in man is relatively protected in utero, and major nutritionally induced problems would be expected later when fetal needs are greater. Thus, the period from birth through two years of age might provide an opportunity for potential recovery or rehabilitation.

The duration of nursing is an important factor in the infant's growth. Although the quantity of mother's milk may be somewhat reduced, it is clear that the quality is not seriously affected by levels of malnutrition that permit delivery of a healthy infant. Differences in age at weaning might partially explain the wide range of behavioral results reported for undernourished human populations; unfortunately, few studies comment on individual or local breast-feeding practices during the early months of life.

Human behavioral retardation. Some studies suggest that there may be selective effects of severe malnutrition on behavioral functions. Data from Guatemala indicate that rehabilitated children exhibit reduced levels of attention to novel stimuli; an earlier study showed that similar
children performed poorly on tasks involving a high level of sustained attention. Other recent data indicate that severe malnutrition impairs the reading, spelling, and arithmetic skills of recovered school-age children, perhaps as a consequence of the impaired auditory-visual and visual-kinesthetic integration reported for a comparable group of children.

In a carefully conducted study, Levitsky and Barnes attempted to separate cognitive or learning factors from other aspects of behavior in rats fed low-protein diets from weaning. They found that, in the absence of a food reward, the malnourished animals explored a maze less actively than well nourished controls. Furthermore, the controls learned enough to improve their performance when later placed in the same maze with a food reward; the deprived animals did not. Following nutritional rehabilitation, the malnourished rats performed at about the same level as animals with no experience in the maze. It is suggested that

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malnutrition functionally isolated the animal from the environment, at least in terms of incidental learning and memory. This concept is supported by the similarity in behavioral (and central nervous system structural) characteristics of severely malnourished experimental animals and those kept in isolated environments during infancy.¹

Zimmermann and his colleagues conducted malnutrition-behavior studies on non-human primates and concluded that the effects of malnutrition are subtle and may be exerted through impaired development of motivational systems.² Young Rhesus monkeys were fed high-protein (25 percent by weight) or low-protein (2 to 3.5 percent by weight) diets starting at about three, seven, or thirteen months of age. The low-protein diet had no apparent adverse effect on physical activity and movement in the cage. These monkeys developed an elevated drive for food, particularly high-protein foods, and were relatively aggressive in group situations involving a food stimulus. Without the food stimulus, their behavior was generally withdrawn. Learning capacity did not appear deficient, but curiosity was diminished. The malnourished animals exhibited a lower level of responsiveness to novel stimuli and decreased puzzle-solving ability in the absence of a food reward. They demonstrated heightened emo-


tional fear and refused to enter a situation involving a new object. Their social behavior and peer group interaction was markedly altered. Although aggressive when approached by other animals, the protein-deprived animals spent much time gazing blankly around the room, walking aimlessly, engaging in self-play, or sitting in a curled position. They tended to sit apart from other monkeys to avoid contact. The investigators described the malnourished monkey as "reactive to stimulus changes, fearful yet aggressive in a social situation. His behavior is, in a sense, very maladaptive to a changing environment, and no environment changes more rapidly than the social situation." Whether these characteristics would change with refeeding and subsequent normal growth is under study.

Chronic Undernutrition

Compared with severe malnutrition, there are fewer studies on moderate malnutrition, and the data are more confusing. Certainly the effects, if any, should be less deleterious.

Nearly all reported studies on moderate malnutrition have been retrospective, with no detailed information on the nature, severity, or duration of malnutrition other than that inferred from anthropometric measurements and dietary assessment at the beginning of the study. In this context, it is pertinent that Pollitt and Ricciuti have pointed out that the
height of children in the slums of Lima, Peru, is associated with a number of biologic and social variables which also contribute to mental development.\(^1\) They state that it is dangerous to attribute differences in mental development to malnutrition alone, particularly in field studies in which malnutrition is defined by physical growth parameters. The non-nutritional factors become increasingly important as the severity of nutritional insult diminishes.

Using growth retardation as an indicator of prior nutritional status, Cravioto and co-workers found that differences in weight among rural Guatemalan children were accompanied by differences in neuro-integrative abilities up to age eleven; this relation was not found in well nourished, urban children.\(^2\) However, these investigators were unable to establish malnutrition \textit{per se} as the causative agent; social factors could not be ruled out.

**Mental development.** Stoch and Smythe have reported on a follow-up study of South African Negro children.\(^3\) Children who had been grossly underweight in early childhood had signi-


significantly lower IQ's at school age and again in adolescence than did a control group. Again, the social-environmental differences, plus differences in school participation, cloud interpretation of these data.

A group of twenty-four inadequately and sixteen adequately nourished children from a nursery school in a lower-middle-class area of New Delhi, India, was studied over a three-year period; nutritional status was defined in terms of expected growth.\(^1\) The home environments were described as "respectable," when parents had an active interest in their children's education. The IQ's were not as low as reported in Africa and Latin America. Nevertheless, differences in head circumference, mean IQ, and visual-motor development were found between the adequately and the inadequately nourished children, suggesting a lag in development in the latter group. The girls in the inadequately nourished group appeared to be more handicapped than the boys.

An eight-year study of Mexican school children from different social classes has shown that intellectual performance when the child enters school is apparently related to his nutritional history, defined in terms of anthropo-

metric measures. However, after four or five years of school attendance, differences to IQ appeared to be related more to socioeconomic conditions and regularly of school attendance than to a history of malnutrition.

Monckeberg and co-workers have reported that the IQ of malnourished, young children in the slums of Santiago, Chile, is lower than that of comparable, adequately nourished children or of children from upper-class families. However, the child's IQ closely parallel that of the mother, suggesting that she may not have been able to provide an adequately stimulating environment. It is pertinent that the mother is central to the nutritional status of the child, involved as she is in food preparation, decision on whether and how long to breast-feed, person hygiene, and a host of other factors in the home.

Nutritional status also correlates closely with the number and spacing of young children in the family, the total number of children, quality of housing, and socioeconomic conditions, not all of which the mother can control.

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young children in the United States.\(^1\) Several studies have been undertaken to determine whether anemia is in any way related to retarded mental development and behavioral problems. One study focused on twenty-eight children under age three with iron deficiency anemia on admission to an urban hospital. A year after treatment, these children exhibited a range of behavioral problems not found in a control group.\(^2\) However, the investigators attributed the problems to parental failure and family disintegration.

In another study of Head Start Children in New Orleans, children with anemia and poorer physical growth had the lowest IQ scores, suggesting that anemia interacts with chronic undernutrition to affect performance. The families of these children also were "disadvantaged" economically and educationally. Thus the conclusion is supported that multiple deprivations may exert an additive effect on psychologic function. In a similar but somewhat larger preschool program in Philadelphia, a relation between anemia and various behavioral measures of attentiveness was found.\(^3\) No effect of iron ther-


Wray cites studies indicating that the average IQ of a child from a family of five children is 22 points below that of an only child.\textsuperscript{1} He states that 27 percent of the children in a poor, rural, Latin American community were from families with five or more children. Whether the effect of the number of children on psychologic development is mediated through crowding, quality of the housing, or lack of "teaching" by busy parents is not clear; however, a recent mental development study reports that these factors were correlated with psychologic test scores and nutritional status in a rural area.\textsuperscript{2}

Carefully planned, prospective studies on high-risk populations are needed. Several such studies are under way, using either the intervention model or an ecologic approach, wherein a wide variety of life conditions are observed.

**Anemia**

Most nutritional problems recently identified in the United States are in the category of "dietary subnutrition," and, as such, are less severe than those prevailing in developing countries. Anemia is by far the most prevalent problem of


young children in the United States.

These and other studies in both animals and man have been reviewed recently.¹ The data suggest that anemia is associated with a marked decrease in attentiveness, less complex or purposeful activity, a narrower attention span, decreased persistence, and a decrease in voluntary activity. As with other forms of malnutrition, the effects of anemia are related to its severity. Children appear to be more susceptible than adults, probably because of the combined impact of anemia and rapid growth. Even in children, significant performance decrements probably do not occur until hemoglobin levels are below 10 gm. per 100 ml. No data suggest permanent neurologic damage from anemia during either pregnancy or early childhood or a sizeable effect on intelligence as measured by standard IQ tests.

Stimulation as a Contributing Factor

As proposed previously, children hospitalized with protein-calorie malnutrition presumably have reduced opportunities for social interaction and cognitive stimulation before, during, and, possibly, for a period after hospitalization.² On the other hand, Geber and Dean observed that


behavioral recovery accelerated when the mother was in the hospital with the child; Yaktin and McLaren have confirmed this in a more carefully designed study of Lebanese children.¹ Children less severely malnourished are listless, apathetic, and disinterested in their environment; such behaviors would, in turn, adversely affect cognitive development apart from any nutritional insult to brain structures. Thus, malnutrition, inactivity, and disinterest form a vicious cycle which retards behavioral development, perhaps permanently.

Several recent studies reinforce this concept. Chavez and co-workers have studied children living under "normal" but low socioeconomic conditions in a rural Mexican community.² Seventeen children were born to mothers living under ordinary conditions; nineteen other mothers received supplements from the forty-fifth day of pregnancy through lactation, and their infants were supplemented from weaning. Physical activity was measured by the frequency with which the child's foot contacted a surface. By one


year of age, physical activity was significantly greater in the supplemented children. A sixfold difference was observed by two years. It is not apparent whether these differences were caused by adaptation to a low-calorie intake or by retarded physiologic development. A preliminary study by Heywood and Latham, using special monitoring equipment, indicated that the heart rate of malnourished but not acutely ill children was somewhat less than that of well nourished controls.\(^1\) In a more complete study, Klein and co-workers noted that severely malnourished infants had a reduced arousal level, as measured by heart rate acceleration, in response to novel stimuli; this pattern persisted even after recovery.\(^2\) Such a low level of activity and responsiveness would be expected to elicit less response from the mother, in turn contributing to retarded behavioral development.

Recently, Pollitt reviewed the literature concerning sucking and mother-infant interaction.\(^3\) He proposes that infant behavior may be a causal factor in nutritional marasmus and cites data showing that sucking is significantly reduced in premature and malnourished infants, thus contributing to


further malnutrition and to early weaning. He emphasized that maternal response to the infant is mediated in part by crying and activity, which are both reduced in malnourished children. He suggests that increased probability of malnutrition with increasing parity may be due to the fact that late-born children "conceivably receive less attention than needed, the problem being accentuated if late-born children are lethargic, possessing a limited behavioral repertoire which fails to attract maternal attention." Pollitt's thesis may be logically extended by noting that reduced mother-infant interaction would also retard behavioral development.

Although data do not provide conclusive evidence as to whether chronic undernutrition affects mental development, they do show the intimate interaction of nutrition, behavioral, and social variables. A major question that can now be posed is whether a combined program of nutrition plus stimulation would be more effective than either alone in overcoming the consequences of poverty and deprivation in undernourished children.

One study which addresses this problem was conducted in an experimental preschool, day care center serving a poor area of Cali, Columbia.\(^1\) All children born during a single

six-month period were identified, through growth retardation studies at age three years, as malnourished or adequately nourished. The program provided nutritional supplementation with or without special educational activities. Nutritional supplementation alone had no appreciable effect on psychologic test scores. Improved nutrition plus cognitive stimulation resulted in marked improvement in both malnourished and normal children; however, during the five months of study, the malnourished children did not achieve the same levels as the well nourished poverty group, and both groups were well below the performance of upper-class children. However, as the malnourished children remained in the nutrition-cognitive stimulation study for longer periods, performance on behavioral tests, as well as their general activity level and alertness, continued to improve markedly. These studies are being continued on similar malnourished children who are enrolled at age four, five, and six to determine the effects of longer periods "deprivation" vs. earlier intervention.

Numerous studies are under way throughout the world to determine the impact of malnutrition on the central nervous system and on behavior. Severe malnutrition during prenatal life and/or infancy in animals and man has been shown to decrease significantly the number of brain cells. Similar levels of malnutrition have been accompanied by behavioral alterations and/or mental retardation. Recent studies on non-human primates have shown that severe malnutrition in the young results in emotional maladaptations to a changing environment,
particularly in a social situation. These findings are most
provocative in terms of human malnutrition.

The effects of moderate malnutrition are not as clearly
established, particularly in man for whom environmental changes
frequently accompany malnutrition. Accumulating evidence sug-
gests that these factors may be equally important in effecting
behavioral changes. The most recent findings indicate that
behavioral alterations may be in specific areas rather than
"across the board" in terms of mental performance. Further-
more, rehabilitation programs may well require a combination
of medical, nutritional, and educational interventions.

Most human studies have been concerned with malnutri-
tion arising from inadequate total food intake or with im-
balances between proteins and calories. Only a few studies
have investigated iron deficiency anemia, probably the most
common nutritional problem in preschool children in the United
States. However, the limited data suggest that anemia results
in behavioral changes that interfere with learning. No neu-
rologic damage has been found to result from anemia occurring
during prenatal life and/or early childhood.
CHAPTER II

BEHAVIORAL CORRELATES OF MALNUTRITION

In focusing on the growth and development of the brain and central nervous system, predominate emphasis quite properly must be given to the physiological aspects of brain growth and maturation. Nevertheless, any such discussion must also encompass the varied environmental factors which contribute to CNS development plus the functional consequences of normal or aberrant brain development. One of the important environmental factors is nutrition. The major functional concerns are the intellectual, motivation, and social capabilities of the individual—particularly when viewed in terms of the demands and expectations of the culture in which the individual lives.

An awareness that there may in fact be a relation between nutrition and behavior has been unfolding for the past quarter century. A detailed study of the impact of starvation on the behavior of adult male volunteers was conducted during the 1940's.\(^1\) Although traumatic changes in behavior were ob-

served as hunger progressed into starvation, the changes were not permanent and could be overcome through nutritional rehabilitation. Among the early reports of behavioral consequences in childhood arising from protein-calorie malnutrition in infancy were those by Gomez et al., in Mexico and Geber and Dean in South Africa.¹ Psychological changes, pronounced motor retardation, and decreased scores on standardized intelligence or development tests were reported.

Since 1960 there has been an acceleration of interest in the impact of malnutrition on behavioral development as the implications for public policy have become apparent. The early studies in Mexico and Africa were under the direction of pediatricians and were primarily clinical in their orientation. More recently behavioral scientists have become interested and concerned with this problem. This has not only broadened the capability for conducting well-planned multidisciplinary studies but also has heightened appreciation for the complexities of the question being asked. Cravioto and his colleagues have developed a thoughtful and thought-provoking series of studies in experimental animals and humans ranging from their early studies of neurosensory integration in children to recent investigations.

of styles of responding to cognitive demands. ¹ A number of carefully planned longitudinal intervention studies are currently underway in several countries which promise to contribute greatly to our understanding.

Space will not permit an exhaustive or even extensive review of the burgeoning literature on nutrition and mental development. The interested reader is referred to recent reviews by Read, Birch, and Riciutti and to several compendia of research reports. ² Furthermore, others have reviewed in this volume the current research bearing on the physiological changes in the brain which result from malnutrition.


Animal Studies

Non-primate animal studies show that severe restriction of protein and/or calorie intake in early life may permanently influence the growth and maturation of the brain. Among the changes which have been documented when severe malnutrition occurs during periods of rapid brain development are reduced brain weight, decreased brain cell number, less myelination, smaller neurons, and decreased cortical thickness. The same degree of malnutrition imposed after most cell division has stopped may reduce brain cell size but the reduction is reversible with refeeding.

Behavioral alterations are seen in adult rats and other species subjected to severe prenatal and/or postnatal dietary restriction even after they have been nutritionally rehabilitated. These effects include apathy, reduced exploratory behavior and motor performance, and lessened problem-solving ability plus heightened irritability, fearfulness, and motivation towards food.¹ Rats undernourished during infancy show a long-lasting, perhaps permanent, lowering of the stress-response system; they overreact to aversive or

startling phenomena. ¹

In a carefully conducted study, Levitsky and Barnes attempted to separate cognitive or learning factors from other aspects of behavior in rats fed low protein diets from weaning. ² They found that, in the absence of a food reward, the malnourished animals explored a maze less actively than well nourished controls. Furthermore, the controls learned enough under these "training" conditions so that they performed better when later placed in the same maze with a food reward; the deprived animals did not. Following nutritional rehabilitation, the malnourished rats performed at about the same level as animals with no experience in the maze.

It is suggested that malnutrition functionally isolates the animal from its environment, at least in terms of incidental learning and memory. This concept is supported by the similarity in behavioral (and central nervous system structural) characteristics of severely malnourished animals and those kept in isolated environments during infancy. ³

Levitsky and Barnes went on to show that isolation rearing had a greater adverse effect on malnourished rats than on


well nourished rats.\textsuperscript{1} Furthermore, handling malnourished animals on a regular basis increased the exploratory activity and decreased fear of new situations. Frankova also has found that fear-related behavior of rats raised on low protein diets (5 percent of calories) can be largely overcome by providing a period of familiarization in the avoidance conditioning test box prior to training.\textsuperscript{2} Following familiarization, the poorly nourished pups performed about as well as control pups.

Using increased litter sizes (4-17 pups/litter) to reduce nutritional intake of the pups. Frankova found that spontaneous activity (standing up) of 100-day-old control animals decreased with increasing litter size.\textsuperscript{3} Regular handling of the pups during nursing greatly increased the spontaneous activity of the adult animals. She further found that the size of the litter greatly modified maternal behavior. The mother with a small litter (4 pups) spent about 8 percent of her time actively involved with the young (grooming, moving them about, etc.) in the nest plus an additional 75 percent of her time passively inside the nest but available for nursing.

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The mother with a larger litter (17 pups) spent about 25 percent of her time actively involved with the young in the nest but was available for nursing only about 40 percent of the time; the remaining 35 percent of the time she was outside the nest and unavailable. In essence the mother gave less time to each pup in the large litters, a variable which could directly influence behavioral development.

Frankova has gone on to quantify the impact of low protein diets on rat maternal behavior. The frequency and duration of contacts between mother and individual infants on day 7 was reduced 75-90 percent in the low protein group.

Following up on this lead, Frankova then sought a means of stimulating the pups without introducing human variables. This was achieved by introducing into the cage for eight hours each day a virgin female littermate of the mother who had been previously exposed to suckling infant rats. By the end of lactation, those pups raised in the presence of the "aunt" showed more frequent rearing, exploratory behavior, sniffing, and manipulation of strange objects (rings, etc.) introduced into the cage. Conversely, the hyperexcitability of the low protein pups when confronted with new objects was markedly reduced by the exposure to the aunt. In general, the low protein pups raised with the aunt did as well as the control pups raised under traditional conditions.

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1S. Frankova, Personal communication (1973).

In summarizing her work Frankova hypothesizes that "for optimum development of the brain and of subsequent behavior, an adequate supply of both nutrients and external stimuli during the decisive developmental periods is essential. A typical picture of malnutrition involves reduction both of the available nutrients and of the environmental stimulation. Increased external stimulation compensates for the sensory impoverishment from the environment, it enhances the activity of various developing organs, and enforces activity of the CNS during the critical period when the developing brain depends greatly on the supply of external stimuli. It may be assumed that stimulation will potentiate adaptive processes which can result in more economic utilization of energy and nutrients, which is particularly important in animals with a low quantity of available food." If this is true, does the effect of stimulation supply equally to all behaviors, or only to selected ones? Is there a critical period early in development when stimulation must be provided or will it be equally effective later in life? What are the limits to the use of stimulation for overcoming the behavioral consequences of malnutrition?

**Subhuman Primate Studies**

Only a few studies have so far been reported in subhuman primates. Such data would help to bridge the gap between experimental animal observations and the situation encountered in the human.
A major stumbling block to research in this area has been the paucity of knowledge about subhuman primate nutrient requirements and difficulty in inducing protein-calorie malnutrition under conditions analogous to man. Deo and Ramalingaswami have produced kwashiorkor in young rhesus monkeys fed diets essentially devoid of protein but with adequate calories and other nutrients.\(^1\) These animals have been shown to have fatty livers, defects in immunologic capacity, changes in bone growth, and a reduction in regeneration capability of liver cells. This research group also has reported that these animals demonstrate abnormalities in the myelin sheaths of the peripheral nerves coupled with a slowing of motor nerve conduction.\(^2\) Further details of this work are presented elsewhere in this volume. On the other hand, Kerr and Waisman have produced growth retardation in rhesus monkeys fed low protein-low calorie diets (dilutions of Similac) in early infancy but they were unable to duplicate the clinical symptoms of kwashiorkor or marasmus in these animals.\(^3\) Riopelle, et. al. found that


rhesus females lost 30 percent or more of their body weight over a six-week period on diets containing protein at a level of 1.7 percent dietary calories; clinical kwashiorkor was not routinely observed.\textsuperscript{1} These investigators therefore selected 3.4 percent protein (1 gm/Kgm body weight/day) as the minimal dietary level for studies of maternal nutrition and infant development. In a preliminary report by Riopelle, this level of protein restriction did not have any significant adverse effects on birthweight or behavioral development during the first months of life.\textsuperscript{2} The studies are continuing.

Manocha and Olkowski have demonstrated the special vulnerability of the cerebellum and of neurons in young squirrel monkeys fed diets containing protein at the level of 2 percent (by weight) for 15 weeks.\textsuperscript{3} Altered enzyme patterns were also found.

Zimmerman and his colleagues have investigated the impact of low protein diets (1.9-3.3 percent of calories) on


behavioral development of the young rhesus.\textsuperscript{1} The diets were started at 3, 7, or 13 months of age and continued over a period of years. Even on these levels of protein, the animals gained some weight, but less than normal. The low protein animals showed no differences in scores on tests normally associated with learning capacity. Curiosity, discrimination, attention, and observing behaviors were markedly reduced. The malnourished monkeys demonstrated heightened emotional fear and refused to enter situations involving a new object. Their social behavior and peer group interactions were markedly altered. Whether these characteristics would change with refeeding is under study.

Elias and Samonds have raised infant cebus monkeys from 8-28 weeks of age on formula diets providing protein at 2.8 percent or 13 percent of calories or on a two-third reduction in total calorie intake from the 13 percent formula.\textsuperscript{2} Half of each group also was provided a stimulating environment or was raised in semi-isolation. The low protein diet severely retarded weight gain and skeletal growth; the calorie restricted animals were somewhat less growth retarded. No differences in perceptual or motor development were found among the various dietary and rearing conditions. Protein,


calorie, and social restriction all diminished exploratory behavior and activity. Protein restriction plus semi-isolation produced particularly severe behavioral impairment.

The incongruities of these data are apparent. Species differences can only partially explain the divergent results. The lack of impact of protein restriction during gestation on birthweight and on infant behavior in Riopelle's animals suggest that much lower protein intakes may be necessary to affect these variables in subhuman primates, at least under conditions of adequate calories in animals previously well nourished. Riopelle has reported some difficulty with high rate of spontaneous abortion in his animals fed 3.4 percent protein diets so that this may well be close to the minimum for sustaining pregnancy however.\textsuperscript{1} The simultaneous imposition of protein and calorie restriction would be of interest. On the other hand, the similarity is striking between Riopelle's negative data and the observation by Stein, et al. that there were little or no developmental consequences in children born to Dutch women who were pregnant during the relatively short but severe famine of World War II.\textsuperscript{2}

The Zimmerman and the Elias and Samonds studies do clearly suggest an impact of current undernutrition, particularly protein deprivation, on behavior. These studies are consistent in that the behavioral effects are more in the

\textsuperscript{1}A. J. Riopelle, Personal communication (1974).

affective and social domain than in the cognitive facet of development. The Manocha and Olkowski report supports these two studies on a physiological level. None of these investigators have yet reported whether the changes are reversible by refeeding.

Malnutrition and the Human Brain

Excellent reviews of the development of the human brain have been published by Dobbing and Dobbing and Sands.¹ They emphasize that the human brain undergoes an early growth spurt in the forebrain at 10-18 weeks of gestation but that the bulk of the growth occurs after mid-pregnancy and continues well into the second postnatal year. They propose that up to 5/6th of human brain development may be postnatal. It is further suggested by them that adverse effects of retarded intrauterine growth might not be expected unless that child is raised in an environment which is nutritionally, medically, and/or socially limiting. This hypothesis requires careful consideration and investigation.

In approaching the subject of nutrition and human development, it is important to emphasize that human malnutrition exists in varying degrees of severity.² The conditions


necessary for permanent neurological changes in the rat, e.g., 40-50 percent restriction of weight gain, are rarely seen in man except perhaps in early marasmus, kwashiorkor, or in "failure-to-thrive." The head circumference and brain size of the PCM or failure-to-thrive child are reduced, particularly in populations where women are chronically undernourished. Children who have died of marasmus during the first year of life have significantly fewer brain cells compared with normal children; these findings are comparable to the data on rats. Other effects of protein-calorie malnutrition on the microstructure of the human brain are unknown.

Engsner and his associates have conducted a careful study of head circumference and brain development in malnourished Ethiopian children.¹ They report that reduced head circumference is more pronounced in cases of marasmus than in kwashiorkor. On the other hand, transillumination and encephalographic measurements indicate reduced brain size relative to skull volume in kwashiorkor patients. Thus both groups show reduced brain size but the etiology may differ considerably—marasmus, which generally starts early and persists over time, may retard total brain and skull development whereas kwashiorkor, which generally starts after the age of two in this population, reduces the size of the brain after skull size has been achieved. These investigations simi-

larly report that the kwashiorkor child may be nutritionally rehabilitated almost to his anthropometric norm; rehabilitation of brain size in the marasmic child is less certain. It is of considerable interest that these investigators found that mild-moderate protein-calorie malnutrition did not markedly influence head circumference during the first two years of life in the Ethiopian children. Valquist has provided a more complete report of these investigations elsewhere in this volume.

Severe Malnutrition and Human Behavior

In spite of the widely held opinion that malnutrition in early life adversely affects mental development, the evidence from human studies is far from definitive. The situation in man is extremely complex.

Evaluating the nutritional status of an individual infant or child is very difficult; in a practical sense anthropometric measurements (height, weight, skin-fold, body proportions, etc.) provide the major source of information, hopefully supplemented with biochemical, dietary, illness, birthweight, and related family factors. Longitudinal data is far preferable to cross sectional measurements. The nature and duration of any illness are particularly important in this regard as prolonged infections may permanently change the rate of growth, decrease nutrient intake, alter family relationships, and, in some cases, directly influence neurological development... particularly during pregnancy and neonatal adaptation.
Similarly, behavior has many dimensions—sensory, perceptual, cognitive, motor and social. The choice of behavioral tests depends on the age of the child and the hypothesis under study. At present there is little or no agreement as to what tests are universally most appropriate, what ages should be tested to maximize predictability, nor how to separate the nutritional from the social-environmental factors in behavioral development.

In spite of these difficulties, certain patterns of behavioral correlates are emerging from the diverse studies around the world. Champakam et al. have shown defects in memory, abstract thinking, and verbal and perceptual ability in children severely malnourished in early life in spite of long-term nutritional supplementation in India.\(^1\) Pollitt has prepared a critical review of eight studies in which children hospitalized with severe protein-calorie malnutrition during the first two years of life were followed after nutritional rehabilitation.\(^2\) These encompassed subjects in Chile, Guatemala, India, Mexico, Peru, Venezuela, and Yugoslavia. Seventy cases of marasmus and 119 cases of kwashiorkor were included in these eight studies with psychological assessments completed at ages ranging from pre-school to


fourteen years. In the studies of children who had been diagnosed as marasmic, Pollitt concluded that when malnutrition resulted in severe retardation in weight gain (e.g. 50 percent below expected weight for age accompanied by reduced height) behavioral deficits were as much as 50 percent below the norms even when equated against children from comparable social groups. In one study (Yugoslavia) the weight deficit varied from 20-50 percent below standards; IQ scores at ages seven to fourteen years were below normal (70-90) in half the cases and none rated above the normal range. In general, kwashiorkor occurred at older ages. The degree of intellectual retardation appeared to be somewhat less than in the marasmus cases; the most severely retarded were cases hospitalized with kwashiorkor before the age of six months.

Comparable studies with severely malnourished children have been reported in the United States by Chase and Martin.¹ Nineteen infants hospitalized with severe malnutrition during their first year of life were studied again three and one half years later. A well nourished matched control group from the same ethnic and socio-economic population and born on the same day was included. The developmental quotient (DQ) in the control group averaged 99; in the malnourished group the average was 82. Surprisingly the most adverse effects were obtained in those children admitted to the hospital after the age of four months (DQ=70). Chase

and Martin interpret this as an indication of duration of severe malnutrition inasmuch as many of the children had gained little over their birthweight at the time of hospitalization.

A careful follow-up study of Jamaican boys hospitalized with protein-calorie malnutrition during the first two years of life has been reported recently by Hertzig, et al.\textsuperscript{1} Intellectual functioning was studied between the ages of six and eleven years. The 74 "index cases" were compared with the 38 male siblings next closest in age within the specified age range and also with 71 unrelated classmates or neighbors of the same social level matched for age and sex but having no history of hospitalization for malnutrition. The means for the Full Scale, Verbal, and Performance IQ scores were significantly lower for the index group, being 7-9 points below the comparison cases. Although the siblings were intermediate, they were not significantly different from the comparison group except on performance IQ. On Full Scale and Verbal IQ's, the siblings were significantly higher than the index cases, but not on Performance IQ. Comparisons also were made among the index cases hospitalized before 8 months of age, between 8 and 12 months, and between 13 and 24 months. No significant differences were found.

between groups for any of the IQ measures. The authors interpret these data as showing that severe malnutrition at any time during the first two years has an equal impact on intelligence. In parallel studies on these same cases, Richardson et al. found that the children hospitalized for malnutrition during the first two years of life did less well than their classmates on formal tests of reading, spelling, and arithmetic.¹ They did not differ on other aspects of the W.I.S.C. tests. They also were judged by their teachers as having special problems in school. Interestingly enough, the index cases did not differ significantly in test performance from their siblings, although the teachers rated the siblings as having no special school problems. Richardson believes that these findings, taken in aggregate, suggest that malnutrition may adversely affect some aspects of intelligence (as shown on the Full Scale and Verbal IQ scores), whereas the environment may be more directly influential in others (such as the Performance IQ and the selected abilities represented by reading, spelling, and arithmetic).

It is of some interest that a similar study has been reported using younger (4-1/2 to 6-1/2 year old) Indian children.²


Although the Wechsler Verbal, Performance, and Full Scale scores were somewhat lower in the children who had had marasmus early in life, the differences were not significant. Significant decrements in visual, haptic, and kinesthetic sense modalities were found. Social maturity did not differ between the groups.

Other studies also have suggested selective effects of severe malnutrition on behavioral functions. Data on rehabilitated Guatemalan children have shown that not all psychological tests showed differences between rehabilitated kwashiorkor cases and their controls.¹ The results of a cluster of tests involving motivation and attention span over time were significantly different for control and rehabilitated subjects whereas other tests in the battery were not different. Similarly, Witkop et al. found Guatemalan children who had recuperated after hospitalization for kwashiorkor performed significantly less well than matched controls on intersensory integration but reacted with a more rapid, impulsive response time.² Response speed was found to be inversely related to the number of errors made.


Cravioto and DeLicardie have also followed a group of recuperated children who were hospitalized for PGM in early childhood.¹ These subjects were part of a longitudinal study of an entire semirural Mexican village that has been underway since the mid-1960's. Up to the age of 9 years the malnourished children demonstrated impaired visual discrimination ability (e.g. inability to discern differences between letters such as p,d,b,q) as well as delayed language development. As has often been shown to be the case in such studies, the malnourished children showed lower scores on the Caldwell Home Stimulation Inventory.

Much more extensive reviews of these data are provided by Read and Birch.² Although the evidence clearly supports the conclusion that early and severe protein calorie malnutrition is associated with intellectual impairment, probably irreversibly, environment also plays an important role. Stoch and Smythe have followed a group of South African infants identified as having been severely malnourished in infancy with a comparison group who were not malnourished.³ The group mal-

¹Cravioto, "Neurointegrative development."


nourished during the first two years of life had smaller head circumferences, aberrant electroencephalograms, were smaller in stature, and differed significantly in psychological test scores (standard IQ tests plus New South Africa Individual Scale). The differences persisted into adolescence. However, the families of the undernourished children exhibited more broken homes, less regular employment, more alcoholism, and other social factors which could influence intellectual development in the child. Differences in school attendance between the two groups also cloud the interpretation. In the Chase and Martin study mentioned previously the malnourished children had more siblings than the controls, suggesting that less time might have been available for the mother to interact with the infant.\(^1\) Also, a higher incidence of alcoholism and of parental separation as well as maternal psychological problems were found in the malnourished group.

A very interesting recent report has drawn upon a population of middle class U. S. children with cystic fibrosis, ideal atresia, or protracted diarrhea requiring hospitalization early in life.\(^2\) Growth retardation and clinical records indicated severe malnutrition of an extended nature during the first six months of life; siblings were used as controls. Significant differences in Merrill-Palmer test scores were seen

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\(^1\)Chase, "Undernutrition and child development," pp. 933-939.

in the younger malnourished children compared to the controls. No differences were found in older children using the Wechsler intelligence Tests. These results suggest that severe malnutrition which impairs mental development early in life may be overcome given adequate nutrition and an environment which provides stimulation for social-behavioral development. It may be pertinent to note, however, that these children were not low birthweight infants, as has been the case for subjects in many other studies.

**Chronic Undernutrition**

Compared with severe malnutrition, there are fewer studies on moderate or chronic undernutrition, and the data are more confusing. A much larger percentage of the world's children suffer from chronic undernutrition which occurs when both the quantity and the quality of food intake are restricted. The child grows at a much slower rate than normal and is more susceptible to such childhood diseases as measles, diarrhea, or pneumonia. The families of these children generally live under poverty conditions so that the environmental factors also are not conducive to optimal mental development.

Nearly all the studies on chronic undernutrition have been retrospective in nature, with no detailed information on the nature, severity, or duration of malnutrition other than that inferred from anthropometric measurements and dietary assessments at the time of the study. Using growth retardation as an indicator of nutritional status, Cravioto and co-
workers found that differences in weight among rural Guatemalan children were accompanied by differences in neurointegrative abilities up to age eleven; this relationship was not found in well-nourished urban children thus eliminating growth per se as the causative factor. On the other hand, these investigators were not able to rule out social differences among the children as major contributing factors; malnutrition could only be interpreted as part of the causative constellation.

In a comparable 8-year study of Mexican children of different social classes, Ramos-Galvan et al. have shown that intellectual performance when the child entered school was apparently related to his nutritional history, defined in terms of anthropometric measures. However, after four or five years of school attendance, differences in IQ appeared to be related more to socioeconomic conditions and regularity of school attendance than to a history of malnutrition.

In a study in New Delhi, Werner and Rajulkashmi have studied 16 adequately nourished and 24 inadequately nourished children from a nursery school in a lower middle class area.

1 Cravioto, "Neurointegrative development and intelligence," pp. 319-322.


Nutritional status was defined in terms of expected growth over the three-year study period. Differences in head circumference, mean IQ and visual motor development were found between the adequately and the inadequately nourished children; no social differences between the families were identified. The inadequately nourished girls appeared to be more handicapped than the boys, suggesting a difference in rearing conditions for the girls.

A carefully monitored longitudinal nutritional intervention study in pregnancy and extending through the first seven years of life is now underway in Guatemala; a summary of the design and birthweight data is presented by Read et al.¹ The children in the study were drawn from a high-risk rural population having high rates of prematurity, low birthweight, infant mortality and growth retardation. Using height and head circumference as indices of nutritional status in children 8, 12, and 16 months of age, Klein et al. found only a low level of correlation between mild-to-moderate protein-calorie malnutrition and mental or motor development.² However, they did find an association between family socioeconomic status, infant-caretaker interaction, and nutritional status which taken together could be expected to play an important role in intel-


lectual development as the child matures. Analyses completed on children who entered the feeding program at 5 years of age and were followed for two years showed no correlation between participation in the feeding program and psychological test performance. Whether these negative results were due to the small sample size or to the lateness of introducing nutritional supplementation was not clear from the data. It is pertinent to note that psychological test performance among these pre-school children was closely correlated with attained size (prior nutrition?) at the time of entry into the study and with family socio-economic status.

Another shorter term study has recently been reported from Bogota, Colombia.¹ Findings are reported from 186 well-nourished and 192 undernourished children under the age of five years enrolled through a well-baby clinic in the slums of Bogota; 218 of the children were part of a supplementation program utilizing regularly available foods. At the beginning of the study the families of the malnourished children differed appreciably in such social factors as parental education, father's occupation, income, nature of the dwelling, family size and family possessions; these differences occurred even though the families all resided in the same poor area of the city. The family health status of the malnourished children was significantly

different, particularly in the prenatal and neonatal periods. Differences in intellectual performance were also found at the outset between the malnourished and adequately nourished children. Significant increments in physical growth and intellectual performance were observed in the supplemented children in contrast to the nonsupplemented children at the end of the one-year study.

As reported by Christiansen, et al. from the Bogota study, the mothers of malnourished children "had lower educational and occupational aspirations for their children, tended to play less, give less verbal reinforcement and do less direct teaching in regard to their children; in addition, they tended more often to give primary child-rearing responsibility to other children in the family."¹ This observation is consonant with comments of others working with families having one or more malnourished children. For instance Graves has explored mother-infant interactions in malnourished children in West Bengal and Nepal.² She found that the maternal response to the child was greater for well-nourished than for poorly nourished children, both from the viewpoint of the mother-initiated and of infant-initiated interactions. These differences increased with age between 8 and 18 months of age.


²P. Graves, Personal communication (1972)
During this same time interval the well-nourished youngsters became significantly more active than the malnourished infant. No differences in infant cognitive development were seen over this ten-month period. These observations are reminiscent of the malnutrition-maternal deprivation interrelations postulated by Frankova and Plaut.¹

Pollitt has studied various medical, socio-economic, and behavioral characteristics of 15 "failure-to-thrive" children living in a low income area of Cambridge, Massachusetts.² They were identified through the outpatient facility of Cambridge City Hospital. For this study "failure-to-thrive" was defined as "simple" growth retardation not requiring hospitalization. The control group, drawn from the same outpatient facility, was matched for sex, age, and race. The main contributing factor associated with growth retardation was dietary intake (particularly calories rather than protein), closely correlated with family income. Using the Caldwell Inventory of Home Stimulation as a measure of mother-child interaction, Pollitt obtained a score of 70 percent for the malnourished children and 94


present for the control group. He emphasized, however, that the mother caretaking behavior towards the growth-retarded children was not the extreme, pathological type frequently found with clinical "failure-to-thrive" cases requiring hospitalization.

Taken together these studies suggest that the mother of a malnourished child may interreact less often and less well with her child than does the mother of a well-nourished child. This could be due to the mother's own nutritional status and energy level. However, in considering the mother-infant dyad, it is important also to take into account the interest and activity level of the infant himself. An inactive, nondemanding infant would be expected to elicit less response from his mother. Increasingly it is becoming apparent that this is the case with malnourished infants and young children.

Chavez and co-workers have studied children living under "normal" but low socio-economic conditions in a rural Mexican community.¹ Seventeen children were born to mothers living under ordinary conditions. A similar number of other mothers received supplements from the forty-fifth day of pregnancy through lactation and their infants were supplemented from weaning. The supplemented children did better

on all aspects of the Gesell test through two years of age. By one year of age, the physical activity was significantly greater in the supplemented children; a sixfold difference was observed by two years. The unsupplemented children spent more time in their cribs or beds and less time exploring, were kept or elected to stay in their houses for the majority of the time, and were held more often by some member of the family during the first year of life. The supplemented children clearly were more exploratory, active and expressive. As the supplemented children grew more rapidly, they received more attention and care from the other family members, particularly the father, a phenomenon which was rarely observed in the case of unsupplemented children. Studies are now underway to quantify differences in exploratory behavior, fear of new situations, and dependence upon maternal support on the part of the children. Preliminary results suggest that the supplemented and unsupplemented children react markedly differently in these situations.

It is of interest that Heywood and Latham, in a preliminary study, have used special monitoring equipment to determine that the heart rate of undernourished but not ill children was somewhat slower than that of well-nourished controls. In a more complete study, Klein, et al. noted that severely malnourished infants had a reduced arousal level, as measured by heart rate acceleration, in response

to novel stimuli; this pattern persisted even after recovery.\textsuperscript{1} Barac and co-workers find that the maximum oxygen consumption is markedly different between undernourished Colombian pre-school children and their adequately-nourished playmates.\textsuperscript{2}

It is apparent from these studies that development of the undernourished child is a composite of many factors. Behavioral recovery from severe malnutrition may be accelerated by maternal intervention.\textsuperscript{3} Conversely, the mother of the malnourished infant may exhibit reduced interest and pay less attention to the malnourished child, thereby further compounding behavioral retardation. Rutishauser and Whitehead have found that previously malnourished Ugandan pre-schoolers (age 1 1$\frac{1}{2}$ to 3 years) engaged in standing and sitting activities with significantly greater frequency than in play activities such as running, jumping, etc. when compared to well-nourished European children of the same age.\textsuperscript{4} The increases in height over the study period were the same in both groups in spite of a markedly lower caloric intake by the Ugan-

\textsuperscript{1}Klein, "Some methodological problems," pp. 61-75.


dan children. These authors suggest that the malnourished children preferentially were utilizing the limited caloric intake for growth rather than for energy-demanding play.

The undernourished child himself is less active and less demanding of his parents, siblings, and peers, thereby contributing to his own retarded development and worsening nutritional status.\(^1\) Thus malnutrition (and its concomitant of increased infection), inactivity, and disinterest form a vicious cycle which retards behavioral development, perhaps permanently. Cravioto and DeLicardie have addressed this possibility eloquently, with emphasis on the cumulative impact on successive generations.\(^2\)

A major question that can now be posed is whether intervention can overcome the cumulative effects of malnutrition and poor environment. Retrospective studies completed in the past have given equivocal answers. But prospective studies now underway suggest that the answer may be yes, at least in part. For instance, low birthweight is a well-known concomitant of mental retardation. The Guatemalan study mentioned previously has shown that nutritional intervention may increase birthweight even in a population


which has experienced generations of undernutrition.¹ Chavez et al. also reports an 8 percent increase in birthweight in his study as well as improved growth and improved performance on psychological tests.² Data from the Bogota study suggest an improvement in behavioral test scores as a result of the one-year feeding program for young children.³ All of these studies are continuing so that several more years will be required for definitive answers to be forthcoming.

Recognizing the intimate intertwining of malnutrition, behavioral change and social variables, is it possible that a combined program of nutritional intervention plus stimulation would be more effective than either of these alone in overcoming the consequences of poverty and deprivation in undernourished children? One study of this possibility is underway in Colombia.⁴ This study is being conducted in an experimental day-care center serving a poor area in Cali. All children born during a single six-month period were identified through growth retardation, at age three, as malnourished or adequately nourished. The program provides nutritional supple-


mentation with or without special educational activities. Nutritional supplementation alone starting at three years of age had no appreciable effect on psychological test performance at ages four or five years. Improved nutrition plus cognitive stimulation resulted in marked improvement in most behavioral areas, with the exception of short-term memory which proved to be resistant to change by either form of intervention. In general, after two years of intervention, the performance of the malnourished children approached but did not equal the performance of the well-nourished upper-income control group. The Bogota group, working in concert with the Cali team, has launched a study of the impact of combined nutritional supplementation (pregnancy and childhood) plus behavioral enrichment during early childhood. Taken together, these two studies should help clarify a most important question for government policy-makers.
CHAPTER 3

SUMMARY

Severe malnutrition during prenatal life and/or infancy in animals and man has been shown to decrease the number of brain cells significantly and to alter brain structure. The neurological consequences of gross growth retardation, of severe protein-calorie malnutrition, or of nutritionally induced dwarfism appear to be permanent in animals and probably in man. These changes are associated with mental retardation and behavioral change which also appear to be permanent and non-reversible.

The effects of moderate (or chronic) malnutrition are not as clearly established. Man lives in a complex environment where nutrition, health, family and social factors interact to shape behavioral development. The most recent reports from cross-sectional and longitudinal studies suggest that the adverse behavioral consequences of chronic undernutrition are more in areas of attentiveness, curiosity, activity and social responsiveness rather than in the cognitive domain. The available information on anemia and behavior further suggests that the consequences of iron deficiency are likely to be in these same facets of behavior.\[1\] It is

interesting that the lack of appropriate psychosocial stimulation affects these same areas. Thus the non-nutritional variables in the life of a malnourished child may well contribute as much to retarded development as malnutrition alone. Conversely, several studies suggest that the malnourished individual may be particularly susceptible to social stresses and deprivations.

It appears from the data that the effects of malnutrition constitute a continuum from permanent neurologic defect to consequences arising essentially from personal interactions between the child and his environment, depending on the timing and severity of malnutrition. These interacting factors must be considered in planning intervention programs for high-risk groups—pregnant women and young children. For children already suffering from malnutrition, it is probable that remedial efforts will need to include both nutritional supplementation and educational stimulation if each child is to come close to his full potential.

In reviewing the available data, it is apparent that there has been a major shift of emphasis away from the clinical concept of mental retardation and toward impaired development of intellectual, social, and motivational competence. Increasingly we are faced with the question of deficit versus lag in development—are the changes irreversible or are they only delayed but remedial through intervention? Ultimately the question which must be answered is: how well will this
person function as an adult in his society? The suggestions from the animal literature that malnourished rats and monkeys are more susceptible to environmental stress (infection, drugs, tension, social change) add urgency to obtaining comparable answers in man. Similar suggestions that the behavioral correlates of malnutrition in one generation may carry over two or three generations in spite of an adequate diet emphasize the importance of initiating feeding programs for pregnant women and young children as soon as possible.

We can be encouraged from the success of the first ten years of the Haitian Mothercraft Center program. A recent evaluation shows that long-range nutrition, health and growth achievement can result from well-planned yet economical preventive programs directed toward mothers within the prevailing social setting.¹ From the viewpoint of malnutrition and mental development, this type of intervention has several main attractions. First, it attacks the problem as essentially nutritional without undue emphasis on protein or any other single nutrient. In this regard there is a growing body of data suggesting that caloric deficit, rather than protein deficiency, may be the telling factor in low birthweight and retarded development, either physiological or behavioral; McLaren has eloquently outlined reasons to believe that our preoccupation with protein deficiency may have been in error.²


The second attraction to the Mothercraft Center concept is the emphasis on training the mother and towards building mother-infant relationships. The present report has attempted to show the importance of this factor. Finally, King, et al. have reported that families which participated in Mothercraft Centers rarely return with malnutrition in succeeding children.¹

We await with interest the completion of studies which will show whether or not the Mothercraft intervention programs will also benefit the mental and behavioral development of the child.

¹King, "Cost vs. benefits," p. 31-32.
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