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# MALNUTRITION-INFECTION INTERACTIONS IN THE TROPICS*

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Mr. President Dr. Rozeboom, Officers and Members of the Society, ladies and gentlemen:

I begin with a word of appreciation to Dr. Desowitz and Members of the Charles Franklin Craig Lectureship Committee for having invited me to speak on the problem of malnutrition and infection in the less developed areas of the world. I accept this invitation because it gives me an opportunity to express to this distinguished Society some views on the nature and origin of malnutrition and infection interactions in the poor nations of the world.

countries can be divided into the highly industrialized and the less developed or preindustrial. The industrialized societies generally have larger natural resources, better developed science and technology, efficient food production and higher levels of education and *health* than ***the*** less developed nations. There is evidence to indicate that the gap is widening.

Biological factors have had more emphasis than socioeconomic factors in attempted derivation of causality in health problems in tropics and subtropics. That effort has provided a relatively good understanding of the health status of human populations in less developed regions, primarily the existence of chronic malnutrition and frequent infectious disease, of risk of premature death, growth retardation and diminished working capacity. Most less developed countries also are experiencing an excessive population growth which bears strongly on the future of human kind as discussed by Professor Snyder in a recent Craig Lecture.'

Dramatic epidemics of plague, typhus, smallpox, yellow fever and cholera, and the devasting effects of malaria, schistosomiasis and dysentery led to an original emphasis on control and prevention of infectious disease. In a preceding Craig Lecture, Professor Pandit showed the consequences of such emphasis in India, and left open the question of how successful were public health efforts when they accentuated population growth.' Similarly, nutrition achieved full recognition in the philosophy of public health in the first half of this century when nutrient deficiencies were identified. This knowledge prompted measures to control and prevent scurvy, pellagra and beriberi, thus contributing its share to demographic growth.

Clinical description of kwashiorkor by Dr. Cicely Williams 30 years ago was followed by surveys to assess its prevalence and health significance in selected areas of the world.' These investigations eventually led to establish that severe protein-calorie malnutrition (PCM) in the form of marasmus and kwashiorkor represented only a small part of the problem, with moderate and milder forms of PCM affecting in fact as much as a half of all children in less developed nations .° The original descriptions of kwashiorkor showed that infection was its common precipitating factor, and highly instrumental ***as*** a cause of death.' Nutritionists were reluctant, however, to recognize the role of infection in the causality of PCM.

An opposite situation was the neglect of nutritional factors by investigators primarily concerned with infectious disease. Professor Scrimshaw and coworkers are credited with conceptualizing that malnutrition and infection in less developed countries are intimately related and commonly associated with each other.° These workers postulated a synergism whereby infection contributes to deterioration of the nutritional state while malnutrition reduces or suppresses host resistance, worsens the outcome of infection and thus establishes a vicious circle of major public health relevance.'

To study these interactions, **a long-term prospective field study has been conducted in a**

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**TABLE** 1

*Distribution of 415 liveborn single-birth infants by birth weight and gestational age. Santo Maria Cau- que, 1964-1972*

| Class | Birth weight, grams | Gestational age range, weeks | Number of infants and (V) |
|---|---|---|---|
| Pre-term | <2,501 | 31-36 | 30 (7.2) |
| Term small-for-gestational age | <2,501 | 37-42 | 143 (34.4) |
| Term adequate-for-gestational age | >2,500 | 37-42 | 242 (58.3) |

TABLE 2

*Incidence of neonates with high concentrations of immunoglobulin M (IgM), in four Guatemalan ladino villages, 1972-1973*

| Village initials | Number of infants | Number (and percent) with fel >0.20 mg/ml' | Range of elevated values |
|---|---|---|---|
| S.D.O. | 48 | 10 (21) | o.22-0.48 |
| S.J.S. | 52 | 4 (8) | 020-0.54 |
| E.S. | 40 | 6 (15) | 0.27-0.74 |
| C. | 67 | 11. (16) | 0.23-0.55 |
| Total | 207 | 31 (15) | |

• Elevated values *in* cord serum were confirmed in infant's blood from the femoral vein.

typical highland village of Guatemala! Systematic observations in this community and in other highland and lowland villages of the country suggest that the findings may be extended to other rural populations in the tropics. The study consisted in recruiting virtually all pregnant women and their newborns, and in a prospective observation of infants and preschool children in the natural village setting. Examinations were frequent and comprised anthropometric, clinical, dietary and microbiological investigations, as well as a study of environmental factors.

Interactions of malnutrition and infection begin in utero. Data on practically all consecutive newborn infants in the village during 8 years of study revealed that 32% were term-small-for-gestational age (or infants having experienced intrauterine malnutrition), and *7%* were pre-term (premature) infants who also had low birth weight (<2,501 grams) (Table 1). A review of the medical literature shows a widespread occurrence of low birth weight throughout less developed nations, a circumstance not recognized by public health officers in its true perspective.[8]

There is evidence that infection during pregnancy also is very common in less developed countries. In a prospective study in four lowland "ladino" ( mestizo) Guatemalan villages, infant's venous blood was obtained within 3 days of birth for investigation of immunoglobulins by radial immunodiffusion. Fifteen percent had levels of IgM in excess of 0.19 mg/mi (Table 2), a finding strengthening previous observations on IgM.fi Since IgM normally does not cross the placental barrier, the findings are interpreted as indicative of fetal antigenic stimulation. The presence of IgM in the fetus or newborn could reflect an increased incidence of intrauterine infection or a response to antigens available during the course of maternal infection, or it may represent fetal antibodies against maternal immunoglobulins syn-thetized during pregnancy as a result of infectious processes. Placental abnormalities observed in malnourished women of the region" hypothetically could favor appearance of IgM in the unborn child.

Of all these possibilities, maternal infection likely seems to be the most important factor, Twelve percent of village women tested sero-logically throughout pregnancy for cytomegalo-viruses, herpes simplex viruses, rubella, syphilis and *Toxoplasma* showed seroconversion during pregnancy to one of these agents. Had more agents been included in the tests, the rate probably would have been greater.[11] Thus, the occurrence of an excess frequency of fetal IgM in less developed societies seems to reflect high attack rates of infectious disease. Table 3 shows that pregnant women often had complications of diarrhea and dysentery, urinary tract infection, and lower respiratory disease—mainly tracheitis and tracheobronchitis. Expectedly, newborn infants of women of this village show evidence of an excess frequency of congenital infection. Neonates may shed enteroviruses in the first days of life, often in high titers evidencing replication in utero. Furthermore, the incidence of *Toxoplasma*-IgM in cord blood is several-fold greater than in industrial societies." While malnutrition-infection interactions deserve more scrutinity, they undoubtedly relate to the high frequency of prematurity and fetal growth retardation in the study village. In the meantime, current knowledge could be applied to control and prevention through

**TABLE 3**

***Incidence of infectious diseases among 82 women observed prospectively from conception, Santa Maria Cau-que, 1972-1973***

| Trimester of pregnancy | Respiratory infection | | Diarrhea and dysentery | Urinary tract bacterial infection* | Other illnessest |
|---|---|---|---|---|---|
| | Upper | Lower | | | |
| 1st | 37 (45)t | 5 (6) | 7 (9) | 8 (10) | 7 (9) |
| 2nd | 26 (32) | 6 (7) | 9(11) | 8(10) | 5 (6) |
| 3rd | 41 (50) | 14 (17) | 13 (16) | 6 (7) | 8 (10) |
| Incidence per 100 pregnancies | 104 (127) | 25 (30) | 29 (36) | 22 (27) | 20 (25) |

*** At least 100,000 colony forming units per ml of urine.**
**f Conjunctivitis, otitis media, stomatitis, skin infection.**
**Number of episodes (rounded percent).**

improvement of maternal and child health programs.

The quality of the fetus is related to survival and growth of the child. Infant size at birth strongly correlates with neonatal survival, to a greater extent than does the quality of the extrauterine environment. Table 4 compares neonatal mortality in the Indian village with that of a population on the east coast of the United States, bringing •out that although neonatal mortality is greater in the village, the difference is minimal once birth weights are taken into account. A practical deduction from this observation is that in developing nations neonatal mortality is less likely to be reduced by medical ***services*** than by improved fetal growth. The cost of intensive care units for the management of small infants precludes their practical application to decrease neonatal mortality.

Small-for-gestational age village infants exhibited a greater risk of malnutrition and infection than did term infants with adequate birth weight for gestational age. Low birth weight infants (mainly small-for-dates) showed greater rates of infection with ***Shigella, Entamoeba histblytica*** and ***Giardia*** in the first months of life. Such infants also exhibited greater rates of diarrheal disease and oral candidosis in the first 6 months than did infants born with larger birth weight (unpublished). An abnormal cell-mediated immune response has been documented among small-for-gestational age infants.[13]

With regard to growth, the various categories of newborns defined by fetal maturity had similar growth rate in the first months of life (Fig. 1). However, initial differences persisted because infants tended to remain in growth tracks defined by gestational age, birth weight or the two criteria combined.[3,14]

Breast-feeding is universal in rural Guatemala as in most rural tropical regions; introduction of supplementary foods of low nutrient value and hygiene begins around 6 months of age. Weaning in this culture is a protracted process averaging 24 months, and marks the initiation of deterioration of the nutritional status, After the period of growth deceleration, at around 6 months and when weaning begins, the growth curves depart from the standard and the children become stunted quite independent of their degree of fetal maturity (Fig. 1). Such findings indicate that negative environmental forces—poor diet and frequent infection—act on all children with similar intensity, accounting for the maintenance of differences in growth observed at birth and in the first months of life.

The relation of infection to nutrition and health has been well documented. There is no question that the nutrition of well nourished individuals deteriorates after attacks of hepatitis, bacillary dysentery, tuberculosis, typhoid fever, malaria, amebic liver abscess, schistosomiasis, and many other diseases. The effects of infection are of

**TABLE *4***

***Infant deaths per 1,000 live births, Santa Maria Cau-que and the United States, by birth weight****

| Birth weight, | Neonatal | | | Postneonatal | | |
|---|---|---|---|---|---|---|
| | S.M.C. | U.S. | Rt | S.M.C. | U.S. | kJ |
| 1,501-2,000 | 273 | 210 | 1.3 | 303 | 26 | 11.7 |
| 2,001-2,500 | 34 | 45 | 0.8 | 34 | 13 | 2.6 |
| 2,501-3,000 | 10 | 10 | 1.0 | 43 | 7 | 6.1 |
| 3,001-3,500 | 0 | 5 | | 23 | 5 | 4.6 |

*** Santa Maria Cauque 1964-1972; United States, Chase (1962). Figures rounded to the nearest integer.**
**t R = ratio S.M.C./U.S.**

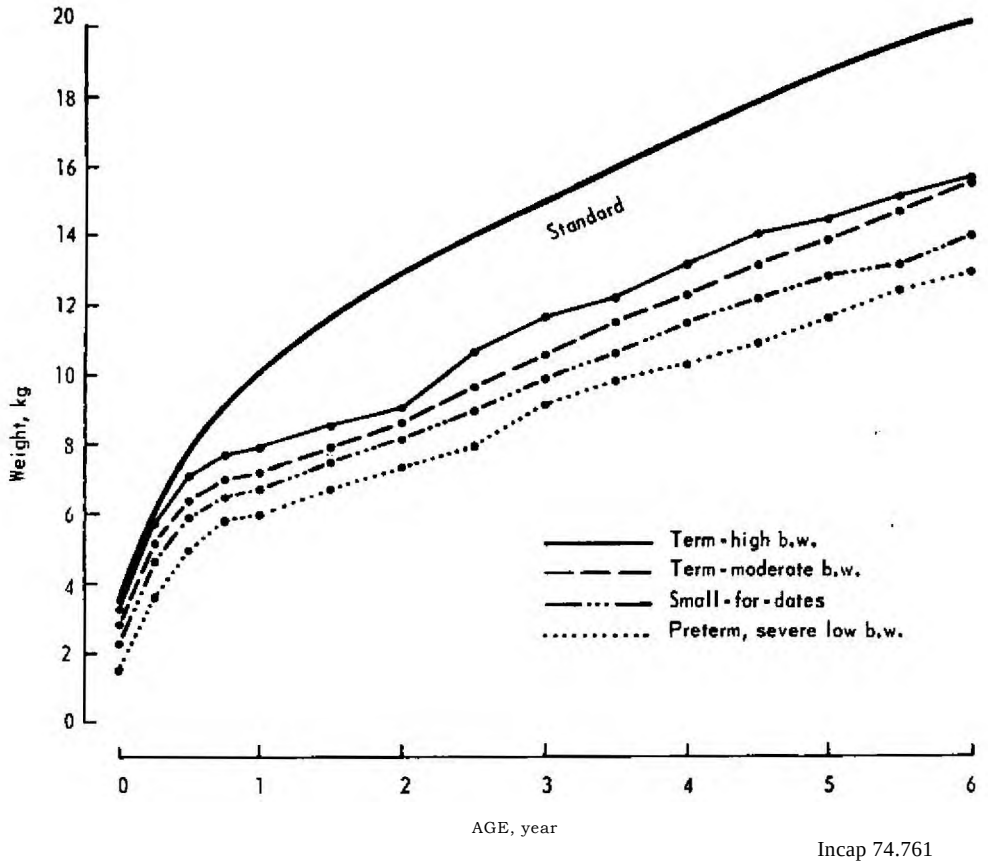


FIGURE 1. Mean curves for weight of cohorts of children of Santa Maria Cauqué defined by maturity at birth. Prospective observation from birth to 6 years of age. Comparison is with the Iowa curves (Jackson and Kelly, *J. Pediat., 27;* 215-229, 1945). Key: high birth weight >3,000 g; moderate birth weight, 2,501 to 3,000 g; severe low birth weight, < 2,001 g.

greater consequence to individuals who already are malnourished, particularly infants and young children. In less developed societies the establishment of an infectious process is often followed by particular familial or societal behavior that influences diet, care, and treatment, accounting for customary diminished food intakes and questionable methods of management.

The direct effects of infection on nutritional state have been reviewed by Scrimshaw and coworkers. [10] Infections commonly are accompanied by anorexia, vomiting, increased peristalsis, and systemic manifestations which often result in marked reduction of food intake, impaired digestion and malabsorption. Other alterations are loss of tissue—particularly epithelium, blood, muscle and liver—depending on the type of infection, its localization and pathogenesis. In many infections there is an increased loss of nitrogen, aminoacids, electrolytes and vitamins. Even suhclinical or silent infections induce stress responses with increased nitrogen excretion in urine.[16]

The metabolic alterations associated with infection have been studied by Dr. Beisel and coworkers and classed as nutrient over-utilization, nutrient sequestration and nutrient diversion"' In over-utilization there is increased expenditure of energy sources such as glycogen, mobilization of aminoacids for gluconeogenesis and of fat, increased synthesis of lipids and over-utilization of vitamins. Sequestration of iron in the liver occurs in the presence of adequate stores of bemosiderin, a phenomenon apparently mediated by a protein factor released by phagocytes. This

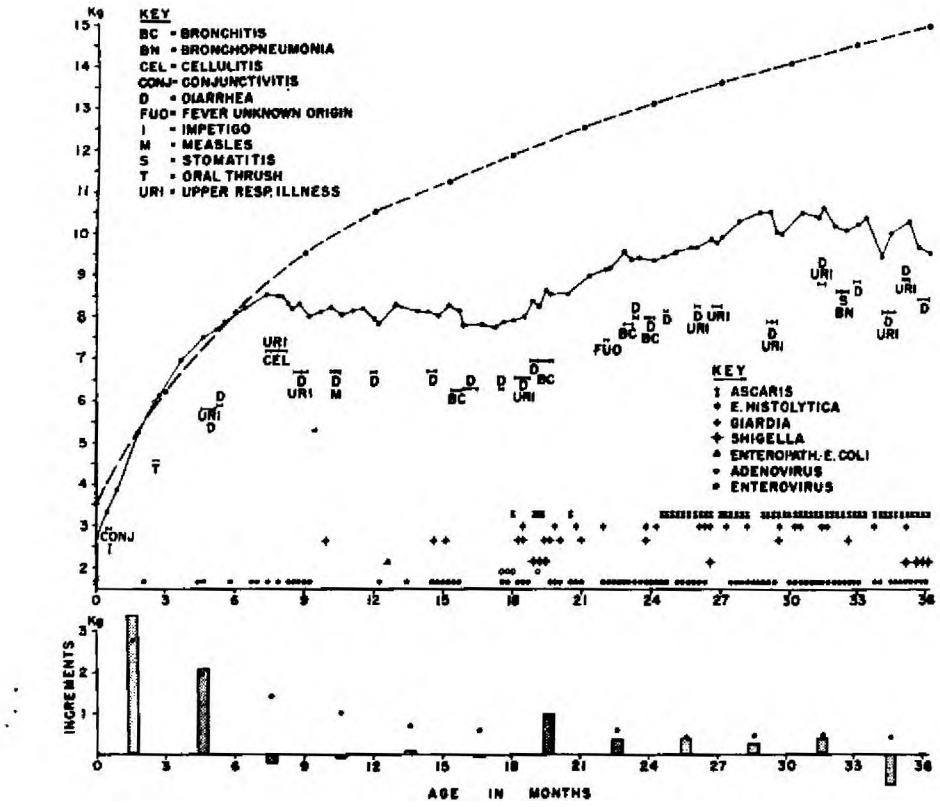


FIGURE 2. Weight, infectious, and infectious disease in a male child of Santa Maria Cauqué, first 3 years of life. ***Top:*** solid line is weight of child; bottom line is median of the Iowa standard. Duration of infectious disease is indicated by the length of horizontal lines. Each symbol shows a week positive for the particular infectious agent. ***Bottom:*** observed weight increments (vertical bars) and expected median increments of the standard ( dots).[29]

mechanism could explain the anemia of children with recurring infection who live in hookworm-free areas where iron intakes are mildly deficient or. adequate. Nutrient diversion is characterized by an uptake of plasma amino-acids for incorporation into "acute phase reactant" proteins, ***a*** phenomenon not yet clear. Abnormal synthesis of haptoglobin, tryptophan-oxigenase, tyroxine-transaminase and other enzymes has been documented. Also, the body diverts its biosynthetic pathways to produce foreign protein, lipids and carbohydrates, as with viral replication.

On the other hand, malnutrition affects the host capacity to respond to infection, an important issue ***when*** one considers that more than a half of the world's population suffers from malnutrition is varying degree, while concomitantly exposed to far greater risks of infection than well nourished societies. Present knowledge indicates that the immunoglobulin system is not affected in persons with mild and moderate forms of malnutrition. Serological surveys in the general population and among vaccinated individuals with these forms reveal an adequate antibody response and protection. However, antibody synthesis is impaired in children with severe forms of PCM.[21-23] Vaccination of untreated kwashiorkor patients with bacterial and viral antigens failed to elicit a *B-cell* response.

Alterations in T-cell immunocyte function and in the amplification of the immune response apparently occur more readily among malnourished persons. In moderate and severe forms of PCM there is ***a*** decrease in the number of immune

TABLE 5

*Mean daily nutrient intake of 2- and 3-year-old children, Santa Marfa Cauqué, 1964-1969*

| | 14 children 2 years old | 31 children 3 years old | INCAS' recommendations 2 years old | 3 years old |
|---|---|---|---|---|
| Calories | 619 (176)* | 992 (272) | 1,350 | 1,550 |
| Total protein, g | 17.4 (4.9) | 26.9 (6.6) | 28 | 30 |
| Animal protein, g | 3.1 (2.5) | 9.7 (7.3) | | |
| Iron, mg | 5.9 (1.8) | 9.6 (3.6) | 10 | • 10 |
| Vitamin A, 'g of retinol | 90 (95) | 111 (77) | 250 | 250 |
| Thiamin, mg | 0.37 (0.17) | 0.55 (0.13) | 0.5 | 0.6 |
| Riboflavin, mg | 0.29 (0.14) | 0.36 (0.15) | 0.7 | 0.9 |
| Niacin, mg | 3.42 (1.06) | 5.81 (1.49) | 8.9 | 10.2 |
| Ascorbic acid, mg | 16.2 (8.3) | 24.3 (10.2) | 13.8 | 15.8 |

[4] Mean (S.D.).

cells in liver, bone marrow, spleen, Peyer's patches and lymph nodes. The diminished replication of immune cells could explain the failure of malnourished children to mount a leukocyte response to bacterial infection. Alterations in phagocytic •cells result in a diminished capacity to ingest and kill bacteria," which appears related more to iron than to protein depletion.' It has already been mentioned that iron sequestration occurs during infection.

Furthermore, malnourished individuals have an altered delayed hypersensitivity." Other manifestations of altered cell-mediated immunity in malnutrition are a depressed capacity of the lymphocyte to transform after challenge with mytogens, a diminished rosette formation and alteration in factors important for the amplification of the immune response. These alterations are evident not only in acute PCM, but also in underweight children who had experienced fetal growth retardation or early nutritional deprivation.[27] [29]

The interrelation between malnutrition and infection in the village ecosystem is made evident by prospective observation of individual children. Figure 2 presents the history of a typical child of a cohort studied from birth to 3 years of age.' Despite low birth weight a good nutrition derived from breast-feeding, passive immunity and resistance factors in breast milk permitted adequate growth during the first 6 months. Supplementary feeding began with broths, gruels and eventually small amounts of solid foods, tortilla (maize), bread and beans. The low level of environmental sanitation and personal hygiene in the village entails a continuous risk of enteric infection by food supplements and other means of transmission. Weight began to deteriorate with the onset of weaning, and for as long as a full year this particular child did not gain weight. By 18 months he had become accustomed to the solid diet of the adult villager, and had developed an immunity against a variety of infectious agents. The child began to grow but marked stunting was already evident. Furthermore, additional infectious episodes occurred at the end of the 3rd year, followed by weight losses.

Diets of weaned village children are deficient in calories, animal protein, vitamin A, riboflavin, niacin and iron (Table 5), but not to the extent once considered. The dNPCal% generally is good; the basic staple food (maize) is complemented with beans, small amounts of animal protein and a variety of wild plants and vegetables.

Clinical and epidemiological observations reveal, on the other hand, that infection is an important cause of weight loss, physical growth retardation and death, sometimes independent of the basal nutritional state, or again often related to the initial malnutrition.[8,12] An idea of the magnitude of infectious disease in *the* study village can be obtained by computing rates per 100 person-months by age (Fig. 3). Rates were high as early as the first 6 months of life but increased considerably in the second half of the first year. Diarrhea and lower respiratory illness were more frequent during the weaning period, from 12 to 29 months of age. Morbidity for these two categories decreased thereafter.

Summarizing, fetal growth retardation, inadequate weaning practices and recurring infections leave a mark in the child's growth as early as the

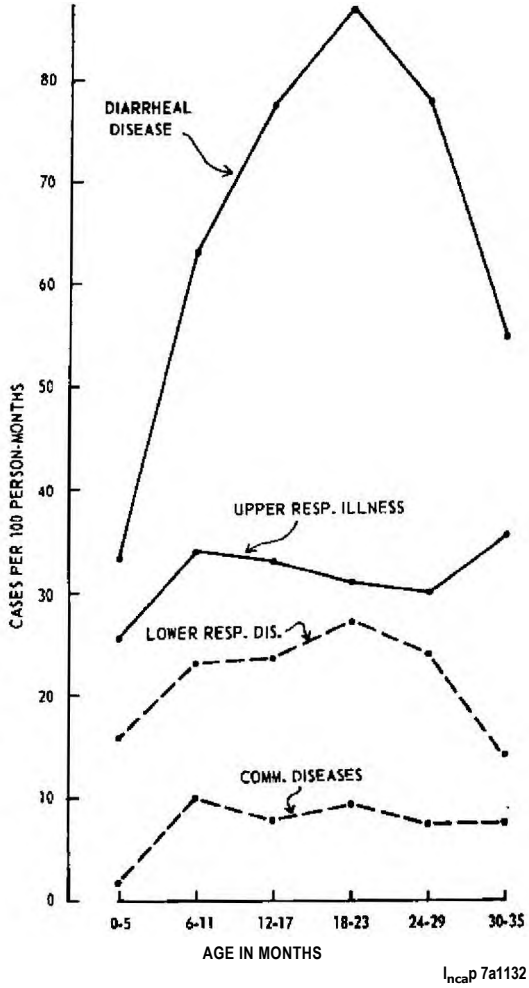


**FIGURE** 3. Morbidity rates of main groups of infectious disease. Rates per 100 person-months, by age, for 45 cohort children observed from birth to age 3 years, Santa Maria Cauqué, 1964 to 1969.

first year of life: there is a diminished immune response, a high incidence of disease and marked growth retardation.

Mortality is a good index of the magnitude of malnutrition-infection interactions. Neonatal mortality was discussed before. Pre-term infants exhibited greater postneonatal infant mortality than other groups (Table 4), but infants who survived the first year, however, fared well there-after. Term-small-for-gestational age infants had higher postneonatal mortality than term-adequate for gestational age infants; their high rates extended into the 4th year (Table 6). These infants likely have an impaired immune response which appears to be maintained or accentuated during infancy and early childhood. Term infants with adequate birth weight showed the lowest mortality of all groups but deaths still were rather high: malnutrition and infection do not spare infants born with adequate birth weight and gestational age.

Prospective observations of children into adolescence indicate that stunting is maintained. The small size of women of reproductive age (average **4'** 8"; 116 lbs.) attests to this observation. Comparison of growth of different ethnic groups but of comparable socioeconomic status shows that the growth potential of man in different geographic localities is similar and independent of race or ethnic origin.[30] Consequently, the short stature of village women is best interpreted as the result of a cumulative effect of malnutrition and infection, present from birth (or even before) through childhood and adolescence, and through generations.

What can be done about the health problem just described? Any attempt to improve health in this kind of society must begin with the mother, to influence child care, nutrition and hygiene. Improved health and growth of children leads to better-nourished adult women more able to sustain fetal growth, as seems to have occurred in Japan [31] With continued action a cumulative **effect may** be expected in following generations. It is also known that breast-fed children require adequate food supplements under hygienic conditions at about 6 months. Water available inside the home drastically reduces transmission of enteric agents, while better housing and more beds will reduce transmission of respiratory **and enteric infections.** Safe and inexpensive vaccines are available for prevention of tetanus, whooping cough, measles and tuberculosis. Appropriate drugs and adequate hydration techniques save many children with pneumonia and diarrheal disease. If these measures are put into effect, morbidity and childhood deaths will inevitably fall; by itself this change eventually will bring a response in population control.

The last paragraphs are easy to put on paper but application of those solutions is utopic under present conditions in most less developed nations. To qualify this statement I shall describe now some features more directly relevant to the exis-

**TABLE** 6
*Postneonatal childhood mortality, by fetal maturity, Santa Maria Cauqué, 1964-1972*

| Class | Postneonatal (29d-11 mo) | Second year | Third year | Fourth year |
|---|---|---|---|---|
| Pre-term | 6 (286),* *N* = 21 | 0 *N =1St* | 0 N = 13 | 0 N = 8 |
| Term, small-for-gestational age | *8 (58), N* = 139 | 8 (76),N=105 | 3 (39),N= 78 | 3 (50),N = 60 |
| Term | 10 (42), *N* = 240 | 9(44),N=204 | 5 (33),N= 153 | 1 (8),N=122 |
| Total | 24 (60), N=400 | 17 (52),N=324 | 8(33),N=244 | 4(21),N=190 |

• Number of deaths (deaths per 1,000 infants alive as the period started). N initial population. t
Attrition in numbers is explained because cohorts have different ages.

tense and action of malnutrition and infection in the Guatemalan village. To this effect, the same situation applies to many tropical regions, for instance in the lowlands of Costa Rica, Panama, Peru, Bolivia and Brazil and in vast areas of Asia and Africa. For many years populations in tropical environments have subsisted by planting small plots of land *("minifundios")* or by working as peasants in large land holdings (fincas or "latifundios"). In rural Guatemala the total land available for cultivation remains rather fixed, but the area per family obviously has decreased." Furthermore, within the prevailing poverty of the village, a few better-off families are acquiring land from others, thus establishing a class differentiation that did not exist in the past. There has been *a* decrease in independent farmers, and an increase in the number of part-time laborers on *"minifundios"* of independent farmers of the locality." The land saturation is forcing men and whole families to move out of the village to the cities, enlarging the peripheral slums and shanty towns, so typical of less developed countries.

The poverty of the rural population, more or less constant for decades, is becoming accentuated as judged by a decrease in mean gross domestic product (MGDP)" in all but three of the 20 Departments of Guatemala (Table 7). In the Department of Sacatepéquez, where the study village is located, the MGDP has decreased by 38% in *15* years. The lack of social and economic development expectedly explains the phenomenon. Recent world inflationary tendencies, coupled with low international prices for products of less developed nations, is hitting *the* villages hard, with more infection and malnutrition to be anticipated in the years ahead. Table 8 illustrates wages and prices of land and food during the last 1.0 years; wages have remained essentially stable but the price of land has risen notably; some land is being sold to outsiders because the price cannot be met by most local villagers; food production per capita has dropped. The cost of

**TABLE** *7*
*Mean gross domestic product, U. S. dollar P/C, selected regions of Guatemala**

| Region | 1951-1952 | 1965-1966 | % change in 15 years |
|---|---|---|---|
| Dept. Guatemala | 847 | 1,071 | +26 |
| Dept. Sacatepequez | 197 | 123 | -38 |
| All Guatemala, excepting 3 Depts. | 144 | 104 | -28 |
| Rural Guatemala | 142 | 105 | -26 |
| Total | 265 | 329 | +24 |

• After Smith (1973).[3"]

TABLE 8
*Wages and value of land and food, quetzals,* Santa Maria Cauque, 1963-1974*

| | 1963 | 1971 | 1974 | % increase in 10 years |
|---|---|---|---|---|
| Farm labor, 8-10 hrt | 0.50 | 0.50 | 0.80 | 60 |
| Mason, 8-10 hr | 1.50 | 1.50 | 2.00 | 33 |
| Salaried farmer, monthly | 20.00 | 20.00 | 30.00 | 50 |
| Land, cuerda (= 0.3 acres) | | | | |
| In town | 150.00 | 250.00 | 300.00 | 100 |
| Outside town | 60.00 | 80.00 | 100.00 | 67 |
| Maize, 100 lbs | | | | |
| Harvest time | 2.50 | 3.00 | 5.00 | 100 |
| Off-season | 4.00 | 4.50 | 8.00 | 100 |
| Black beans, lb | 0.08 | 0.12 | 0.20 | 150 |
| Stewing beef with bone, lb | 0.20 | 0.35 | 0.45 | 125 |

One quetzal = 1 U. S. dollar.
t Includes noon meal.

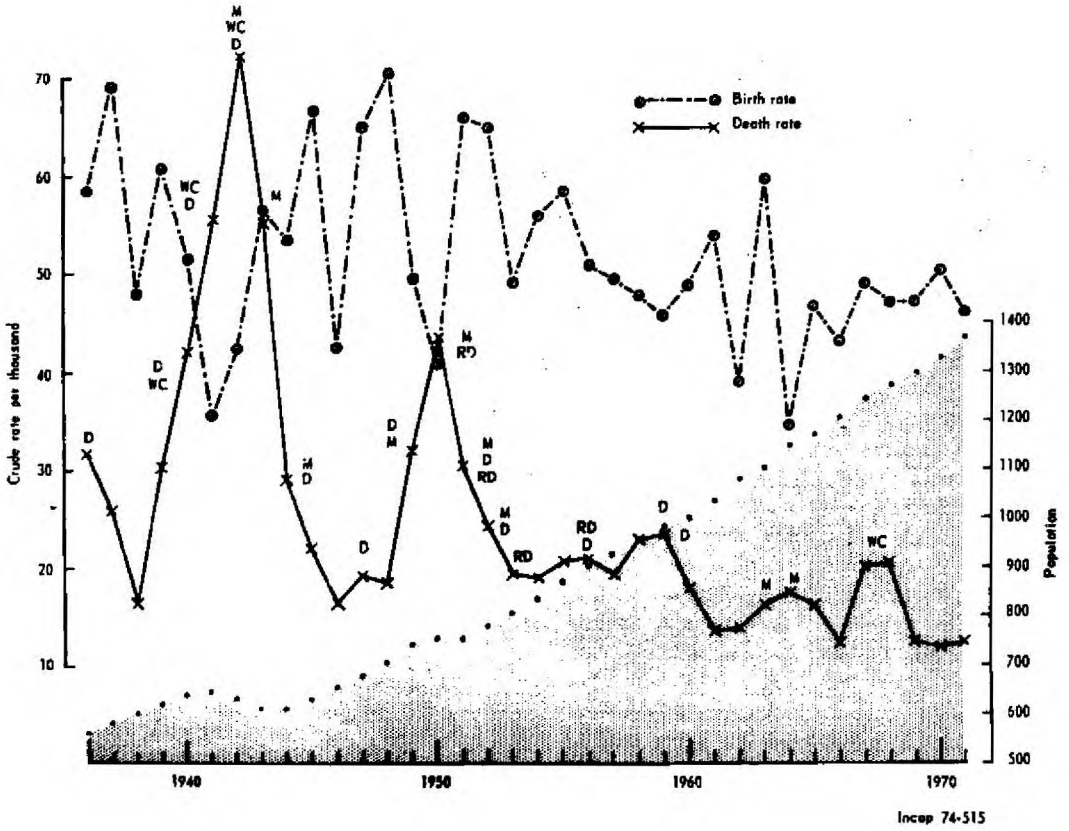


**FIGURE** 4. Birth and death rates per 1,000 population; population estimates and major epidemics; Santa Maria Cauqué, 1936 to 1972. *Key:* D, diarrheal disease; M, measles; RD, respiratory disease; WC, whooping cough [s2] Key words at the top of epidemic peaks indicate that the base and peak of the epidemic was formed mainly by those diseases.

essential items has risen dramatically, reducing to a half or more the, villagers' purchasing power. Collaterally, community development proceeds slowly: there are no outstanding programs of environmental sanitation, of water supplies, housing or education. Agrarian reform is decidedly modest and governmental efforts in improving production of food crops, methods of grain storage, and marketing and price control are small in most countries of the world.

High birth and death rates led to population stability until World War II. Thereafter a material reduction in deaths with a rather minimal change in birth rates resulted in a steady growth of 3% per year (Fig. 4), similar to the growth rate of Guatemala as a whole.as

A common thesis of our times is that population explosion, the most serious threat to health and survival of mankind, cannot be brought under control until childhood deaths are reduced. Twenty years ago Professor John Gordon already was talking of the ***need*** to improve the quality of human life to **accomplish such reduction." Epidemiologically,** improved survival has been followed by marked reduction in numbers of births, the two events following each other within intervals of one or more generations. The nations achieving those changes did so at the cost of sacrifices incident to industrialization, through improvement in the quality of biological and social life. Other events played a role in the process. There was opportunity for massive migration to the Americas, Asia and Africa and colonization and neocolonialism permitted gains in resources and in labor force. Concomitantly, infection remained rampant among the industrial-

ized nations of the 18th and 19th centuries, and deaths were mainly among the malnourished, thus exerting a natural selection of the fittest.

The situation of modern man in the less developed tropical nations is of a different order. On the one hand, he is a peasant or a servant either to a big land holding or to his own small plot. He is as malnourished as his compatriot of earlier centuries and he lives in an equally unsanitary environment. He has some access to the consumable goods of modern society, including medical services. More malnourished children now survive attacks of infectious disease. Techniques for correcting water and electrolyte imbalance save children with brain damage. Deaths of patients with severe protein-calorie malnutrition have been decreased by 50%, but survivors may have sequelae of various kinds. Childhood mortality, however, continues high; the gains of medicine and public health are reflected more in an exceedingly high population growth than in more individuals of adequate biological quality. Other more current problems are evident. The land saturation will create intense pressure on society, just as it did in Europe in the past. The difference is that the world of today offers less possibility for peaceful expansion or the romantic arrangement of some sort of colonialism.

Thus, the study in field and laboratory of malnutrition-infection interactions in less developed nations come abruptly into contact with the inevitable societal need to recognize the true causes of such interactions. The only logical solution is to improve the quality of life which is easy to prescribe but difficult to accomplish. Although the pool of knowledge is not too great, we do know enough about simple ways to diminish infection and utilize food better and methods to improve education. The approach should be societal; it has to come from within the developing nations themselves through a sincere and total commitment to make whatever sacrifices the task demands. The effort invested by the poor nations must be acknowledged by the industrial powers through compromise of an appreciable part of their political. economical and social potential; by a better understanding of the struggle of the less developed countries. That understanding necessarily brings into play a long-range effort toward a better world for all, if humankind is to be judged responsible by the peoples of tomorrow.

## REFERENCES


1, Snyder, J. C., 1972. Population and disease control. Am. *J. Trop. Med. Hyg., 21:* 386-391.

2. Pandit, C. G., 1970. Communicable diseases in twentieth-century India. *Am. J. Trap. Med. H3Tg. , 19:* 375-382.

3. Brock,. J. F., and Autret, M., 1952. *Le kwashiorkor en Afrique*. Organization Mundiale de la Sante: Serie de Monographies, No. 8 Geneve; Etudes de Nutrition *de* la FAO, No. 8, Rome.

4. Goldsmith, G. A., 1974. Current status of malnutrition in the tropics. *Am. J. Trop. Med. Hyg., 23:* 756-766.

5. Scrimshaw, N. S., Taylor, C. E., and Gordon, J. E., 1968. *Interactions of Nutrition and Infection.* WHO Monograph, Ser. No. 57, 329 pp.

6. Scrimshaw, N. S., Taylor, C. E., and Gordon, J. E., 1959. Interactions of nutrition and infection. *Am. J. Med. Sd., 237:* 367-403.

7. Meta, L. J., Urrutia, J. J., and Garcia, B., 1967. Effect of infection and diet on child growth: Experience in a Guatemalan village. Pages 112-126 in G. E. W. Wolstenholme and M. O'Connor, eds., *Nutrition and Infection.* Ciba Foundation, Study Group No. 31.

8. Mata, L. J., Kronmal, R. A., Urrutia, J. J., and Garcia, B. Antenatal events and postnatal growth and survival of children. Prospective observation in a rural Guatemalan village. In: *Proc. Western Hemisphere Nutr. Congr. IV.* In press.

9. Lechtig, A., and Mate., L. J., 1971. Levels of IgG, IgA and IgM in cord blood of Latin American newborns from different ecosystems. *Rev. Lat-amer. Microbiol., 13:* 173-179.

10. Laga, E. M., Driscoll, S. G., and Munro, H. N., 1972. Comparison of placentas from two socioeconomic groups. I. Morphometry. *Pediatrics, 50:* 24-32.

11. Urrutia, J. 5., Meta, L. J., Trent, F.; Cruz, J. R., Villatoro, E., and Alexander, R. E. Infection and infectious disease during pregnancy. Study in an Indian village of Guatemala. *Am. J. Dis. Child.* In press.

12. Mata, L. J., Urrutia, J. J., Caceres, A., and Guzman, M. A., 1972. The biological environment in a Guatemalan rural community. In: *Proceedings of the Western Hemisphere Nutrition Congress III.* Futura Pub. Co., Inc., N. Y., pp. 257-264.

13. Chandra, R. Fetal malnutrition and postnatal immunocompetence. Am. *J. Dis. Child.* In *press.*

14. Mata, L. J., Urrutia, J. J, Kronmal, R. A., and Joplin, C. Survival and physical growth in infancy and early childhood, by birth weight and gestational age. Study in a Guatemalan Indian village. *Am. J. Dis. Child.* In press.

15. Gandra, Y. R., and Scrimshaw, N. S., 1961.

fever vaccine on nitrogen metabolism in children. ***Am. J. Clin. Nutr., 9:*** 159-163.

16. Beisel, W. R., Sawyer, W. D., RylI, E. D., and Crozier, D., 1967. Metabolic effects of intracellular infections in man. ***Ann. Intern. Med., 67:*** 744-779.

17. Beisel, W. R., 1972. Interrelated changes in host metabolism during generalized infectious illness. ***Am. J. Clin. Nutr., 25:*** 1254-1260.

18. Feigin, R. D., Klainer, A. S., Beisel, W. R., and Hornick, R. B., 1968. Whole blood amino acids in experimentally induced typhoid fever in ***man. N. Engl. J. Med., 278:*** 293-298.

19. Pekarek, R. S., and Beisel, W. R., 1971. Characterization of the endogenous mediator(s) of serum zinc and iron depression during infection and other stresses. ***Proc. Soc. Exp. Biol. Med., 138:*** 728-732.

20. Wannemacher, R. W., Jr., DuPont, H. L., Peka-rek, R. S., Powands, M. C., Schwartz, A., Hornick, R. B., and Beisel, W. R., 1972. An endogenous mediator of depression of amino acids and trace metals in serum during typhoid fever. ***J. Infect. Dis., 126:*** 77-86.

21. Awdeh, Z. L., Bengoa, J., Demaeyer, E. M., Dixon, H., Edsall, G., Faulk, W. P., Goodman, H. C., Hopwood, B. E. C., Jose, D. G., Keller, W. D. E., Kumate, ***J.,*** Mata, L. *J.,* McGregor, I. A., Miescher, P. A., Rowe, D. S., Taylor, C. E., and Torrigiani, G., 1972. A survey of nutritional- immunological interactions. ***Bull. W. 11.0., 46:*** 537-546.

22. Mata, L. J., and Faulk, W. P., 1973. The immune response of malnourished subjects with special reference to measles. ***Arch. Latinamer. Nutr., 23:*** 345-362.

23. Faulk, W. P., Demaeyer, E. M., and Davies, A. *J.* S., 1974. Some effects of malnutrition on the immune response in man. ***Ant. J. Clin. Nutr., 27:*** 638-646.

24. Selvaraj, R. J., and Bhat, K. S., 1972. tein-calorie malnutrition. Am. ***J. Clin. Nutr., 25:*** 166-174.

25. Arbeter, A., Echeverri, L., Franco, D., Munson, D., Velez, H., and Vitale, J. *J.,* 1971. Nutrition and infection. ***Fed. Proc.,*** 30: 1421-1428.

26. Harland, P. S. E., and Brown, R. E., 1965. Tuberculin sensitivity following B.C.G. vaccination in undernourished children. ***E. Afr. Meds. .1., 42:*** 233-238.

27. Chandra, R. K., 1972. Immunocompetence in undernutrition. ***J. Pediat., 81:*** 1194-1200.

28. Jose, D. G., Stutman, 0., and Good, R. A., 1973. Long term effects on immune function of early nutritional deprivation. ***Nature, 241:*** 57-58.

29. Mata, L. J., Urrutia, J. J., and Lechtig, A., 1971. Infection and nutrition of children of a low socioeconomic rural community. Am. ***J. Clin.*** Nutr., ***24:*** 249-259.

30. Habicht, J. P., Martorell, R., Yarbrough, C., Malina, R. M., and Klein, R. E., 1974. Height and weight standards for preschool children. How relevant are differences in growth potential? ***Lancet, 1 :*** 611-615.

31. Gruenwald, P., Funakawa, H., Mitani, S., Nishimura, T., and Takeuchi, S., 1967. Influence of environmental factors on foetal growth in man. ***Lancet, 1:*** 1026-1029.

32. Malta, L. J., Urrutia, *J.* J., Garcia, B., Kronmal, R. A., Trent, ***F.,*** and Cruz, J. R. Determinantes ambientales de la salud, la enfermedad y el crecimiento de la poblacion. ***Bol. Of. San. Panam.*** In press.

33. Smith, G. H., 1973. ***Income and Nutrition in the Guatemalan Highlands.*** A dissertation. Dept. of Economics and the Graduate School of the University of Oregon, 1072. University Microfilms, Ann Arbor, Michigan (Pub.). xiv-183 pp.

34. Gordon, J. E., Wyon, J. B., and Ingalls, T. H., 1954. Public health as a demographic influence.