A strong association exists between malnutrition early in life and late malnutritions of intellectual impairment. What factors (biological, social, psychological) are involved and in what way are the questions considered in this review of recent research on the problem. The author offers a new hypothesis to explain the role of malnutrition in retarded intellectual development.

THE EFFECTS OF MALNUTRITION ON INTELLECTUAL DEVELOPMENT AND LEARNING

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IN Colombia, South America, a dark-haired little girl named Maria lives with her family in a shack on a steep hill overlooking the south side of the city of Bogotá. She is four years old, yet weighs only 22 pounds and is not yet 3 feet tall. She is lighter and shorter than Virginia who is half her age and is the child of a neighbor. A psychological test revealed that Maria has an IQ of only 69, whereas that of Virginia is normal at 103. Maria's poor physical growth is due to protein-calorie malnutrition, a lack of food in early childhood including a deficiency in high quality protein. Was this malnutrition also a cause of her retarded intellectual development?

At the Denver General Hospital in Colorado, Dr. H. Peter Chase reported that 19 children admitted between 1962 and 1967 at less than a year of age with generalized undernutrition scored poorly on intelligence tests when tested some years later. The mean Development Quotient of the 19 previously malnourished children was 82.1, whereas 16 children chosen as controls on the basis of age, sex, birth weight, race and being born and followed in the same hospital, had a mean Development Quotient of 99.4[1]

These two examples,[2] one from the slums of a developing country and one from a corner of this wealthy nation, may suggest that dietary deficiencies in young children *cause* a retardation in intellectual development and mental functioning. Let us examine the evidence. We need first, however, to be clear about what form of malnutrition is being considered.

Protein-Calorie Malnutrition of Young Children

There is good evidence to show that certain kinds of malnutrition and nutrition related diseases can result in mental retardation and severe mental illness. For example, in certain areas of the world where pellagra is endemic 20 per cent or more of the inmates of mental institutions are there because of the effects of this classic deficiency disease. There is no doubt that inborn errors of metabolism such as phenylketonuria (PKU) cause irreversible mental defectiveness in children. The Wernicke-

Korsakoff syndrome which swells many institutions in the United States is not due to alcoholic poisoning, as was formerly believed, but is due rather to thiamine deficiency in alcoholics.

However, when talking of the possible role of malnutrition on the mental development of children, we are normally considering protein-calorie malnutrition (PCM). This is the most important deficiency disease in the world and affects huge numbers of children. Protein-calorie malnutrition is seen as two extreme clinical syndromes,[3] notably kwashiorkor and nutritional marasmus, as well as certain intermediate forms such as marasmic kwashiorkor. Far more prevalent than these severe forms is mild or moderate protein-calorie malnutrition which manifests itself mainly by retarded physical growth and development. In some countries the majority of children develop some degree of protein-calorie malnutrition during their early life.

The prevalence of this condition in the United States is not exactly known. Early results from the National Nutrition Survey suggest that protein-calorie malnutrition is an important form of malnutrition among the poor in this country.

That protein and calorie deficiencies can cause a permanent retardation in physical growth has been known for some time. The question now is whether they cause a retardation in intellectual development. If they do, it becomes important to know what mechanism is involved, what degree of malnutrition has an effect, and at what age malnutrition has its greatest impact.

Although many studies have shown a very close association between early malnutrition and subsequent poor intellectual development, it has been difficult, especially in human studies, to demonstrate clearly that this association is one of cause and effect. Even in laboratory animals there is still much that is unknown.

Animal Research

There have been reports from many studies which purport to show that early malnutrition in particular experimental animals affects their learning and therefore their intelligence.

At Cambridge University, Widdowson and McCance[4] showed that rats from small litters as well as being better grown also explore their surroundings more than do rats from large litters. Cowley and Griesel[5] reported that previously malnourished rats scored more poorly than well-nourished controls when tested on the Hebb-Williams maze. Winick and Noble[6] have shown that baby rats that were malnourished during the suckling period have reduced numbers of cells in the brain. In these experiments Winick used the technique of Enesco and Leblond[7] which relates DNA content to cell numbers.

A kwashiorkor-like disease has been induced in pigs at Cornell University by ad libitum feeding of low protein diets.[8] These animals after recuperation showed an abnormally high state of "excitability and emotionality" when subjected to a stressful situation involving the avoidance of an electric shock. The malnourished pigs also have an exaggerated food drive.

In London extensive experiments on dogs showed that those which had protein-calorie malnutrition showed marked behavioral abnormalities. Their brains were reduced in size, and had pathologic lesions.

Despite this and a considerable body of other experiments there are still many uncertainties, even in animals, about the relationship of protein-calorie malnutrition to learning and intelligence. There have been studies in which malnutrition produced no differences in performance.[9,10] A major research problem is that in the animal the learning process itself cannot be measured, only its effect upon performance. The animal's

performance is affected not by learning alone. Emotion, motivation, and the incentive value of the reinforcement used in test situations all may affect learning.

Levitsky and Barnes[11] have recently, in a critical review, stated that they do not believe that malnutrition has been adequately shown to produce deleterious effects directly on the learning process. They suggest that it may influence performance by affecting the emotionality of the animal. Their work showed that animals who have experienced protein-calorie malnutrition early in life are more sensitive to excessive stimulation and therefore exhibit greater emotionality. They suggest that there are several striking similarities between the effects produced by early protein-calorie malnutrition and those observed following early environmental isolation. They mention work done in monkeys, which seems to support this important hypothesis.

Human Studies

Because protein-calorie malnutrition results in abnormal behavioral development in the rat, the pig, the dog, (and probably also the monkey), it has been tempting to extrapolate these results to man. For ethical and other reasons it is not possible to repeat in the human the neat and well-controlled studies that have been conducted in laboratory animals. Man differs more from the animal in his intellectual than in his physical or biochemical development. Cultural factors which have little or no influence on the experimental animal are very important in the psychological development of the child.

Because brain growth is accomplished largely by protein synthesis, it is easy to assume that protein deficiency will adversely affect this process. In the months just prior to and just after birth, the brain is growing very rapidly. The brain of a three-year-old child is usually 80 per cent of its adult weight. In contrast, the total body weight of the child normally reaches 80 per cent of adult weight after puberty.

In several studies[12,13] a low head circumference has been related to an earlier episode of malnutrition. Although there is little doubt that a close correlation exists between head circumference and brain size, there is no good evidence to indicate that brain size in man is related to intelligence.

Winick and Rosso[14] compared the brains of 9 Chilean infants who had died of severe nutritional marasmus with those of 10 control children who had died acutely of accidents or poisoning. Using the same technique that they had used on rat brains, they concluded that there was a reduction in the number of brain cells in the malnourished compared with the control children. Although this study provides important new evidence in the human—evidence that was previously inferred from work in animals—nevertheless there is still much that is unknown. All 9 children had very severe nutritional marasmus and died as a result of this condition. Several of them had very low birth weights. It is not known how severe the malnutrition needs to be to produce this reduction in cell numbers, nor what effects this would have had on the mental performance of these children had they survived.

Cross-sectional studies from many different countries have shown that children who have suffered from protein-calorie malnutrition early in their life subsequently scored more poorly on a variety of mental tests when compared with control children of the same race who had apparently not suffered from malnutrition. Thus, Cravioto and Robles[15] in Mexico found that a group of malnourished children had a lower performance in four fields of behavior when compared with control children of similar ethnic background and age. Cravioto and his group[16] later extended this work to primary school children. They found that the intersensory skill

of the tallest 25 per cent of children was significantly better than that of the shortest children. They assumed that poor nutrition had caused a stunting of the growth of the short children. Therefore, it appeared that malnutrition was closely associated with poor mental development.

In India, 19 children who had been treated for kwashiorkor at the Nutrition Research Laboratories in Hyderabad 8 to 11 years previously were traced.[17] They were then matched for age and certain social criteria with a group of schoolmates. Both groups of children were subjected to the same intelligence tests. The malnourished children scored significantly more poorly than the control children in these tests.

In Colombia, we have also found that children who have been malnourished have poorer psychological development than do children in the same community who have never had malnutrition.[18] Similar findings have been reported from Peru,[19] Chile,[20] the United States[1] and other countries.

In South Africa, Stoch and Smythe[12] have conducted one of the few longitudinal studies investigating the role of malnutrition in intellectual development. They have followed two groups of children for over 11 years. When the study began, the 20 children in the first group were grossly malnourished and those in the second group were apparently well-nourished infants. Marked differences in the physical and mental development of these two groups of children have been maintained throughout the 11 years of this continuing study. A significant finding has been that the head circumference of the malnourished group has remained smaller than that of the control children.

Malnutrition: Cause or Associate of Mental Retardation?

From the foregoing the reader might feel convinced that the weight of evidence shows that malnutrition *causes* retarded intellectual development. This would be a false conclusion. The truth is that proof exists that poor psychological development is associated with, not necessarily caused by, malnutrition. Two phenomena may be associated with a third independent variable which may be a factor in the causation of both.

Those of us who have worked on the public health aspects of malnutrition in poverty areas know that protein-calorie malnutrition seldom occurs as an isolated phenomenon. It is found typically in an environment which includes poverty, ignorance, poor housing, a high prevalence of infectious and parasitic disease, crowding, and poor sanitation. Poor nutrition in children is often associated with illiterate or even retarded parents and with poor child-rearing practices. Where there is a deficiency of nutrients there is also often a deficiency of intellectual stimulation. Therefore, in any family or community, factors which are important in the etiology of malnutrition may also be factors in the etiology of impaired psychological development.

There is no question that a strong association exists between malnutrition early in life and late manifestations of intellectual impairment.

Therefore in the South African study of Stoch and Smythe, mentioned earlier, it was later found that although the malnourished and control children were both drawn from the lowest socioeconomic level of people in the same community, there was nevertheless a great disparity between the living conditions of the two groups. There was also more unemployment, illegitimacy, broken homes and alcoholism among the families of the malnourished children than in those of the controls. Some of these factors may have contributed to the poor intellectual development, as well as to the malnutrition in these children.

Similarly in the Indian study,[17] the level of intelligence, motivation and resourcefulness of the parents of the con-

trol children was probably superior to that of the malnourished. The children of parents who are deficient in these qualities may be especially vulnerable to malnutrition, but are also likely to receive less intellectual stimulation.

Our studies in Bogotá have also not convinced us that malnutrition per se is the most important factor in the below average intelligence of the children we have examined. For this reason, our research is aiming to control as far as possible the social and to some extent the genetic variables. In this way we hope to be in a better position to give an estimate of the role of malnutrition in contrast to social factors in the retarded intellectual development of children.

It should be recalled that following the early descriptions of kwashiorkor, it had become clear that psychological changes were prominent clinical features of the disease itself.[3] Apathy, irritability, and a lack of interest and exploratory desire are features well-known to all who have dealt with children suffering from this disease. In successful treatment, among the first changes to be noticed is an alteration in these psychological signs, and, in my experience this precedes measurable physical changes. The child that smiles is on his way to recovery. Apathy, which is a constant early feature of kwashiorkor, may itself reduce the responsiveness and warmth of the mother to the child. She requires the stimulus of the child before she reacts fully; and so the apathy of malnutrition may reduce the interaction between the mother and the child.[21] This factor, which has not been adequately studied, may be one of the keys to the apparently poor psychological development of children following kwashiorkor. These various mental changes evident during the clinical phases of the disease are important because of their possible relationship with subsequent abnormalities in cognitive, behavioral and emotional development.

The Possible Role of Social Deprivation

There is no doubt that environmental and social factors during early childhood have an extremely important effect on human development. A deprivation of certain social and physical needs of the young child can cause serious obstacles to normal development and may leave permanent stigmata on the surviving individual.

Our aim should be to provide all children in all countries the best possible opportunity to develop normally and optimally. René Dubos has written:[22] "It can be unequivocally stated that the beneficial effects derived from building ultramodern hospitals with up-to-date equipment are trivial when compared with the results that could be achieved at much lower cost by providing infants and children with well-balanced food, sanitary conditions and a stimulating environment."

However, when we talk of "normal" or "optimal" development, we really have no definition of these. When we use the term "deprived" or "culturally deprived" for the child brought up in poverty we are immediately making a judgment and using our own psychological and cultural development or that of the middle-class child as being the ideal or at least the reference psychological profile. One might legitimately question whether the middle-class child is ideal and whether he has not areas which are by some other standards deprived.

David Glass has discussed the subject this way:[23] "Recent research shows that differences in behavior and mental organization such as that between middle class and lower middle-class children does not emerge until after two years of age. Data suggest that every child requires a set of schemata to interpret experience; distinctive events to promote the development of such schemata; perception of a model whom the child views as possessing attributes

he values; a set of goals promoted by people the child admires; and, finally, some degree of certainty about the occurrences of each day. Some children are deprived of all or most of these ingredients and it is this group which is customarily considered 'culturally deprived'."

The very young child in pre-industrial societies has been found to have a more advanced psychomotor development than children of the same age in industrialized countries. This was first shown in Africa by Geber and Dean[24] using the Gesell technique. They showed that Ugandan children during the early months of life had better motor, adaptive, personal-social and language development than comparable European children. Similar findings have been reported in Mexican and Guatemalan children. It seems that societies in developing countries provide an environment (perhaps aided by local child-rearing practices) which may promote earlier psychological development than occurs in North American or European children. This advanced development is usually lost by the second birthday of the child. Research of potential value would be to find a means of maintaining this early precocity.

Most psychologists agree that social isolation inhibits psychological development whereas social interaction is beneficial. However it has been noted that humans try to isolate themselves from further stimulation after a high degree of social interaction. Additional social contact may lower rather than raise performance level. There is evidently an optimal level of arousal

Kagan[25] has contrasted the middle-class child waking in a bedroom in a suburban home. The mother enters and speaks to the child. The auditory intrusion is maximally distinctive and is likely to orient the infant to her mother and to the vocalization. If the child responds vocally, the mother is likely to continue the dialogue. In contrast, the infant from a slum home is likely to awaken in a room where there is a sea of sound from the television, the other siblings etc. in a crowded apartment. The mother's communication is minimally distinctive from background noise and is not likely to get the infant's attention. Similarly, the infant's vocalizations are not likely to be heard or elicit response. Kagan tends to minimize the importance of the absolute amount of stimulation the child receives and spotlights instead the distinctiveness of this stimulation.

Kagan also points out that the lower class preschool child is less frequently required by the parents to master instrumental skills especially language skills than is the middle-class child. The middle-class mother corrects the child's speech, the lower-class mother has not this preoccupation with speech mastery. The middle-class parent values intellectual development, the lower middle-class mother insists more on obedience. Each child imprints on the parents major concern.

In order to improve the intellectual development of the culturally deprived child, we require a serious intervention into the social ecology in which these children spend most of their day.

In this respect, Bronfenbrenner[26] has stated that because of the lower level of stimulation (especially verbal stimulation) provided by the lower-class mother, we need to design programs eliciting change in the behavior of the mother. This is an area in which there has been very little research. We need to design strategies for modifying the behavior of the mother.

Bronfenbrenner believes that the development of dependency drive on the one hand, and control and richness of the young child's physical environment on the other, are differentially distributed by social class.

A number of authors have shown that

the child's intelligence is related to the level of education of the mother. Knobloch and Pasamanick[27] have reported that the variation of development quotients in children they studied was related to the level of maternal education and that the older the child the more manifest was this relation. The importance of sociocultural factors playing a significant role in normal development and maturation has been pointed out by Kagan and Moss.[28] In their work, they showed a marked correlation between the mother's education and the IQ of both boys and girls at 3.6 and 10 years of age.

The Effect of Malnutrition on School Performance

There has been inadequate research into the relationships between nutritional status, the participation in school lunch programs and school performance. Most of the evidence which shows improved school performance resulting from a school lunch is based on rather subjective evaluation.

In East Africa, Latham and Robson[29] showed that Tanzanian children receiving a school snack had better growth and improved hemoglobin levels compared with control children. They also reported that there was subjective evidence that the midday snacks did improve concentration, alertness, and learning. It definitely reduced absenteeism. Teachers reported that the snacks improved school performance.

A study in Kentucky showed that with improved diets children in experimental schools over a period of 3 years gained 30 months in mental age compared with 15.5 months gained by children in the control schools.[30] This Sloan Foundation Study has been criticized because of the inadequacy of the intelligence testing instruments.

No correlation was found between school performance (judged by grade point average) and diet (rated by intake of nutrients) in a study conducted by Hampton and his colleagues.[31] In contrast, Tuttle and Herbert[32] showed that school performance was poorer in children not having had a breakfast prior to coming to school. The lack of breakfast probably detrimentally affected attitudes and concentration, and in this way resulted in poor school performance.

Sulzer and Hansche[33] reported that 450 black children in a Head Start Program in New Orleans were tested on a variety of measures of psychological function. Those with low hemoglobin levels revealed significantly poorer scores on verbal tests, performance tests of intelligence and on measures of associative reaction time. No differences were found in certain other measures, notably moral judgment, syntactic complexity, object sorting or short-term memory.

Research Project in Bogotá, Colombia

The difficulty in proving that malnutrition actually causes retarded psychological development lies in the fact that dietary deficiencies are only one part of the deprived environment which is an epidemiological feature both of malnutrition and of retarded childhood development. Because several causative factors may be involved, some of them possibly acting synergistically, it is difficult to design a study which will determine the contribution of one single factor to the poor intellectual development of children in poverty areas.

The field work of a research project on malnutrition and mental development began in Bogotá in June, 1968. This is a cooperative study being undertaken by the Colombian Institute of Family Welfare, the Department of Nutrition of Harvard University, and the Graduate School of Nutrition of Cornell University. The main objectives of the research are to investigate whether malnutrition

early in life has an effect on subsequent psychological development and mental functioning, and if so, to describe and quantitate that effect. This research has been entered upon with an open mind. If the effects of malnutrition on mental development are shown by the results to be negligible, this will be just as important a finding as if they are found to be marked.

A design has been elaborated in which certain of the variables can be controlled either fully or partially by utilizing young sibling pairs, some malnourished, some well-nourished and some mixed. By supplying dietary supplements to all sibling pairs the mental development of the previously malnourished child can be compared with a matched sibling who in some cases has not been malnourished. Genetic, social and familial factors can, in this design, be somewhat controlled, and can also be studied. It should be noted that most of the other large human research projects investigating the effects of malnutrition on mental development are rural or village studies. Our project is urban utilizing a few families from a target poverty area with a population of over 400,000 people. There will thus be few study effects on the community. Another important difference is that the supplement we provide is for consumption in the home, not in a study center.

Research in the general area of malnutrition and mental development immediately raises two main methodological difficulties. First is the need to control a large number of variables while manipulating the nutritional variable, and secondly, it is essential to have available instruments designed to accurately measure the mental development and psychological functioning of the children being studied.

In the Bogotá study, the first methodological difficulty is being solved by adopting a design utilizing siblings who fit certain criteria in relation to age, residence, and state of nutrition. The second methodological difficulty has been overcome by allowing adequate time for selecting, testing, and standardizing (validity and reliability) instruments for measurement of psychological development and also in the field of nutrition and sociology.

Because of the complex nature of conducting a longitudinal study, the research is being conducted in three phases as follows:

Phase I—Planning. Actively began in the field in June, 1968, and concluded March, 1969.

Phase II—Pilot Study. Began March 21, 1969, and will last 3 years.

Phase III—Definitive Longitudinal Study using siblings which will last about 5 years.

The intention in the Definitive Study is to enroll sex-matched siblings the elder of whom is under 3½ years and the younger of whom is not more than 3 years his junior. These children will be selected on the basis of their nutritional status at the time of entry into the study, but certain health and social factors will be grounds for exclusion. The sibling pairs will be enrolled into 4 basic groups (probably of equal size).

Group I—the older and younger sibling will both be normal nutritionally.

Group II—the older sibling will be malnourished and the younger well-nourished.

Group III—the older sibling will be well-nourished and the younger will be malnourished.

Group IV—both siblings will be malnourished.

All children in Groups I to IV, both the malnourished and the well-nourished, will receive dietary supplements for the 4 to 5 year duration of the study. It is hoped that the supplements will result in the nutritional recuperation of the malnourished children and that it will prevent the well-nourished child from becoming malnourished. This design allows over the years a comparison of the physical and psychological de-

velopment of sibling pairs, having identical parents, living in the same environment and presumably being reared in a similar way. The results should indicate whether an episode of malnutrition early in life has any lasting effect on physical growth and psychological development.

In order to assess the effects of supplementation, per se, a fifth group will be enrolled in which no supplements will be supplied. In this group, siblings will be chosen in which the older and younger are both well-nourished. No ethical difficulties arise in having non-supplemented well-nourished children, whereas it would be undesirable to have a malnourished non-supplemented group.

The study design can be visualized as follows:

		Older sibling	
		Normal	Malnourished
		V	
Younger Sibling	Normal	I	II
	Malnourished	III	IV

This design lends itself to statistical evaluation and makes it possible to study several effects independently of each other. The most important analysis will be a comparison of intellectual development of each sibling with his sex-matched brother or sister at corresponding ages in order to ascertain whether those who have had malnutrition will score significantly differently from those who have not had malnutrition. The study design allows an assessment to be made both of study effects and secular change on the younger sibling.

Because the hypothesis being tested is whether there is a difference in development between children who have had malnutrition and those who have not, it is essential that a wide "no man's land" exist between the two states.

In conducting the field research in the southern poverty belt of Bogotá, three subteams have been established—a nutrition and health team, a social anthropology team, and a psychology team. These teams work closely together and pool their data to be analyzed by a fourth statistical team. They are also undertaking some separate substudies, all of which will contribute to the longitudinal definitive study.

(a) *The Nutrition and Health Team* —This team first undertook a number of investigations to define the problem of malnutrition in this area of Bogotá. One of the main aims was to determine the prevalence of different degrees of malnutrition in the target population.

A study of 398 children under 5 years of age was conducted at three health centers in conjunction with the social anthropology team. The study showed a high prevalence of malnutrition in the area; it provided information on childhood diets, on weaning ages, on child-rearing practices; and it gave basic biochemical data. Sixty-seven per cent of the 398 children had some degree of malnutrition using the Gomez classification (Table 1).

A second study was undertaken in the same general area, but instead of enrolling children at the Health Centers, they were located in the community by house-to-house visiting. In this study, 862 children under 5 years of age were examined. Twenty-five per cent of the children were normal nutritionally, 49.5 per cent had Grade I malnutrition, 24 per cent Grade II, and 1.5 per cent Grade III (Table 2).

Although only 4 per cent of the children had never been breast-fed, 26 per cent had been completely weaned from the breast by 3 months of age, and 53 per cent by 6 months of age. Dietary investigations conducted on families showed that there was a mean deficiency of 20 per cent in calories, of 23 per cent in protein, and of 70 per cent in vitamin A available, compared with the recommended allowances for Colombia.

It was found that 54 per cent of mothers withhold food when their children have diarrhea, and 39 per cent when their children have fever. Because diarrhea and infectious disease is very prevalent in this area, this "therapy" provided to children with infections might be very important in influencing nutritional status. Thirty-nine per cent of mothers were found to provide vitamin preparations or medicinal tonics to their children. In contrast, despite public health work, nutrition education, and an extensive advertising campaign including the mass media, only 15 per cent of mothers had ever supplied Incaparina to their children.

A further investigation was carried out to determine the availability of subjects in the area who fitted those entry criteria which might be used in the Definitive Study. During this study 2,056 households were visited. From anthropometric data collected during this and the other studies, it was learned that it would be entirely feasible to enroll adequate numbers of subjects fulfilling rather stringent entry criteria.

From the households visited, a small group of families was selected for a longitudinal study on the effects of supplementation. In all families chosen, there was an older child under 4.5 years of age who had second or third degree malnutrition and a younger well-nourished sibling who was normal on the Gomez classification. Twenty-two families have now received dietary supplementation for almost two years. Supplements were provided in the first instance by delivery to the home, but later it was found more satisfactory if each family collected the food supplements from a Health Center. Sufficient supplement was provided to allow all the children in each household to benefit from the supplement, and not only the two siblings under study. Various anthropometric data were collected every two weeks, biochemical data at the beginning and again

Table 1—Distribution of 398 children from target area* according to age and classification of nutritional status†

Age	Normal Health centers						First degree malnutrition Health centers						Second degree malnutrition Health centers						Third degree malnutrition Health centers					
	28		15		13		28		15		13		28		15		13		28		15		13	
(years)	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
<1	44	48	8	36	31	40	34	37	11	50	11	40	13	14	1	5	4	15	0	—	2	9	1	4
1	21	26	2	17	0	—	42	53	3	25	6	67	17	21	4	33	3	33	0	—	3	25	0	—
2	16	25	0	—	1	25	28	44	7	63	2	50	18	28	3	27	0	—	2	3	1	10	1	25
3	16	36	0	—	1	50	22	50	3	44	0	—	6	14	2	28	1	50	0	—	2	28	0	—
4	7	35	0	—	2	50	11	55	1	100	1	35	2	10	0	—	1	25	0	—	0	—	0	—
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	104	35	10	19	15	32	137	46	25	47	20	44	56	18	10	19	9	20	2	1	8	15	2	4

* 299 from Health Center No. 28, 53 from Health Center No. 15, and 46 from Health Center No. 13.
† Gomez classification using standards of weight for age prepared by Ramos Galvan and Luna-Jaspe.

after 6 months, and records were kept of illness experience.

The results have shown that the malnourished older siblings recuperated at a moderate rate, that nearly all reached a satisfactory weight for height ratio within 6 months, but that few of them attained a normal or standard height for age ratio. The younger, originally well-nourished, siblings varied in their growth pattern. About half showed entirely satisfactory physical growth, whereas others gradually failed to maintain an entirely standard height and weight for age path. All but a very few maintained a good weight for height ratio and none became severely malnourished. Infections were common, and diarrhea was found to be a serious problem especially in the younger children, who in this substudy were all well-nourished when first enrolled. The conclusion can be drawn that age is more important than nutritional status as a factor in diarrhea, at least in this community.

A second supplementation study is under way in which three groups, each consisting of 50 sibling pairs, have been enrolled. Fifty pairs in Group A are receiving dietary supplements, pediatric care, immunizations and health education. The siblings in Group B are receiving supplementation alone. Group C is a control group.

One of the problems facing research studies and applied nutrition programs in which home consumption of a dietary supplement by children is a feature, is a means of knowing whether the children are in fact consuming the supplement. In Bogotá, a number of different methods are used to help ensure that the food supplements are consumed by the target children. These have included weekly questioning of the mother, surprise visits to the household and compulsory return of the empty plastic packets in which the supplements are provided.

It is surprising that there is very little in the literature concerning the use of tracers in food in the way that they have been tried in certain medicines. A food-tracer would obviously need to be harmless, not detectible by the subject, and something that could be tested for in the urine of the consumer. Early in the Bogotá study, the possibility of using riboflavin as a tracer in milk was assessed. It was possible to add quantities that were not obvious to the recipients, and which could be tested for subsequently. However, it did not seem the ideal substance. We have now been using D-xylose and find that this very satisfactorily serves our purposes. The addition of D-xylose to milk powder is now a feature of the supplementation studies. Periodic spot-checks of urine from study subjects gives an indication of whether

Table 2—Distribution of 862 children randomly selected in a house-to-house survey in Health Center No. 28 according to nutritional status

Age groups (years)	Classification of malnutrition							
	Normal		First degree		Second degree		Third degree	
	No.	%	No.	%	No.	%	No.	%
Under 1	55	43	43	34	27	21	2	1.6
1	37	24	76	49	41	27	1	0.6
2	37	22	67	51	46	27	2	1.2
3	34	21	86	52	40	24	5	3.1
4	30	24	64	52	29	23	1	0.8
5	21	18	72	61	24	20	2	1.7
Total	214	25	428	50	207	24	13	1.5

they are consuming the milk, and it is also possible to determine if the parents are utilizing the milk which has been prescribed for the children.

(b) *The Social Anthropology Team*—The first activity undertaken was an investigation of the "literature" pertaining to the sociocultural aspects of the barrios in the southern poverty belt of Bogotá. This subteam then ran a questionnaire to obtain sociocultural data on the same 407 families from the three health centers that had been used in one of the nutrition studies. This provided data on population distribution by age and sex, family structure, literacy and levels of education, occupation, length of residence in the household, patterns of household ownership, types of housing, density of people in the house, and mobility in the barrios. This study showed, for example, that the majority of families originated from Boyacá and Cundinamarca, that education levels of parents was very low, that the mean income was 500 Colombian pesos (30 U.S. dollars), and that the majority of families (58%) owned their houses.

The main sociocultural study was a detailed ethnographic survey of the target area, namely the southern poverty belt of Bogotá. The place of origin of a sample of the inhabitants was investigated, and the population was found to be more homogeneous than at first believed. For example, 82 per cent were found to be in-migrants moving to an urban environment for similar socioeconomic reasons. The ecology of the area including the pattern of tenure was studied. It was shown that none of the barrios in the target area could be defined as "invasiones" or squatter settlements, yet they did include the poorest areas of the city. Many factors discovered by the investigation indicate a rather stable and homogeneous population.

A survey showed that family structure is characterized by networks of relationships both official, consanguineal, and individual. This suggests social stability which will be helpful for the Definitive Study. Overcrowding and poor sanitation were found to be widespread, but there are improvements taking place.

An interview questionnaire was completed for a randomly selected sample of 207 households. Employment by residents in these areas was mainly of the non-skilled variety (11.2% were unemployed) and the wages received were low. Of the heads of household interviewed only 3.3 per cent had been to secondary school and 61.6 per cent to primary school. The respondents' attitudes towards life in the city was on the whole positive. None of these people told the social anthropologist during direct questioning that they intended to move out of this urban area. Movement in general was from house-to-house within the target area, rather than out of it. There is practically no evidence of return from the city to rural areas. In general, a change from agricultural laborer to urban dweller was considered one step up the social ladder, and implies a change in social class. A detailed report over 80 pages in length has been prepared which describes the sociocultural characteristics of the target population and area. This type of ethnographic survey is an essential part of any ecological nutrition study.

Both a retrospective and prospective study of geographic mobility were undertaken. In any longitudinal study, it is important to know what the losses of study subjects are likely to be during the period of the research. Mobility within the barrios of the target area was quite high, but mobility to other areas of the city and out of Bogotá was found to be low. Both studies indicated that a loss of 30 per cent of subjects might be ex-

pected over a five-year period, due to families moving to areas which would be inaccessible to the study.

Sociological data has been collected relevant to income, education, prestige of the paternal occupation and place of residence, and these have led to a scoring system which will be used to produce a five-level stratification of social class in the area. Much other baseline sociological data which has been obtained is now in the process of analysis.

An instrument to assess social change in the target area has been developed. This consists of a rather comprehensive questionnaire covering many sociological variables believed relevant to the longitudinal study.

(c) *The Psychology Team*—This team, after a thorough review of the literature, began to develop a conceptual framework that would suit the needs of the study. One premise from which this framework needed to be developed was based on the fact that in several parts of the world malnourished children had been found to have lower than average "intelligence scores" when tested with a variety of standard instruments. However, it was also known that when children from poor families were compared with children from rich families, or when children with illiterate parents were compared with children of educated parents, the same or larger differences were found. The tests so far used in studies of malnutrition and mental development have usually been selected from several of the standard tests that have been developed for use in industrialized countries (where they have been standardized), often using middle-class subjects. These tests have been translated and minimally adapted for use in other cultures and among poor people.

It would have been relatively simple for the psychology team to have chosen to use with slight modification certain batteries of tests being utilized in Latin America. However, there have been developments in psychology which throw serious doubt on the validity of the interpretation of test results in other cultures when the old intelligence quotient or general quotient tests are used. It was decided in the Bogotá study that it would add a new dimension and greater depth to the research if an attempt was made to measure performance and also to assess what has been termed the "structure of intelligence." In this latter respect, an attempt would be made to look at stages of development as conceptualized by Piaget.

The battery of tests selected will be based on the following:

The Griffiths Scales
The Einstein Scale
The Montreal Scale No. 1 and No. 2
The Guatemala Scale

With regard to "traditional" psychometric instruments which are able to measure deprivatory effects in terms of general quotient of intelligence, there are a huge number of available instruments. Each scale has its disciples and critics. The Griffiths Scale appeared to have several advantages over the others that were considered. First, with the new extension, it offered a single scale covering the ages from 1 to 8 years without a break. This is the age range required for the Definitive Study. Secondly, its reliability and validity had been established, and it was an instrument characterized by its simplicity, short time of administration and facility of scoring. It considers the following areas of "performance": locomotor, personal social, hearing and speech, eye and hand, and general area of performance. It can be scored to provide a profile of performance.

The Einstein Scale of Sensori-motor Development was developed by Dr. Sybille Escalona and Dr. Harvey Corman at the Albert Einstein College of Medicine. It is based on Piagetian psychology. This cognitive scale provides a way

of examining and diagnosing the stage of development of a given individual by assessing the presence or absence of operations with three different sequences of sensori-motor development.

The Montreal Scales of Mental Development are instruments devised by Professor Adrien Pinard and his associates at the University of Montreal. The scales are based on the theories of Piaget and consist of an ordinal scale of mental development applicable to children 2 to 12 years of age. They allow for a psychological diagnosis of intelligence, and not simply an evaluation of its actual functioning.

The Guatemala Scale is a group of tests selected by Dr. Robert Klein working on a project at INCAP in Guatemala. The reason for selecting parts of this instrument is that it has been translated into Spanish, and it is being standardized and validated in a developing country and used on deprived children. It was also felt that comparisons of results in similar studies in Guatemala and Bogotá would be useful.

The various instruments, having been translated, were preliminarily tested in Bogotá, some adaptations and eliminations made, and manuals prepared for each. The basic objective of field testing during the Planning Phase was to demonstrate that the use of these instruments was feasible under local conditions, and that the tests under study were appropriate for the population. In pursuing these objectives, useful information was also obtained pertaining to the availability of children for testing, the acceptability of the team by the community, and the length of time that tests take.

During the Planning Phase the Griffiths Scale was administered to three groups of children (Group I being from the low socioeconomic class and recuperating from malnutrition; Group II being from the same socioeconomic class but not malnourished; and Group III from the middle socioeconomic class and also not malnourished). These tests were carried out on small groups of children to ascertain the feasibility of using this scale in Bogotá (Table 3). The malnourished children scored most poorly (GQ 56), the well-nourished children from the low socioeconomic class were intermediate (GQ 75), and the well-nourished children from the middle socioeconomic class had scores (GQ 103), which are similar to European or North American children. The differences between the malnourished and the well-nourished children might be due to genetic factors or to ecological factors other than nutrition.

During the past 18 months, the psychology team has been involved in the mammoth task of standardizing and validating the four groups of psychological tests. This has involved the careful use of these tests on over 2,000 children of different age groups in Bogotá. The psychology team are now well-satisfied with the instruments they have selected.

A New Hypothesis Concerning the Role of Malnutrition in Retarded Intellectual Development

Any review of the literature makes it abundantly clear that a close association exists between early protein-calorie malnutrition and a subsequent retardation of intellectual development. If the relation is causal, then it is usually assumed that a deficiency of nutrients, particularly of protein, during the period of rapid brain growth will retard growth and hence functioning of the brain. However, there is practically no evidence in the human to prove this, especially in moderately as opposed to severely malnourished children. It is not therefore known if the association between early malnutrition and subsequent poor intellectual development is due to brain damage or to other factors.[34]

The hypothesis that we propose is

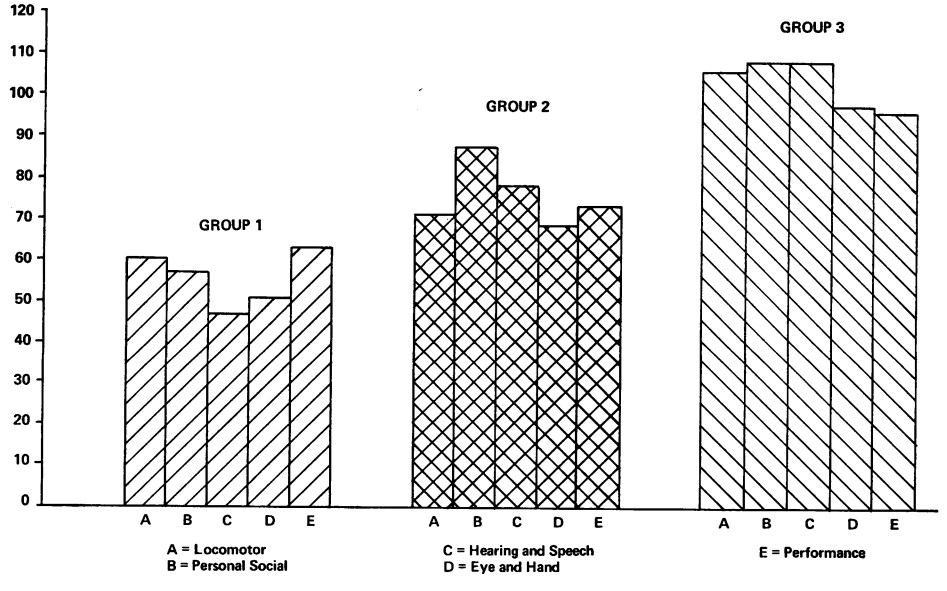
that the poor performance of many previously malnourished children is not due to pathological changes in the central nervous system, but results from the fact that a calorie deficiency has restricted the activities and learning opportunities of the child. It is well-known that a chronic calorie deficit will lead to a reduction of activity in laboratory animals or in adult man. This physiological response to a calorie deficient diet is a protective mechanism to conserve energy.

When faced with a chronic deficit in calories, the young child could be expected also to respond by conserving his energy for purposes of growth and for essential activities. By restricting his movements and by spending long periods of time passively, the malnourished child may be greatly limiting the time spent playing with his peers, verbalizing with his mother, manipulating objects, stimulating his senses, and so on. His subsequent poor performance in intelligence tests which assess his verbal, personal-social, sensori-motor and other skills may be due to the fact that he has remained sitting passively in a corner for much of his waking life. His intellectual retardation, in comparison to well-nourished children of his age, may be due to a deficiency of calories, which reduced his activity, and not to the fact that a lack of nutrients affected his brain growth. There may also be non-nutritional factors, both genetic and environmental, which contribute importantly to the retarded psychological development of malnourished children.

Until very recently, energy expenditure studies in man have used methods

Table 3—Administration of Griffiths Scale 1 to 3 different groups

Institution	G.Q.	G.Q.A.	G.Q.B.	G.Q.C.	G.Q.D.	G.Q.E.
Hosp. La Mis.	56	61	57	47	51	63
Nursery C.28	75	71	87	78	68	73
Clin. D. Rest.	103	105	107	107	97	96



which measured the oxygen consumed by the subject during the period of the study. This meant that if the calorie expenditure of an African farmer or a Scottish miner was being determined, the subject had to work wearing a mask and carrying a knapsack containing the necessary scientific apparatus. These encumbrances were likely always to affect both the attitude of the subject to his job and also his ability to perform that task in a routine fashion. Because of the difficulties, relatively few energy expenditure studies have been undertaken, and practically none have been performed in young children.

The accurate determination of energy expenditure in an unencumbered adult, or child, is still not possible. Nevertheless the knowledge of the relationship between pulse rate and oxygen consumption together with the development of new heart-rate counters, has been a new spur to the study of energy metabolism.

In particular, two new methods have been introduced to measure heart rate during normal activities. The first of these uses telemetric equipment to transmit the rate of the heartbeat to a monitoring device which can be set up as far as three miles from the subject being monitored. The second method uses electrochemical accumulators which are attached to the subject by electrodes, and which are small enough to allow heart rate to be unobtrusively determined while the subject performs his normal activities.

The activity of young children in Bogotá is being compared using one of the new methods of counting heart rate. The equipment in use is the SAMI (Socially Acceptable Monitoring Instrument) heart-rate counter. This instrument is capable of integrating the heart rate of an individual over a long period of time.[35] This method provides practically no encumbrance to the subject. Unlike the telemetric equipment, there are no considerations of range.

During a period of approximately two months, the SAMI was used on 18 children, 10 of whom had protein-calorie malnutrition and 8 of whom were well-nourished controls. The malnourished children had evidence of retarded physical growth (all but one were below 75 per cent of expected weight for age). They were not acutely ill at the time of the testing, and none had edema.

The preliminary results indicate differences between malnourished children and sex- and age-matched controls. The mean number of heartbeats per minute of the malnourished subjects was considerably lower than that of the well-nourished controls.[36]

A subgroup of 4 malnourished children was chosen for the longitudinal study. All were on a diet which was designed to improve their growth and nutritional status. The SAMI was used on these 4 children at the beginning of the study, and again approximately 3 and 6 weeks later. Heart rates during a 2-to-4-hour period of activity at three stages of recuperation were obtained. In this subgroup, each subject acted as his own control and heart rate was serving as an index of activity. The results of this part of the study are less clear-cut than in the comparison of well-nourished with malnourished children. However, there is a suggestion that activity increased as recuperation progressed. Clearly, the number of children was very small, the length of recuperation was short, and several intervening factors need to be considered in this type of study.

This preliminary study indicates the feasibility of using the SAMI equipment on preschool children. In the absence of accurate and easily used field methods for the determination of oxygen consumption in children, the SAMI makes possible the determination of a reasonably objective index of habitual energy expenditure. The hypothesis that chronic calorie deficiencies reduces energy expenditure and activity, and may be

a mechanism in the retarded intellectual development of malnourished children, requires further study. The preliminary data suggest that there may be some basis for this hypothesis and that a study involving a larger number of children tested over a longer time period is needed.

Conclusion—Action Now

Several studies now under way in Colombia, Guatemala, Mexico and elsewhere, will, we hope, in the next few years transform into well-based facts what are now surmises about the relationship of malnutrition to intellectual development. This is of great importance to developing countries where malnutrition is often the rule, not the exception. These countries' development is dependent on an improvement of the knowledge and skills of their people. In the United States and other affluent nations, there are sections of the population who are both poor and poorly nourished. It is now clear that this environment which leads to malnutrition also results in reduced physical and mental development.

There are a large number of children at risk in the world, children who, either because of malnutrition, or because of other remediable social and economic conditions, are not reaching their full intellectual potential. Investments in education are to some extent being wasted if today's children are being mentally scarred in this way.

It is true that we lack knowledge on the exact contribution of dietary deficiencies or of each of several other deprivations to the retardation of intellectual development of children. We should not let this ignorance prevent us from taking action now. This should not be an excuse for passivity on the part of affluent people and nations. Further research should be encouraged. Far more resources should be devoted to preventive action. There is adequate scientific proof that improved diets will have many beneficial effects, and that when combined with improvements in economic and social conditions, will result in the intellectual betterment of those who live in the culture of poverty.

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This paper was presented before a joint session of the American School Health Association, the National Dairy Council, and the Food and Nutrition and School Health Sections of the American Public Health Association at the Ninety-Eighth Annual Meeting in Houston, Tex., October 28, 1970.