

ENVIRONMENTAL CORRELATES OF SEVERE CLINICAL MALNUTRITION AND LANGUAGE DEVELOPMENT IN SURVIVORS OF KWASHIORKOR OR MARASMUS^{1, 2}

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A prime concern of current nutritional research is how malnutrition in early life may affect an individual's ability to function later on. The work reported here seeks part of the answer to this question by studying children in a rural Mexican community over an extended period of time. It also involves extensive research on ways that environmental factors might selectively promote severe cases of malnutrition among children of such a community.

Introduction

At the community level, malnutrition, or more specifically protein-calorie malnutrition, is a man-made disorder characteristic of the poorer segments of society, particularly in preindustrial societies. In the latter the social system consciously or unconsciously creates malnourished individuals, generation after generation, through a series of social mechanisms that include limited access to goods and services, limited social mobility, and restricted opportunities at crucial points in life.

When applied to an individual, the term "protein-calorie malnutrition" is a generic term used to cover the whole range of mild to severe clinical and biochemical signs present in children as a consequence of deficient intake or utilization of foods of animal origin, combined with variable intake of carbohydrate-rich foods. Kwashiorkor and marasmus are names given in the United States of America and British Commonwealth literature to the two extreme clinical varieties of the syndrome that occur in

infants and children. The appearance of marasmus or kwashiorkor is related to the age of the child, its age when fully weaned, the time when food was introduced as a supplement to breast milk, the caloric density and protein concentration of supplements the child actually ingests, and the frequency and severity of infectious diseases present during weaning.

Research in this field has recently centered on the question of how malnutrition affects the later behavior of individuals who suffered from it in early life. A series of studies done in various parts of the world have shown that survivors of early severe malnutrition function differently from well-nourished children in a great variety of ways. These differences involve things ranging all the way from psychomotor behavior to intersensory organization (2, 4, 5, 6, 7, 10, 12, 13, 15, 16, 17, 18). The problem now is to separate the specific role that deficient food intake can play from the effects of other factors that interfere with the correct functioning of the individual. This is because malnutrition in humans is the result of ecological conditions (11). Thus many of the factors that either cause or accompany it can themselves have a negative effect on mental and behavioral development.

Clearly, this type of research question can only be dealt with through longitudinal observation of children at risk and of appropriate

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A significant percentage of the Hemisphere's preschool children suffer from protein-calorie malnutrition, which often causes retarded mental growth and development.

control children. With this idea in mind, we have been engaged since March 1966 in an ecologic study of a cohort⁴ of children born in a community where preschool malnutrition is highly prevalent, and where other factors related to the life of the children have variations of sufficient range to permit associative analyses to be carried out.

In brief, the project is the study of a total one-year cohort of children, all born in a rural village between 1 March 1966 and 28 February 1967. The children and their families have been closely observed from the nutritional, pediatric, socioeconomic, and developmental points of view. This has been done in a coordinated manner, with great attention to detail and (so far as possible) making use of validated research

⁴A group of individuals with one or more statistical factors in common.

instruments. A good number of the instruments were devised and tested by the project staff during the 10 years preceding the cohort's formation.

The objective of the study is to analyze the relationships between the conditions surrounding child care (especially as they affect nutrition) and the course of physical growth, mental development, and learning. The main hypothesis to be tested is that intellectual growth at all stages and school-age performance are related to the nutritional and health conditions to which the child has been exposed.

The children first brought into the study during the prenatal period have been observed for five years and will continue to be studied until they have completed their first seven years (March 1974). This will be the earliest time at which certain crucial mental examinations can be meaningfully applied. At that time the children can all be assessed in the relatively uniform environment of a primary school.

The particular focus of the project is on the relationship between nutrition and mental development. However, the nature of both variables caused the project to be designed as an ecological study of young children in their familial and social environments.

The ecological approach was chosen because it is a particular form of the natural history method which seeks to determine the nature of effective variables by considering their interrelations in a single population. When applied to the problem of malnutrition, it attempts to determine patterns of cause and consequence by considering the interrelations among nutritional, health, and social factors. By orienting itself longitudinally, the ecological approach can identify age-specific risk conditions, can relate antecedents to consequences at different developmental stages, and can integrate biological and social time scales. It can also take into account both the general environment and the microenvironment of the developing individual and deal with the interaction of biological and social variables.

Perhaps the most important reason for the ecological method's usefulness is the fact that it

employs uncontrolled variation as a basic analytical tool. An essential requirement for its use is, therefore, sufficient variation in the attributes to be considered among the population studied. If such variation is present, associative analysis can identify, segregate, and interrelate the influential factors that affect the consequences with which one is concerned.

Using the ecological method we plan to analyze: (1) the influence of social, economic, and familial conditions on the development of malnutrition; (2) the effect of malnutrition on physical growth, mental development, and learning, and (3) the interaction of nutritional factors with infectious diseases, family circumstances, and social circumstances—and the impact of these interactions on the processes of growth and development. This intensive analysis can be understood only through a detailed acquaintance with the setting of the study, the cohort under observation, and the nature of the data used.

The Setting of the Study

To examine the complex set of variables with which our investigation is concerned, we have had to study a large group of children. Preliminary estimates indicated that the community selected for the study would have to be large enough to provide at least 250 births per year, so that the annual cohort to be observed could include at least this number of children. The community chosen also had to contain a considerable range of social and nutritional conditions—and to have a population likely to cooperate, willing to enroll, and willing to remain in the study. For a longitudinal study such as this, it was clearly essential that the population be relatively stable, and that a high proportion of the families and infants enrolled in the study continue to live in the community for the duration of the inquiry period.

The community chosen met these requirements. The selection was based on previous experience with rural communities and field studies. The village selected had been a participating community in one of these studies; it

had shown a high level of population stability over time, excellent cooperation, and a wide range of variation in social, economic, familial, and health features. Furthermore, the average number of births expected in one year was 300.

The village is located in a semitropical, subhumid, primarily agricultural zone in southwestern Mexico where arid hillsides alternate with fertile valleys and meadows. It is at an altitude of between 900 and 950 m above sea level and has a climate modified by altitude. The median annual temperature is between 23°C and 25°C in the shade, and the climate ranges from chilly in winter to very hot in summer. Summer temperatures of 40°C are common. A small river runs through the village, and its waters are used for irrigation, laundering, and other general purposes.

As is characteristic of Mexican rural villages in this region, the town radiates outward from a shaded central plaza along a series of unpaved and rutted dirt streets, which form roughly quadrangular blocks.

The area surrounding the townsite is entirely agricultural, with sugar cane constituting the major commercial crop. Small amounts of cotton and rice are also grown commercially. Interspersed among the large commercially organized fields are small family parcels and rentable areas where the villagers produce food crops—principally corn, chili peppers, tomatoes, other garden crops, and fruits—for their own consumption.

In 1965 we carried out a census of all village households. Our findings indicated the presence of 5,637 persons, organized in 1,041 families and ranging from 0 through 85 years of age. The numbers of men (2,830) and women (2,807) did not differ significantly. The population's distribution by age and sex is presented in Figure 1. As may be seen, the population was relatively young: fully 50 per cent of the inhabitants were under 15 years of age, and 80 per cent were under 35. In a stable community such as this, these age ratios normally reflect a low life expectancy at birth. No notable sex differences within particular age groups were found.

Birth rates over the previous 20 years had been at a mean of approximately 55 per thousand, leading us to estimate approximately 300 births per year. For the 12-month series of births upon which the current study is based, this estimate proved accurate.

The principal occupation of the villagers was agriculture, although relatively small numbers of people were employed as workers and artisans, and a still smaller number were engaged in commerce or the practice of a profession. These occupations, as reflected by the main sources of family income, are shown in Figure 2. Approximately 65 per cent of the population gained its livelihood directly from agriculture; 12.5 per cent worked at a variety of jobs (including transport work, labor at a small cotton gin and a mattress factory, carpentry, masonry, or other skilled and semiskilled crafts); and 9 per cent were small tradesmen, shopkeepers, or teachers. The latter group also included one architect, one engineer, and two physicians who served both the village proper and surrounding communities.

The social and economic status of those people who worked in agriculture was by no means homogeneous, as can be seen in Figure 3.

FIGURE 1—Age pyramid by sex.

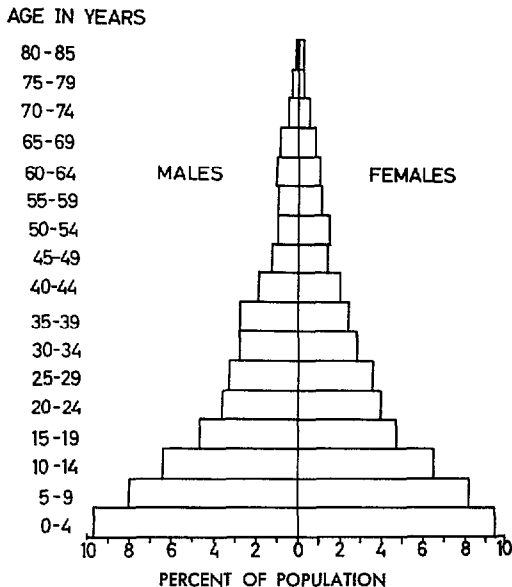
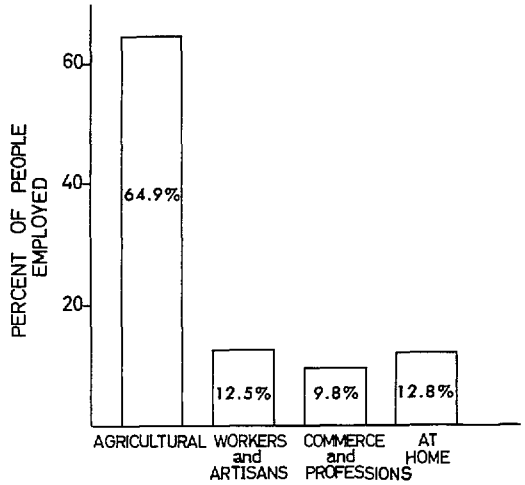
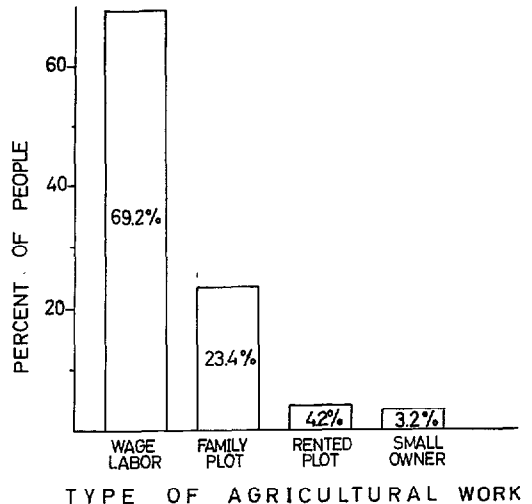


FIGURE 2—Main sources of family income in the village. "At home" families are those in which mothers and children were mainly dependent on some other source of support.



Most of them were agricultural day laborers (*jornaleros*), who earned a marginal income from seasonal employment. They supplemented their income with seasonal plantings of food crops on communal lands at some distance from the village. A second group, comprising some 23 per cent of those engaged in agriculture, had family plots cultivated for both subsistence and small-scale commerce. The

FIGURE 3.—Percentages of people engaged in different types of agricultural work.



'best-situated cultivators were either small owners or renters of relatively high-grade farm-lands; taken together, these two groups constituted approximately 7 per cent of those using agriculture directly as the main source of family income.

If the different kinds of agricultural work performed are to be understood, a few words about landholding are required. The *jornalero* owns no land and works entirely for wages. He is generally not insured for social and health services and represents the most economically deprived and unstable segment of the population. He may be described as an agricultural proletarian.

Two kinds of land are owned by individuals in this area, the first of which is the family plot, usually in the form of an *ejido*. This latter is a small parcel of land, usually ranging from 0.5 to 1.25 hectares, that was distributed to landless peasants (*peones*) at the time of the agrarian reform of 1917. Such land is held by the family in perpetuity so long as it is worked; but it may not be sold, traded, divided, or attached for debt. In the case of the village being studied, all the *ejidos* owned by the villagers had been amalgamated into a sugar cooperative.

The second type of individually owned land is the small proprietor's plot. This is generally larger than the *ejido*. Such plots may be bartered, mortgaged, attached for debt as private property, and divided or sold, all without special limitations. Those which are rented are generally larger than the rest, and those who operate them are usually better off economically than the other agricultural groups.

Until 30 years ago the village was almost totally agricultural in character. Since then it has been in a state of slow transition to a mixed economy representing more advanced levels of both industrial technology and agricultural organization. The beginning of the transition was marked by a national law authorizing and facilitating the development of agricultural combines and cooperatives. Shortly after this law was enacted, a large cane-growing cooperative was established, along with a sugar refinery 17 km from the village. Much of the land

surrounding the village was assimilated into this large cooperative. A mattress factory employing 20 workers was established 12 years ago, and this was followed five years later by construction and operation of a small cotton gin.

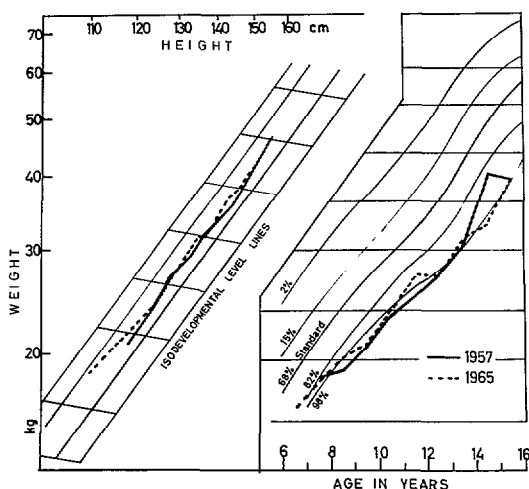
These economic changes have been accompanied by greater availability of transportation, improvement and construction of roads, and a considerable increase in interaction between people in the village and more advanced urban and semiurban centers. The technological advances have also been accompanied by installation or improvement of a variety of village services, including schools, social welfare and health centers, and a central water supply. The village now has one kindergarten, two primary schools, and one school accepting pupils up through the ninth grade. Compulsory school attendance starts at seven years of age and continues for six years; beyond this, study may be voluntarily continued for three more years inside the village and at higher levels outside it.

Variations in community health conditions and the relative opportunities available for child growth and development are reflected in two sets of data. The first deals with the weights and heights of schoolchildren. A comparison of the growth attained by children attending school in 1965 with that of children at school a generation earlier suggests that technological changes were not accompanied by changes in either mean height or mean weight for any particular age group; nor was there any diminution in the variability of these characteristics within the population. The Wetzel grids shown in Figure 4 illustrate this lack of change.

The second set of data uses tuberculin reactivity as an index of health risk. It reflects the high frequency of children's exposure to sources of infection. Age-specific values for positive reaction to tuberculin show a continuing rise of positive reactors with age, as can be seen in Table 1.

As a final step in assessing the suitability of the village for our purposes, a survey was made of a sampling of households with children of preschool age. The data obtained was used for clinical evaluation of the children and assess-

FIGURE 4—Relation between height and weight in two generations of school children.



ment of the incidence of subnutrition, as indicated by depression of weight with respect to age (see Table 2). The figures indicate that mild, moderate, and severe degrees of malnutrition were present at all levels in the preschool period, with a frequency that made the village fairly representative of communities where chronic subnutrition is prevalent.

All the data presented here provided a basis for choosing the community as a suitable site in which to conduct a longitudinal study of the ecology of growth and development in a total

TABLE 1—Distribution by age of positive PPD reactors among village children.

Age (years)	Positive reactors (%)
3	0
4	0
5	3.7
6	2.1
7	7.8
8	12.4
9	8.7
10	7.6
11	12.3
12	12.6
13	16.1
14	15.9
15	20.0
16	37.5
Average	11.2

TABLE 2—Nutritional status of preschool children in the village.

Age (months)	No. of children	Malnutrition (%)		
		Third degree	Mild-moderate	Normal (%)
0-5	132	0	5	95
6-11	112	3	9	88
12-23	210	5	18	77
24-35	207	9	21	70
36-47	212	8	8	84
48-59	201	5	11	84

annual cohort of births over the preschool and school years.

The Birth Cohort

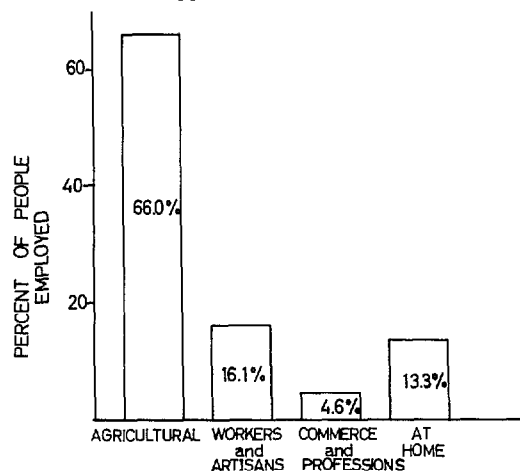
The Children

Of the 300 infants born during the 12-month period in which the cohort of births was compiled, there were equal numbers of boys and girls. The social origins of these children closely matched the distribution of principal sources of income and occupation in the village as a whole. Minor deviations from the overall distribution pattern can be attributed to the constricted age range associated with reproduction.

The manner in which principal sources of family income were represented in the cohort are shown in Figure 5. The great majority of the cohort children's families (66 per cent) were agricultural. Sixteen per cent were families of workers or artisans, with four times as many of the former type represented than the latter; and 4.6 per cent were families of tradesmen or professional men, an equal number pertaining to each of these two social groups. Some 13 per cent of the births occurred in families in which it was difficult or impossible to define an intrafamilial source of income. This means that the mother and children were generally dependent upon some other familial or social source of support.

The distribution of birth weights in the annual cohort is presented in Figure 6. Among the 291 infants who lived long enough to be

FIGURE 5—Main sources of family income in the cohort. "At home" families are those in which mothers and children were mainly dependent on some other source of support.



weighed, there were eight weighing 1,500 to 1,999 g, 28 weighing 2,000 to 2,499 g, 147 weighing 2,500 to 2,999 g, 86 weighing 3,000 to 3,499 g, and 22 weighing 3,500 to 3,999 g. The mean birth weight was $2,898 \pm 444$ g. A birth weight of less than 2,500 g thus pertained for 12.3 per cent of the cohort, whereas only 7.6 per cent of the children weighed more than 3,500 g. As would have been expected from other data, the mean birth weight of boys was significantly higher than that of girls (Figure 7). The mean birth weight of boys was $2,977 \pm 394$ g and that of girls was $2,860 \pm 408$ g. The mean

FIGURE 6—Birth weight of children in the annual cohort of births.

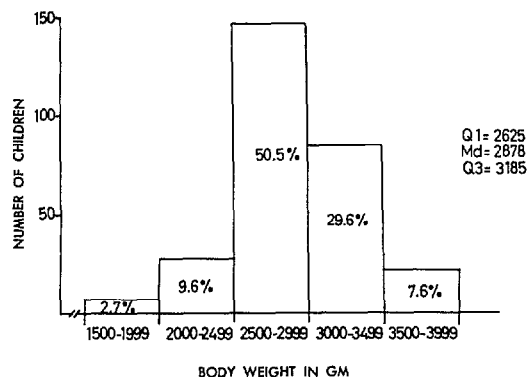
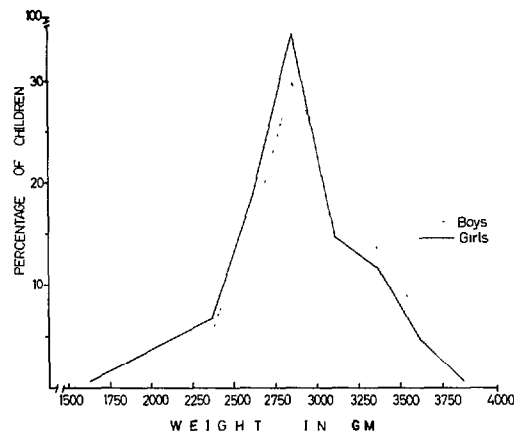


FIGURE 7—Sex distribution of body weight at birth within the cohort.



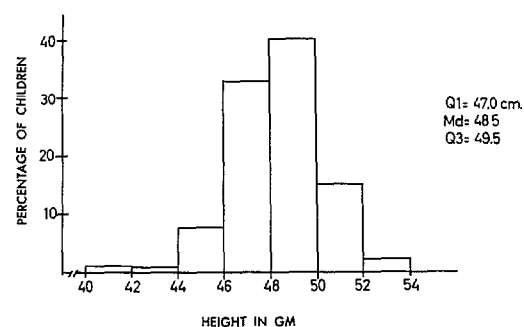
difference of 117 g was significant at the 0.02 level of confidence.

The distribution of total body length at birth for the children in the cohort is presented in Figure 8. The median body length was 48.5 cm, with 25 per cent of the children having a body length of less than 47 cm and an equal percentage having body lengths between 49.5 and 53 cm. As with birth weight, mean body length at birth was significantly higher in boys than in girls. Boys had a mean length of 48.7 ± 1.8 cm and girls had one of 48.0 ± 2.0 cm. This difference, though small absolutely, is statistically significant ($t = 3.3$; $p < 0.1\%$).

Mortality and Emigration

Of the 300 children delivered, 296 were alive at birth and four were dead. The stillborn did

FIGURE 8—Distribution of total body length at birth within the cohort.



not belong to families of any particular occupational group. One was born to a family whose principal source of income was agricultural day-labor, one to a cultivator of rented lands, and two others to owners of family plots. Of the 296 live-born infants, seven died during the first week of life (a mortality rate of 23.6 per 1,000). Three others died during the remainder of the first month. If all the stillbirths and deaths during the first week of life are considered perinatal deaths, the rate of such deaths was 36.7 per thousand. Combining all deaths of live-born infants during the first month yielded a neonatal death rate of 33.8 per thousand.

For the most part, the infants who were stillborn or who died during the first month of life had a low birth weight. Unfortunately, customary practices prevented those that were stillborn or died a few hours after birth from being weighed. The seven children who were weighed had birth weights below 2,300 g.

Nine infants died during the remainder of the first year of life, seven of them between the second and sixth months. One of the two infants whose death occurred after six months of life was mortally bitten by a scorpion. In all, 19 live-born infants of the cohort died during the first year of life, with a resultant infant mortality rate of 63.3 per thousand.

The children who died were not randomly distributed in the cohort with respect to weight or body length at birth. The mean birth weight in the cohort was 2,898 g, and the mean birth weight of the children who died during the first year of life was 2,536 g. Similarly, mean body length of the deceased was 45.8 cm, as contrasted to a mean body length of almost 49 cm in the cohort as a whole. Both of these mean differences were significant at less than the 0.01 level of confidence.

It is of course possible that these mean differences resulted from an excess of premature infants among the infants who were stillborn or who died in the first year of life. Such a possibility is supported by the fact that six of the infants who died were premature. The resulting prematurity rate of 260 per thousand deliveries is more than twice the rate

of 124 per thousand deliveries for the cohort as a whole. Considering only infants above 2,500 g at birth among the stillborn and infant deaths, however, one still notes a preponderance of poorly developed children. In all, 63 per cent of them had birth weights below the median of the cohort, and the remainder had birth weights just slightly higher than the median.

Only three of the 23 infants had body lengths equal to or greater than the median of the cohort as a whole. Two were exactly at the median and one was 1 cm higher. All other infants were between 1.5 and 7.0 cm shorter than the median body length for the cohort. It appears, therefore, that those that were stillborn or that died during the first year of life were less well developed *in utero* than the survivors.

After the cohort's first year of life 10 more children died. With the exception of two whose deaths were due to accidents (severe extensive burns and bronchoaspiration) and a child who died of hypoprothrombinemia and purpura, all deaths in this four-year period can be directly related to infectious disease accompanied in most cases by severe malnutrition.

Table 3 shows the age, sex, and probable cause of death of each child that died during the cohort's first five years.

Besides the 300 children born in the village during the calendar year 1966-1967, twelve families came to live in the village during the time the cohort was being composed. These families had children less than one year old, and they were included in the longitudinal study.

Also, during the five years covered, a total of 50 families left the village. Reasons for emigration were mainly related to better working conditions in another, larger town or in Mexico City. Table 4 shows the time spent in the cohort by the children of these families.

As may be seen from the cumulative frequency figures, all 50 children who left the village were examined, at least during the first few days of life. We have data about the first three months of life for 44, the first six months for 34, the first year for 22, the first two years for seven, and the first three years for two.

TABLE 3—Mortality in the cohort during the first five years of study.

Period	Number	Code	Sex	Age at death	Cause of death
Still-born	1	13.12	M	0	unknown
	2	13.5	F	0	unknown
	3	13.26	M	0	unknown
	4	4.22	F	0	unknown
First week of life	1	12.24	F	1 hour	unknown
	2	13.28	F	1 hour	unknown
	3	7.12	F	5 hours	bronchoaspiration
	4	9.18	M	5 hours	prematurity
	5	6.11	M	6 hours	hyaline membrane
	6	8.24	M	2 days	congenital malformations and bronchopneumonia
	7	13.2	M	3 days	bronchopneumonia
Days 8-30	1	4.23	F	9 days	ABO incompatibility
	2	2.3	F	17 days	electrolyte disturbance
	3	12.15	F	21 days	prematurity
Days 30-360	1	13.29	M	40 days	electrolyte disturbance due to diarrhea
	2	13.16	M	43 days	pyelonephritis
	3	12.14	F	76 days	electrolyte disturbance due to diarrhea
	4	10.13	F	78 days	septicemia
	5	11.2	F	85 days	bronchopneumonia
	6	11.27	F	130 days	electrolyte disturbance due to diarrhea
	7	12.17	F	139 days	electrolyte disturbance due to diarrhea
	8	7.11	F	268 days	scorpion bite
	9	5.24	M	312 days	electrolyte disturbance due to diarrhea
One to five years	1	3.22	M	375 days	electrolyte disturbance due to diarrhea
	2	13.6	F	400 days	bronchopneumonia and malnutrition
	3	1.21	M	405 days	bronchoaspiration
	4	11.6	F	435 days	bronchopneumonia and malnutrition
	5	4.19	M	654 days	acute miliary tuberculosis
	6	2.22	F	737 days	kwashiorkor amebiasis
	7	11.20	M	1,036 days	kwashiorkor diarrhea
	8	3.1	M	1,229 days	electrolyte disturbance due to diarrhea
	9	9.13	M	1,240 days	third-degree burns
	10	8.22	F	1,413 days	kwashiorkor purpura

Family data were available for all 50 children who emigrated.

Familial and Social Backgrounds

Broadly speaking, background factors in the cohort were of three kinds: first, the mother as a biological and social organism; second, the family structure; and third, objective circumstances of life such as sources of family income and the family's housing conditions. Each kind of factor will be considered in turn, with the exception of sources of income, which has already been discussed.

To begin with, it is important to consider

some features of the mother—such as her age, height, weight, and previous pregnancies. The age distribution of mothers in the cohort is presented in Figure 9. Ages ranged over 30 years; the mothers included two girls who had their first children at age 13, and one woman who had a child at age 43. The mean age was 25.6 ± 6.8 years, and the median age was 24 years. Seventy-five per cent of the mothers were under 30 years of age. The distribution of maternal age tends toward bimodality and, as a whole, contains sufficient variability to permit associative analysis.

The heights and weights of the mothers also varied widely (see Figures 10 and 11). Heights

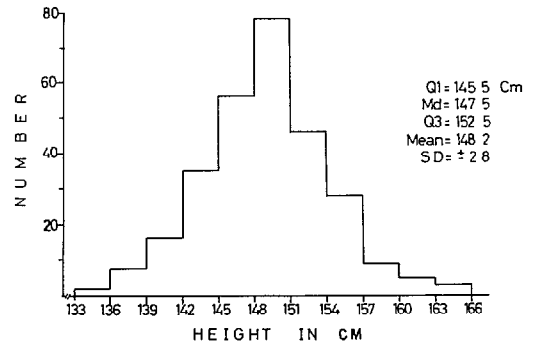
TABLE 4—Time spent in the study by children whose families emigrated from the village.

Days under observation	Number of children	Number of children remaining
0	0	50
1-3	0	50
4-15	1	49
16-30	1	48
31-90	4	44
91-180	10	34
181-270	7	27
271-360	5	22
361-420	5	17
421-540	3	14
541-610	4	10
611-720	3	7
721-810	1	6
811-900	2	4
901-990	1	3
991-1,080	1	0
1,081-1,170	0	2
1,171-1,260	1	1
1,261-1,350	0	1
1,351-1,440	1	0

ranged from 133 to 165 cm, with a mean value of 148.2 ± 2.8 cm. The heights were fairly normally distributed, with a slight tendency toward increased frequency in the lower range of stature. The median value was 147.5 cm, and 75 per cent of the women were less than 153 cm tall.

Weights ranged from 32 to 86 kg. This upper weight was markedly atypical and is so indicated by a break in the distribution of values on the x axis of Figure 11. Mean weight was 53.0 ± 4.8 kg with a median value of 51 kg,

FIGURE 10—Height of cohort mothers.



suggesting a slight preponderance of frequencies at the lower end of the distribution. Both height and weight showed sufficient variability to make associative analysis feasible.

The total number of pregnancies experienced by the various cohort mothers is shown in Figure 12. This number ranged from one to more than 11, with the highest being 16. Similar numbers of cohort infants were born to mothers for whom this was the first, second, third, or fourth pregnancy. Mothers with higher numbers of pregnancies tended to account for decreasing shares of cohort births. From the viewpoint of epidemiologic evidence in obstetrics, it is not meaningful to consider the distribution of parities in terms of mean value. Available evidence suggests that special conditions of risk attend first births and births that occur after the fifth pregnancy; enough cases in each of these parity ranges exist to permit analysis within the cohort of births.

FIGURE 9—Age distribution of mothers in cohort.

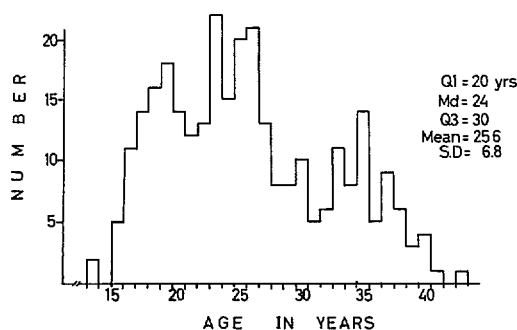


FIGURE 11—Weight of cohort mothers.

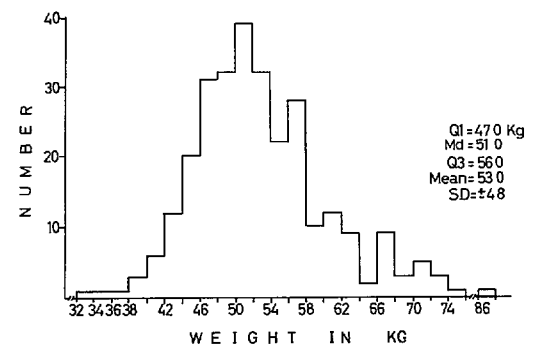
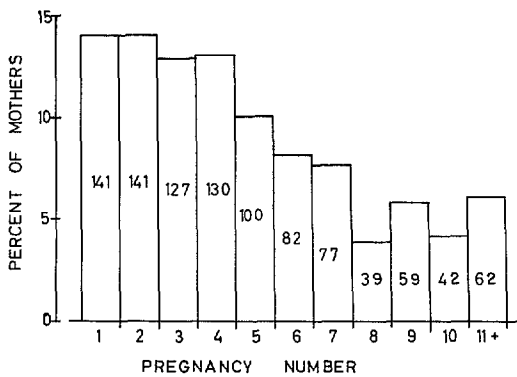


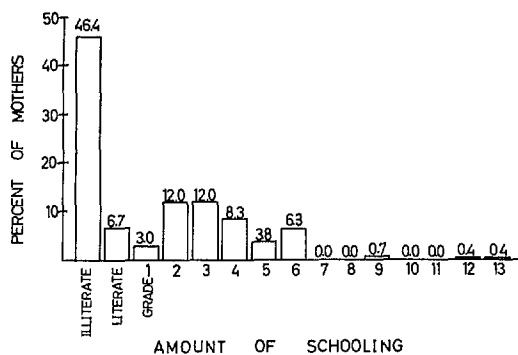
FIGURE 12-Number of pregnancies of cohort mothers.



In addition to the foregoing, the mother's personal hygiene, literacy and educational level, and contact with mass media may be considered in relation to the child's condition. Ratings of personal hygiene ranged from a low of 20 per cent to a high of 100 per cent. The median score was 56.6 per cent, with three-fourths of the mothers scoring below an estimated cleanliness level of 76 per cent. Wide variations in personal cleanliness existed among the mothers, and personal hygiene subgroups could readily be defined.

The mother's literacy and school attainments are shown in Figure 13. Almost half the mothers were completely illiterate. Another 10 per cent had either become literate through adult literacy campaigns or had acquired basic literacy by completing one school grade. Only 8

FIGURE 13'-Literacy and school grade completed by cohort mothers.



per cent had completed the full six-year primary school curriculum, of which only 1.5 per cent had obtained additional schooling. From a functional point of view it was possible to group the mothers into four classes: (1) the illiterates; (2) the adult literates and those who had completed the first and second grades; (3) those who had completed the third, fourth, or fifth grades; and (4) those who had completed primary school. These functional groupings have been used in later associative analyses.

As may be seen in Figure 14, very few of the women had any exposure to television. Half had little or no regular contact with radio, and almost 70 per cent read newspapers only sporadically or not at all. If consideration of newspaper reading is limited only to the literate segment of the population, slightly fewer than 50 per cent of the literate mothers actually did such reading. Thus the present study indicates that radio has the widest audience for disseminating mass information in this community. For this reason our consideration of the relation between the child's characteristics and the mother's contact with mass media has been limited to this medium.

Data on family size and sanitary characteristics of households are presented in Figures 15 and 16, respectively. There was considerable variation in both of these attributes. Family size ranged from a single-child family of three

FIGURE 14-Contact of cohort mothers with mass media (classified on the basis of no exposure, some exposure, or no regular exposure).

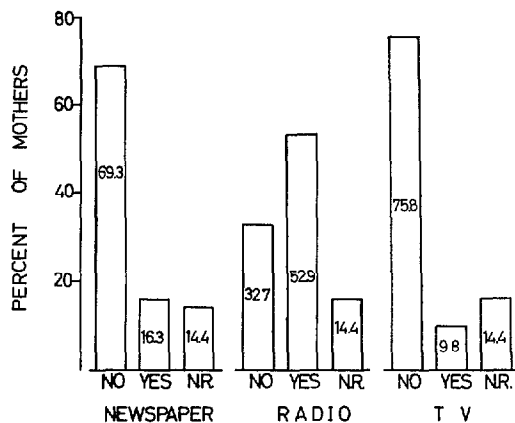


FIGURE 15—Size of cohort families.

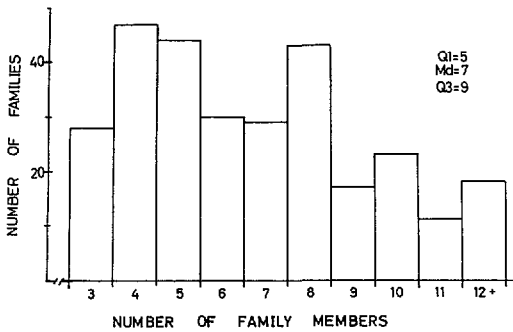
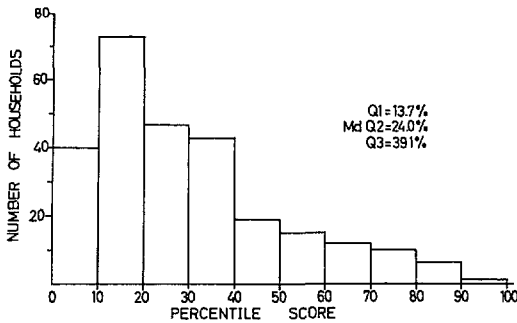


FIGURE 16—Sanitary characteristics of cohort households.



individuals to both nuclear and extended families of a dozen or more members.

The sanitary characteristics of different households varied widely. Most were substandard, but a considerable number had good to excellent sanitary conditions and facilities. Sufficient variation existed to permit the sanitary characteristics of the household to be related, as a differential background factor, to characteristics of the child.

The Variables

In the course of the study we have been concerned with two sets of variables: those relating to the child's family circumstances and background environment, and those relating to characteristics of the child himself. We have avoided the terms "antecedent" and "outcome variables," because among each of the general sets of factors certain characteristics may, with

equal justification, be considered antecedents or consequences of others within the same set. Thus, the mother's education may well affect her patterns of personal hygiene and preferred mode of child care. Similarly, among the variables that characterize the child, a factor such as birth weight may well be an important antecedent for outcomes at later ages.

In general, three types of background factors have been considered: family patterns, biological and psychosocial characteristics of the parents and caretakers, and macroenvironmental characteristics of the child ranging from survival to physical and behavioral changes over time.

Data for ratings of variables were obtained by interviews, direct observation and measurement, clinical assessments, and the application of special tests.

The reliability of all measures and ratings have been assessed; any measures with excessive intraexaminer, interexaminer, or score-rescore error levels were either improved by modification or eliminated. Scales for somatometric measurements including weight and height were regularly recalibrated and examined. Errors beyond the 2 per cent level were considered excessive. For rating scales, reliability levels expressed as retest, rescore, or retest-rescore correlation coefficients of less than 0.82 were considered unacceptable.

The director of the study, the senior psychologist, the senior pediatrician, and the social worker-nutritionist, acting as a research committee, shared the responsibilities for quality control, maintenance of strict standardization, and completeness of collected data. The senior biostatistician of the project has been a member of this committee since the time he joined the team.

The types of studies already made of each of the 229 children⁵ remaining in the cohort at five years of age, as well as the tests to be given those remaining in the study in their fifth and sixth years, are shown in Table 5.

⁵Three hundred births plus 12 arrivals during the first year, minus 33 deaths and 50 emigrations.

Table 5—Studies made of children in the cohort.

Variables	Measurements	Age period	Frequency
1) Growth			
(a) Physical growth	Body weight	0-5 years	fortnightly
	Height; head, chest, and arm circumference	0-3 years	monthly
		3-4 years	bimonthly
		4-5 years	thrice yearly
	Skinfold thickness	0-3 years	monthly
		3-4 years	bimonthly
		4-5 years	thrice yearly
	Bone age	4-5 years	yearly
(b) Mental growth	Psychomotor, adaptive, language, and social-personal development	0-2 years	monthly
		2-3 years	quarterly
		3-4 years	thrice yearly
	Bipolar concept formation	2-3 years	thrice yearly
		3-4 years	twice yearly
		4-5 years	twice yearly
	Finger-thumb opposition	3-5 years	twice yearly
	Finger localization	4-5 years	twice yearly
	Wechsler preschool and primary scale of intelligence	4-5 years	twice yearly
	Styles of response to cognitive demands	4-5 years	twice yearly
	Sensory-motor and movement skills: static balance; dynamic balance; visual-motor coordination involving aiming and accuracy, motor control, and inhibition	4-5 years	twice yearly
	Spontaneous language	5-7 years	twice yearly
	Psycholinguistic abilities: language decoding (meaning); language encoding (expression); grammatical levels of decoding and encoding; development and growth of grammatical language	5-7 years	twice yearly
	Visual perception and form recognition	5-7 years	twice yearly
	Intersensory integration: visual-haptic, visual-kinesthetic, kinesthetic-haptic, auditory-visual	5-7 years	twice yearly
		6-7 years	twice yearly
	Analysis and synthesis of geometric forms	6-7 years	twice yearly
	Learning strategies: concrete operations (Piaget)	6-7 years	yearly
2) Nutrition	Food consumption (child)	0-2 years	monthly
		2-3 years	quarterly
		3-4 years	twice yearly
		4-5 years	yearly
	Family food consumption	3-4 years	twice yearly
		4-5 years	yearly
	Clinical signs of child's malnutrition	0-5 years	fortnightly
3) Health	Prenatal and delivery history	—	once
	Pediatric examination; morbidity history of child and of each member of the household	0-5 years	fortnightly
4) Mother-child interaction	Time-sample observation and inventory of home stimulation	0-3 years	monthly
		0-3 years	quarterly
		3-4 years	twice yearly
		4-5 years	yearly

Table 5 (cont.)

Variables	Measurements	Age period	Frequency
5) Sociocultural characteristics			
(a) Familial			
	Family composition and organization; family type; family size;	0-5 years	yearly
	Main source of income and annual income;	0-5 years	once
	Sanitary facilities; social morbidity; social change; informal communication net; mortality record	0-5 years	fortnightly
(b) Parental			
(i) Biological			
	Age, weight, height	0-5 years	once
	Parity and reproductive history ^a	0-5 years	yearly
(ii) Sociocultural			
	Personal cleanliness	0-3 years	monthly
		3-5 years	thrice yearly
	Formal education and contact with mass media	0-5 years	yearly
	Nutritional knowledge; ^a health education; ^a proclivity toward change; ^a cultural mobility ^a	0-5 years	once
	Psychological profile; ^a maternal attitudes; intelligence performance ^a	0-5 years	once

^aMother only.

Language Development and Malnutrition

Having described in detail the setting of the study and the birth cohort, we wish to present the preliminary results of a study of certain language features in a group of children who developed severe clinical malnutrition.

During the first five years of life of the cohort, 22 children—14 girls and eight boys—were found to be suffering from severe clinical malnutrition. It must be said that such cases appeared despite all medical efforts to prevent them. The patients' ages at the time of diagnosis ranged from four to 53 months. Only one child was below one year of age, nine were between one and two years, eight were between two and three years, three were between three and four years, and one was 53 months old.

Fifteen of the 22 cases matched the clinical picture of kwashiorkor; the other seven cases were of the marasmic variety (*I*). The proportion of marasmus in girls and boys was 4:3, but the number of girls with kwashiorkor was twice the number of boys. Because of the small number of cases, these differences are not of statistical significance.

Ten children, six with kwashiorkor and four with marasmus, were treated at home; nine

children with kwashiorkor and three with marasmus were treated in the hospital. The average duration of each hospital stay was 30 days, and none of the children stayed longer than 60 days. No deaths occurred in the hospital-treated group. In contrast, three of the 10 children treated at home died. Of the latter, two had kwashiorkor and one had marasmus; their respective ages at the time of diagnosis were 12, 14, and 22 months. All three patients who died did so within 15 to 60 days of diagnosis. Of the 19 survivors, one child emigrated from the village after his discharge from the hospital, leaving a total of 18 cases for study.

The present report compares perceived language development in the 19 children who developed severe clinical malnutrition before the age of 39 months with the language development of a group of children from the same birth cohort who were never considered as severely malnourished and who were matched at birth for gestational age, body weight, and total body length.

As may be seen in Table 6 and Figure 17, mean language development, as measured by the Gesell method (*14*), was very similar in the malnourished group and the controls during the first year of life. Only one case of severe

TABLE 6—Language development scores, measured in day equivalents, of severely malnourished children and matched controls.

Age (days)	Birth	180	360	540	720	900	1,080
Past or present severe malnutrition	27 ± 3.2	167 ± 14.4	289 ± 47.2	385 ± 86.0	467 ± 102.7	534 ± 103.0	657 ± 119.5
Control group	28 ± 1	177 ± 21.2	334 ± 55.4	490 ± 73.3	633 ± 93.4	785 ± 143.1	947 ± 135.2
"t" test	1.37	1.69	2.69 ^a	3.90 ^a	4.80 ^a	5.80 ^a	6.53 ^a

^aSignificant at less than 0.01.

malnutrition was diagnosed during this period. As time elapsed and more children came down with severe malnutrition, a difference in language performance favorable to the matched controls became evident. The difference was more pronounced at each successive age tested.

Not only were mean values significantly lower in the malnourished group, but the distribution of individual scores was also markedly different from that obtained in the control group. Thus, for example, at three years of age (Figure 18) 11 children of the control group had language scores above 1,021 days' equivalent and only one child scored below 720 days'

equivalent. In contrast, none of the children with past malnutrition scored above 960 days' equivalent, 12 children had values below 720 days' equivalent, and three of the latter had language performances six months behind those of the control children with the lowest scores.

Concept development, particularly the emergence of verbal concepts, has long been viewed as a basic factor in the development of human intelligence. The emergence of the concept of opposites, and with it bipolar labelling, represents an early and readily measured aspect of concept development in young children.

As a consequence of their concern with

FIGURE 17—Mean language development as a function of age in severely malnourished children and matched controls.

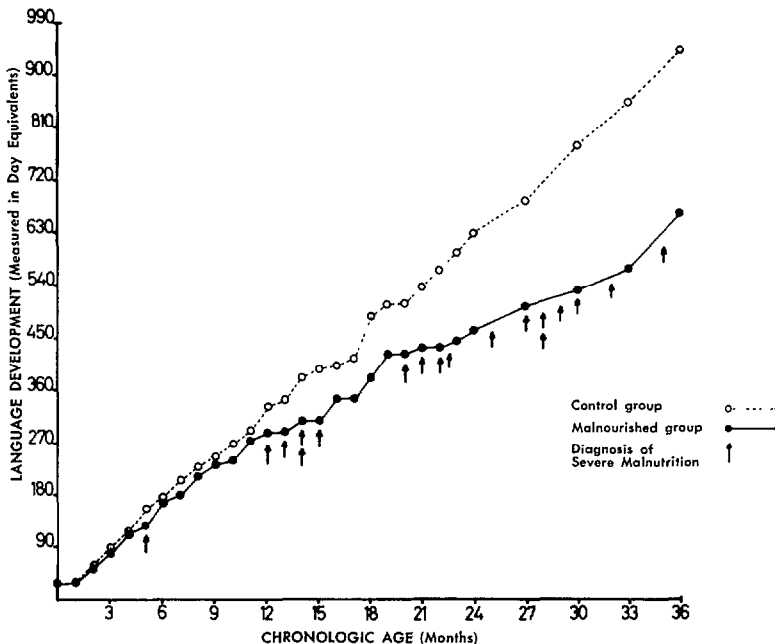
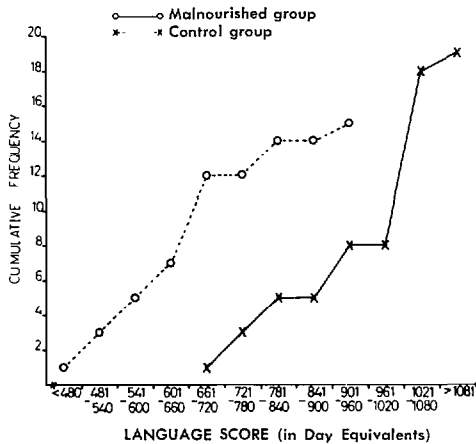


FIGURE 18—Distribution of language scores at 1,080 days of life of malnourished children and controls matched at birth for sex and body length.



improving the school performance of disadvantaged children, Francis H. Palmer and his colleagues at the Institute for Child Development and Experimental Education of the City University of New York evolved the view that development of a progressively more difficult series of bipolar concepts could be used for systematic training and enrichment of language experience. Accordingly, as part of their studies on the effects of intervention programs started at age two, they developed a test covering both "poles" of 23 concepts (e.g., big-little, long-short, in-out) in two different situations. The score derived from the test provides a measure of the child's knowledge of various conceptual categories that are commonly used in organizing sensory experience.

Although Palmer and his associates had not designed the series of bipolar concepts that were developed to be a language test, it is

implicit that the progressively more difficult training series could be used by itself, without training, as a way of assessing the natural acquisition of bipolar concepts in young children.

To test this hypothesis, we administered 22 of the 23 concepts selected by Palmer as a repeated test of bipolar concept acquisition at ages 26, 31, 34, and 38 months to the total cohort of 229 children living in a preindustrial society (9). All items were presented to the children at all ages, independently of the number of successes or failures. In all instances the order of presentation was the same, beginning with the first item contained in Form I. Data obtained at the successive ages tested clearly demonstrated a developmental course of competence in response to tasks involving the utilization of bipolar concepts.

Data on bipolar concept acquisition in children with past or present severe malnutrition, as compared with matched controls, is presented in Table 7 and Figure 19. As may be seen, the mean number of bipolar concepts acquired by the malnourished children was significantly lower than the mean number of concepts grasped by the control group.

It is important to remember that after 40 months all the children included in the malnourished group represented cases rehabilitated from severe clinical malnutrition, i.e., survivors considered cured of the disease. It may be noted in this respect that the mean test score of the malnourished group at 46 months was almost twice the score obtained at 38 months. Nonetheless, the increase is not enough to bring the previously malnourished children up to the level of the controls. In other words, the lag in

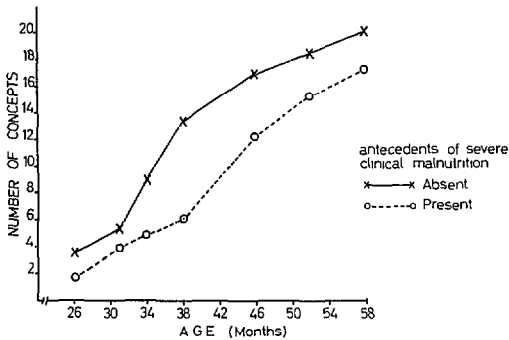
TABLE 7—Mean number of bipolar concepts in children with past or present severe malnutrition and in matched controls.

Age (months)	26	31	34	38	46	52	58
Past or present malnutrition	1.61 ± 1.26	3.92 ± 2.56	4.85 ± 3.15	6.07 ± 2.94	12.16 ± 4.13	15.35 ± 3.05	17.21 ± 2.60
Control group	3.54 ± 2.11	5.46 ± 2.96	8.92 ± 3.26	13.42 ± 3.56	16.92 ± 3.26	18.42 ± 3.29	20.07 ± 1.38
"t" test	2.68 ^a	1.42	3.36 ^b	5.97 ^b	3.23 ^b	2.57 ^a	3.66 ^b

^aSignificant at less than 0.05.

^bSignificant at less than 0.01.

FIGURE 19—Number of bipolar language concepts in children with and without antecedents of severe clinical malnutrition.



language development found in severely malnourished children continued to be present after clinical recovery had taken place.

It has been repeatedly stated that human malnutrition does not occur in a vacuum, and that it is the outcome of an ecological situation characteristic of preindustrial societies (8). Because of this multiple causation, before interpreting our findings as due simply to severe malnutrition, it is necessary to try to sort out what other factors besides the nutritional deficiency may have been interfering with the normal development of these children. In trying to answer this question we have compared the family macroenvironments and some features of the family microenvironments of the severely malnourished children with those of the matched control group.

Environmental Factors

Broadly speaking, there are three kinds of macroenvironmental factors. These relate first to the parents as biologic and social organisms; second to the family structure; and third to objective circumstances of life such as sources of family income, income per capita, and sanitary facilities present in the household. Since a detailed description of these factors has already been presented, the association of each one with the presence or absence of severe malnutrition can now be considered.

Biological Characteristics of the Parents

Differences in the age, height, or weight of either parent; in the mother's number of pregnancies; or in the number of live children in the family failed to distinguish between families with and without severely malnourished children.

Sociocultural Characteristics

No significant relationship was found between the presence or absence of severe clinical malnutrition and the variables of personal cleanliness, literacy, and educational level.

Contact with mass media was explored through literate parents' newspaper reading and radio listening. The number of mothers or fathers of malnourished children who were regular newspaper readers was not significantly different from the number in the matched control group. Similarly, the number of fathers who listened regularly to the radio was similar in both the malnourished group and the control group.

As may be seen in Table 8, the case of the mothers was different. There were almost equal numbers of radio listeners and nonlisteners in the malnourished group, but the number of listeners among the matched control group was more than three times the number of nonlisteners. The difference is significant at the 0.05 level of statistical confidence (Chi square = 4.20; Df = 1; p < 0.05).

Family Structure and Economic Status

No significant differences between the mal-

TABLE 8—Radio listening by mothers of severely malnourished children and matched controls.

Mother of	Radio listening		
	Yes	No	Total
Severely malnourished children	8	10	18
Matched controls	14	4	18
Total	22	14	36

$\chi^2 = 4.20; Df = 1; p < 0.05.$

nourished and control groups were found with respect to family size or type of family (nuclear or extended).

The socioeconomic status of the families was estimated using four indicators: main source of family income, sanitary facilities in the household, annual income per capita, and percentage of total expenditures spent on food. No significant associations were found between any of these four indicators and the presence or absence of severe malnutrition.

In summary, considering all features of the macroenvironment, the only differential between severely malnourished children and controls—matched at birth for gestational age, body weight, and total body length—was the mother's contact with the world outside the village through regular radio listening. None of the other characteristics of the parents (biological, social, or cultural) or family circumstances (including per capita income, main source of income, and family size) were significantly associated with the presence or absence of severe malnourishment.

The Microenvironment

Since the features of the macroenvironment could not explain severe malnutrition, our attention was directed toward analysis of the microenvironments of the two sets of children. We selected the potential stimulation of the home as our first general indicator of the quality of child care, and the mother as the principal stimulating agent for young children.

The instrument used for estimating home stimulation was the inventory developed by Beatty Caldwell (3). This inventory was designed to sample certain aspects of the quantity (and in some ways the quality) of social, emotional, and cognitive stimulation available to a young child within his home. Two forms of the inventory were used, one designed for infants up to three years of age and the other for children three to six years old. In both versions the selection of items included has been guided by a set of assumptions about conditions that foster development.

Accordingly, the inventory describes and quantifies the following eight areas of the home environment: (1) frequency and stability of adult contact; (2) vocal stimulation; (3) need gratification; (4) emotional climate; (5) avoidance of restriction; (6) breadth of experience; (7) aspects of the physical environment; and (8) available play materials. In each of these areas almost all items receive binary scores; no attempt is made to rate finer gradations. The total score is the number of items recorded as positive for the child's development. If desired, each area may be scored separately and related to specific features of development.

A trained psychologist recorded the inventory of home stimulation for every child in the cohort at six-month intervals during the first three years of life and at yearly intervals thereafter. At the time of data collection and scoring, the psychologist was unaware of the nutritional antecedents of the children.

Figures 20 and 21 show the distribution of total home stimulation scores obtained by malnourished and control children at six and 48 months of age. As may be noted even at six months, when only one case of severe clinical malnutrition was present, the control children

FIGURE 20—Proportion of malnourished and control children showing different home stimulation scores at six months of age.

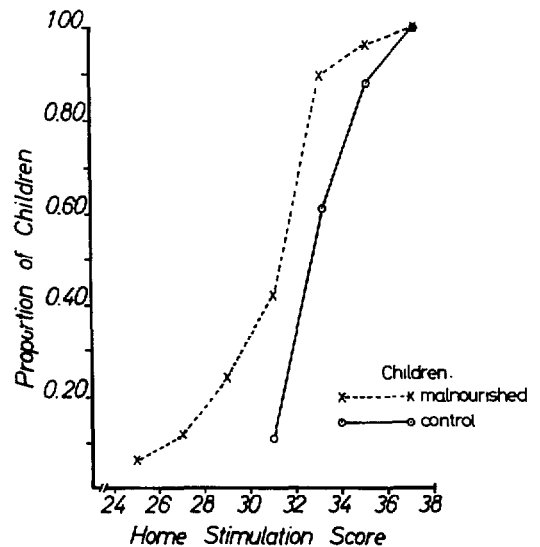
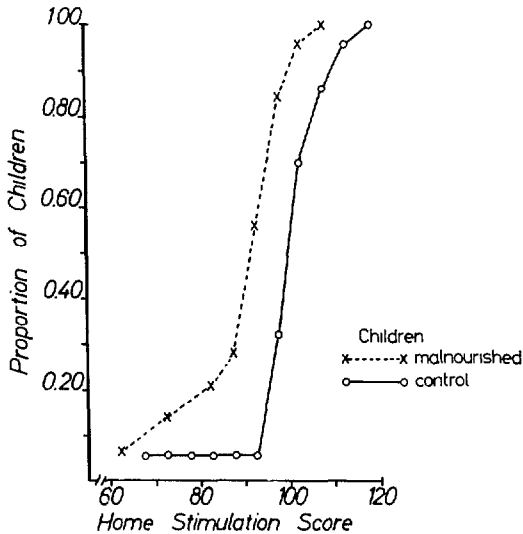


FIGURE 21—Proportion of malnourished and control children showing different home stimulation scores at 48 months of age.



had significantly higher home stimulation scores. Thus, while none of the control children's homes scored less than 30 points, almost one-fourth of the homes of the future malnourished children scored below 30 and almost one-half had scores below 32 points. Similarly, at 48 months of age, children who had recovered from malnutrition were living in homes whose scores were well below those in which the control children were living. With scores ranging from 60 to 120, about one-half of the survivors of severe clinical malnutrition had home stimulation scores below 94 points, and only one had a home that scored between 105 and 109. This distribution of scores is markedly different from that shown by the homes of the control children. Only one of these homes had a score below 95 while four reached values between 110 and 120. These differences are statistically significant at the 0.01 level of confidence.

The difference found in the quality of the home environment points toward the value of analyzing other features of the microenvironment. Associations between the presence of severe clinical malnutrition and the mother's psychological profile, maternal attitudes, pro-

clivity for change, concepts of health and disease, concepts of food and feeding, and family visiting pattern are now under analysis.

Malnutrition, Language Development, and Home Stimulation

Since the presence of severe malnutrition had been significantly associated with home stimulation, and since survivors of severe malnutrition showed a significant lag in language bipolar concept formation, it seemed logical to investigate the interrelations among these three factors. As a first approach to this matter a technique of partial correlation was used to look at the degree of association between two variables "holding constant" the influence of the third variable. Since the number of cases of malnutrition was rather small, we decided to test for interrelationships in the total birth cohort.

The coefficients of correlation product moment among home stimulation scores, total body height, and number of bipolar concepts present at 46 months of age in the total cohort (229 children) were:

Home stimulation score:	
Number of bipolar concepts =	0.20
Home stimulation score:	
Total body height =	0.23
Total body height:	
Number of bipolar concepts =	0.26

There are various approaches to this matter of relative contributions by several variables to both the presence of malnutrition and the presence of somatic and mental lags in survivors (such as regression analyses and multivariate analysis of variance). Such approaches should be used in order to obtain a more quantitative answer to this question.

Conclusions

With the results now available, one can fairly state the following conclusions:

1) Susceptible infants cannot be identified before the development of severe clinical mal-

nutrition, since they do not differ from the rest of their birth cohort somatically or behaviorally.

2) The appearance of severe clinical malnutrition seems to be associated, in some preindustrial communities, with features of the microenvironment.

3) Children who have recovered from severe

clinical malnutrition lag behind controls in language development, but poor microenvironmental conditions are not sufficient to fully explain the behavioral lag.

4) How long the survivors will perform more poorly than the matched controls is a question which has not yet been adequately answered.

SUMMARY

The authors have selected a specific group or "cohort" of Mexican children born over a one-year period and have observed them for a number of years in order to study their nutritional status. The cohort selected was composed of 300 children born in a rural village between 1 March 1966 and 28 February 1967. The study is expected to run seven years, though only five years of observations are covered in the report presented here.

The village in question is primarily agricultural and in 1965 was inhabited by roughly 5,600 persons ranging in age from 0 to 85 years old. Fifty per cent of these people were less than 15 years old, indicating low life expectancy at birth. Agriculture was the villagers' main activity, though relatively small numbers of people were engaged principally in factory work, crafts, commerce, or the professions. The social and economic status of those with agricultural occupations varied considerably.

The cohort contained equal numbers of girls and boys, with the children's social origins closely matching those of the village as a whole. The mean birth weight of cohort children was $2,848 \pm 444$ grams and their median body length was 48.5 cm. As would be expected, the boys had a higher mean weight and greater median length at birth than did the girls.

The height, weight, and age of cohort mothers varied widely (the mean values being 148.2 ± 2.8 cm, 53.0 ± 4.8 kg, and 25.6 ± 6.8 years). Nearly half of the mothers had been pregnant three or more times before, and over 46 per cent were completely illiterate. Few had any contact with television and half had little or no regular contact with radio. Sanitary characteristics of their households varied widely, but a considerable number of the homes had good to excellent sanitary conditions and facilities.

Twenty-three of the 300 infants delivered failed to survive a month; four were stillborn,

seven died the first week after birth, three died during the remainder of the first month, and nine died during the remainder of the first year. Those that died tended to be shorter and weigh less than the survivors. Though this may have been due to prematurity in some cases, only three of the 23 dead infants had a body length equal to or greater than the median of the cohort as a whole. Ten deaths occurred in cohort children between the ages of one and five years. Seven of these were directly related to infectious disease accompanied in most cases by severe malnutrition.

During the first five years a total of 22 cohort children were found to be suffering from severe clinical malnutrition—despite medical efforts to prevent such cases. Twelve of the children were given hospital treatment and ten were treated at home. All the hospitalized cases recovered, but three of those treated at home died.

For purposes of subsequent study, the 19 survivors were matched with other cohort children who had never been considered severely malnourished. The matching was done with respect to birth data—including gestational age, body weight, and total body length.

Tests of the two groups showed that on the average the malnourished children were less able to develop certain types of mental concepts than their counterparts in the control group. This lag continued long after the once malnourished children had recovered their health. However, it is unclear whether the lag was the direct result of malnutrition or whether other ecological factors played a major role.

Data concerning the children's parents; family structure; sources and amounts of family income; sanitary facilities in each household; and the mother's personal cleanliness, literacy, and educational level failed to indicate statistically significant relationships between any of these variables and the malnourished children.

The only statistically significant factor of this kind discovered was radio listening by the child's mother. There were almost equal numbers of listeners and nonlisteners among mothers of the malnourished group, but the number of listeners among control group mothers was more than three times the number of nonlisteners.

These generally negative findings directed attention to the "microenvironment," in particular the stimulation received by the child within its home. Tests using the inventory

developed by Beatty Caldwell showed that members of the malnourished group tended to receive significantly less home stimulation than control group members. This indicates that other microenvironmental factors should be investigated. At the present time the authors are analyzing possible associations between malnutrition and such factors as the mother's psychological profile, maternal attitudes, proclivity for change, concepts of health and disease, and concepts of food and feeding—as well as the family's visiting pattern.

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