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Effect of Environment on Nutritional Status

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The cause of any disease is only partially accounted for by identification of the specific agent; nutritional diseases are no exception. Whether the specific agent is a microorganism or the lack of an essential nutrient, the development of actual disease will be the result of the interaction between host and agent. Under natural circumstances the pathogenicity and dose of the agent will vary widely, and in given instances the production of disease by the agent will also depend, in part, upon the interaction of a series of so-called host factors, such as age, sex, activity, and genetic variation, plus physiological states, including growth, pregnancy and lactation, and pathological states, such as neoplasms, infections, trauma, and metabolic abnormalities. According to the epidemiological concept of multiple causation, agent and host factors are further influenced by a wide range of environmental factors, each of which involve either host or agent or both.

Environmental factors which influence the nutritional status of individuals or populations may be said to affect (*a*) the nutritional requirements of the host, (*b*) the availability of nutrients, and (*c*) consumption of nutrients in a form and quantity appropriate for utilization by the host. Besides, it has been suggested that environmental factors can be separated appropriately into 3 main categories; physical, biological, and socio-economic. As far as applicable each of these categories will be considered for each environmental influence.

A. *Environmental Factors Affecting Nutritional Requirements of the Host.* 1. Physical Factors: The principal physical factor influencing the nutritional requirements of the host is temperature. In general, the en-

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ergy requirements of individuals in a cold environment are increased by muscular activity, either work or shivering, to maintain body temperature and by the customary ingestion of food with high specific dynamic action. However, the effect of a cold environment is greatly moderated by the type of clothing and housing which may serve to maintain an individual in a microclimate approaching that of the tropics. Babbott et al.[1] have shown that Eskimos when inside igloos live in such a tropical microenvironment that they are subject to the same intestinal parasites and are afflicted with as high infection rates as persons living in the tropics.[2,3]

Gray, Consolazio, and Kark concluded from experiments with 5 healthy men performing the same amount of muscular work at 3 ambient temperatures (−16, 59, and 93 F) and wearing clothing appropriate for each temperature level that "change in metabolism due to the hobbling effect of clothing appears to be at least twice as great as the change due to ambient temperature and must be regarded as playing a major role in the increased caloric requirement as the temperature is lowered. . .".[4] Thiamine requirements are directly related to caloric requirements and increase as caloric intakes increase.

Excretion of urinary *N*-methylnicotinamide is related to environmental temperature and has been found to be greater with increasing cold even though the level of niacin intake is maintained constant.[5] This suggests that the stress of cold increases the output of total nicotinic acid in the urine, although this effect is not large enough to be of any real significance. On the other hand, the urinary excretion of ascorbic acid is depressed by cold.[6]

In experiments with rats, which are not dependent on dietary ascorbic acid, daily supplements of this vitamin have been found to aid adaptation to prolonged temperatures in the range of +4 C to −4 C. In the guinea pig, which normally requires ascorbic acid in the diet, adaptation to an environment of +8 C to −8 C, as measured by body weight changes, depended upon the ascorbic acid level of the daily diet and was best at the highest levels of intake. In both rats and guinea pigs receiving large doses of ascorbic acid, the enlargement of adrenal glands as a result of the cold stress was completely prevented.[7]

Guinea pigs exposed to a temperature of 0 C until death following 4 weeks of ad libitum feeding at a room temperature of 20 C with diets containing 0, 3, and 30 mg. of ascorbic acid, showed much greater daily weight loss and shorter survival time on the diets containing no ascorbic acid,[8] but 30 mg. of ascorbic acid daily per animal appeared to be no more beneficial than 3 mg.

Previous deficiencies of either vitamin A or thiamine also impaired the resistance of rats to cold.[9] In these instances the deficiencies seemed to interfere with the ability of tissue energy reserves to meet the caloric requirements imposed by cold.

When rats were exposed to moderate cold, an increase in the output of urinary nitrogen and in protein catabolism occurred with simultaneous loss of weight. It is not surprising, therefore, that rats with inadequate protein intakes show less resistance to cold.[10] Systematic studies of this nature have not been performed in man.

When active individuals are overdressed in cold weather, water and nutrient losses during periods of heavy muscular activity may be similar to those due to high environmental temperatures. Because individuals are too impatient or lack time or fuel to melt adequate amounts of snow, water intakes may fall below normal requirements and dehydration may often become a serious problem under arctic conditions.[11]

The direct effect of a high environmental temperature may be partially compensated for by the use of lighter clothing and the extent of individual acclimatization. However, the reduced caloric requirement for temperature maintenance under these conditions is further lowered by the fact that the same amount of work requires less expenditure of energy when lighter clothing can be worn. Actually, the amount of physical labor varies tremendously and can overbalance these effects.[4]

Requirements for salt are markedly affected by heat because of increased loss of this substance in perspiration. For men doing light work at a maximum temperature of 95 F, sweat losses increased water requirements by 4 liters; while for men performing heavy work at a temperature of 113 F, requirements were increased up to 13 liters per day.[12] Although water had to be replaced at frequent intervals to maintain operational efficiency, salt loss could be replaced at mealtimes without altering the sodium economy.[13,14]

In addition to sodium, almost all minerals are lost to some degree through sweat. In India there is evidence that the dermal loss of iron in women of childbearing age (when they are on borderline intakes of dietary iron) is a significant factor, along with repeated pregnancies and lactation, in the development of iron-deficiency anemia in this group.[15-17] Stransky and Dauis-Lawas [18] believe the relatively higher incidence of iron-deficiency anemias in infants and children in the tropics may also be due, in part, to excessive losses of iron from this cause.

Hourly losses of calcium in sweat have been reported to range from 5.3 mg. over an 8-hour period under comfortable conditions to 15.1 mg. under hot, humid conditions, when sweat losses averaged 700-800 gm. per hour.[19] However, the loss of calcium in sweat is reduced by a diminution in concentration as sweating proceeds.[6] In calcium-balance studies in 4 subjects at an intake of 0.7 gm. per day, the average calcium retention was 100 mg. less per day in a hot, humid environment than in a comfortable environment. When the intake was 1.7 gm. the difference was more than 400 mg. less. Data on individual balances, however, were highly variable and statistically insignificant. Since only the fecal output of calcium was significantly increased, it appears probable that increased fecal output in a tropical environment accounts for the higher net calcium loss reported for persons in the tropics.[19]

Potassium in sweat usually averages 45 to 50 mg. % [20,21] although there have been reports of higher concentrations. Iodine concentration in sweat appears related to blood plasma concentration,[22] and the amount lost is not sufficient to influence the development of endemic goiter.

The nitrogen concentration in human sweat has been reported as varying from 47 to 130 mg. % [6] with a total daily output ranging from 71 mg. to 5.28 gm., depending upon muscular activity and ambient temperature. At a temperature of 90 F in New Orleans, Bost and Borgstrom [23] observed an output of 75 mg. of nitrogen per hour in sweat, but these results should not be generalized, since Cuthbertson and Guthrie [24] found a clear relationship between the daily excretion of sweat nitrogen and dietary protein intakes ranging from 70 to 180 gm. per day.

While Hier, Cornbleet, and Bergeim [25] found the secretion of amino acids in sweat to be independent of diet or food ingestion, they did not consider the amounts involved to be "strikingly significant on the economy of amino acids by the body." On the basis of data obtained from subjects under average conditions of temperature and humidity, they theorize that only 1.3 gm. of the 10 essential amino acids would be lost through sweating in warm weather by subjects performing active work which might result in the formation of as much as 3 liters of sweat; this amount would contain 2.2 to 2.6 gm. of total amino acids. On this same basis, 10 liters, an attainable daily volume, would contain 7.3 to 8.6 gm. of amino acids,[6] and such a loss could be significant to persons on a borderline diet.

A number of studies of the loss of water-soluble vitamins in sweat have been carried out, but the results vary greatly due to differences in analytical methods and sweat collection. It seems highly unlikely, however, that the small quantities involved are of practical significance in human nutrition.[6]

Besides the loss of nutrients in sweat there are other possible mechanisms by which a high environmental temperature may influence nutrient requirements. Mills,[26-29] in a series of studies with rats and chicks, claimed that requirements for thiamine, choline, and vitamin K sharply increased in a tropical environment, but that requirements for riboflavin, pyridoxine, pantothenic acid, *p*-aminobenzoic acid, and inositol were not affected. Since these experiments were based on ad libitum feeding in which appetite was an important variable, these findings are difficult to interpret.

Robinson determined the minimum amount of thiamine required to prevent increased excretion of pyruvate in the urine of rats at different environmental temperatures and found a range of 0.7μg. per gram of food at 15 C to 2.4μg. per gram of food at 35 C.[30] The practical significance of these findings is lessened by the fact that at higher temperatures caloric requirements are likely to be lower, and consequently the requirements for thiamine decrease.

Kurokawa[31,32] reported that avitaminosis A could be induced more rapidly in rats in a hot environment than in a cool one, but this has not been confirmed. In experiments with rats, a greater sensitivity to rickets at temperatures of 80 F or above was demonstrated[33]; however, in later experiments[34] by other workers using rachitogenic diets, 3 temperature gradients, and carefully selected test animals, the results indicated "that environmental temperature is *not* an important consideration in either the production or cure of rickets in the rat." Furthermore, animals consuming the largest amount of food with subsequent greatest increase in body weight, showed the more severe rickets.[34,35] It seems probable that if the rats which had been subjected to heat had consumed the same amount of food as those exposed to cold, they would have developed more severe rachitic lesions.

Other climatic variables affect the nutritional status of the host. Among these is the clear-cut relationship between lack of sunlight and the development of the deficiency-disease rickets. At one time there was a high incidence of rickets in northern countries because of the wintertime shortage of the sunlight necessary for the conversion of ergosterol in the skin to active vitamin D. Today in these countries rickets is almost extinct due to the use of vitamin D concentrates. Rickets is, however, sometimes observed in tropical and subtropical regions despite the abundance of sunlight in these areas, and it occurs when children in the slums of tropic cities are deprived of exposure to sunlight because of illness, living in tenements with little opportunity for exposure, or staying with the working mother whose occupation keeps her within a building during the daylight hours.

A direct effect of exposure to sunlight is the exacerbation of the skin lesions of pellagra. In fact, pellagrous dermatosis develops only on those areas of the body exposed to sunlight and occurs at the time of the year when the work pattern and climatic cycle result in greatest exposure.[36] Experimentally, patients consuming niacin-deficient, low-tryptophan diets with no signs of pellagrous dermatosis develop typical lesions only a few hours after exposure to sunlight.[37]

There is no real evidence to support a belief that altitude markedly alters the nutritional requirements of man. At some point low oxygen tension depresses metabolic processes, discourages muscular activity, and lowers work capacity, but this point is rarely reached. Vitamin supplements have proved of no benefit in increasing tolerance to the anoxia associated with altitude.[6]

2. Biological and Socioeconomic Factors: It is obvious that those aspects of the environment that are biological and socioeconomic affect primarily the availability and consumption of food rather than the nutrient requirements of the individual. In one sense, however, the concentration and distribution of disease organisms in the environment can be said to affect nutrient requirements indirectly, since any infection itself is likely to alter nutritional patterns.[38] The mechanisms include a direct reduction of appetite and tolerance to food as a result of infection as well as increased loss of nitrogen and other nutrients in the urine and a tendency to change the diet to a more restricted and less nutritious one for supposed therapeutic purposes. In this same sense, any toxic or hazardous aspect of the environment which augments the likelihood of pathology in the host is likely to result in an increase in the

nutrient requirements of many individuals in a population, and this factor must at times be taken into account in calculating the nutrient needs of a population.

B. *Environmental Factors Affecting the Nutrient Availability by Influencing the Production, Processing, Conservation and Distribution of Food.*—1. Physical Factors: Physical factors exerting great influence on the production of food are the type of climate and the frequency of natural disasters such as floods, droughts, and severe storms. Since the nutrients for a plant must come from the soil on which it is grown, soil mineral deficiencies reduce the yield and sometimes the quality of crops. In addition to nitrogen which is needed in large quantities there are over 30 elements required in at least trace quantities for good plant growth. After being produced, much of the food is wasted or lost in one way or another before man ever has an opportunity to consume it. A warm, humid climate is particularly conducive to spoilage, and for most parts of the world artificial refrigeration is essential for efficient handling of many types of food supplies. The physical environment also helps to determine the extent to which those features of the biological environment, such as rodents, insect pests, and fungi, interfere with food conservation.

Food distribution is hindered by such geographical characteristics of the country as mountain ranges, deserts, and jungles and is facilitated by inland waterways, accessibility to seaports, and terrain that lends itself easily to road building. The proximity to a sea coast makes fresh fish and seafood more readily available for human consumption, and any large body of water offers a potential source of fresh fish.

2. Biological: A major biological limitation to the production of food is the types of plants which can be grown under specific climatic and physical conditions. These environmental factors also determine the various animal species which an area can support. Another biological limitation to food production is the presence of plant and animal diseases which tend, unfortunately, to be most prevalent in the very areas where increased food production is most needed. Similarly, the effect of the presence of rodents, insect pests, and fungi on the conservation of food can scarcely be overemphasized. In the United States crop losses from insects alone are estimated to represent an economic loss of nearly 2 billion dollars annually.[89] In technically underdeveloped areas, the decreased use of insecticides and poorer storage and food handling facilities contribute to proportionately higher losses.

Responsibility for the poor animal production in many areas is largely attributable to parasites and animal diseases. The former problem of the screw worm in cattle in Florida and the prevalence of hoof and mouth disease in some parts of the world are specific examples. Finally, the effect of the biological environment on man has important repercussions on his capacity to produce food. Regions in which malaria and other highly endemic infections have not been controlled may have fertile soil and be potentially productive but will remain underdeveloped until public health measures improve the biological environment of man himself.

Important as a determinant of both availability and adequacy of food is the density of population. Through public health efforts mortality rates have been lowered, and life expectancy has been raised. Food production, however, has not increased proportionately in many of the heavily populated areas where malnutrition is a serious problem, and in some the per capita food availability has decreased. In some of these areas reduction in birth rates would provide a partial solution, while in others a widespread adoption of modern agricultural methods could meet, at least temporarily, the demands of an expanding population.

3. Socioeconomic Factors: Many of the biological and physical limitations to food production, processing, storage, and distribution could be overcome if socioeconomic factors could be modified. Successful crop production is dependent upon the implementation of knowledge of suitable varieties, the application of modern methods of planting,

cultivating, and harvesting, the use of fertilizers, and the control of plant and animal diseases and pests. Similarly, the proper choice of species of animals for breeding, good feeding and management procedures, and control of diseases and other aspects of animal husbandry determine the gross availability of meat, dairy products, poultry, and eggs. Where fish resources exist or can be established, the efficiency of catching, storing, and processing them will determine, in large measure, the availability and cost of fish and fish products.

Even with adequate knowledge, however, food production may be hampered by the lack of either working capital or reasonable credit for rural workers, as well as by governmental regulations and controls.

Efficient methods of processing, handling, and storing foods are almost as important as production in assuring adequate food supplies. Older methods of food preparation, such as dehydration and canning, often resulted in greater losses of essential nutrients than modern methods of freezing and freeze-drying. Today's food industry requires a technology sufficiently developed to make practical the application of new and improved methods and to insure that the net agricultural product available for consumption is in its highest nutritive state.

C. *Environmental Factors Affecting Food Consumption.*—1. Physical Factors: Temperature has a marked influence on the amount and kind of food which people eat. It is usually easier to achieve nutritional adequacy by eating the balanced diet of a temperate region than it is by eating the diets which are traditional at the extremes of physical environment. The psychological and physical effects of high environmental temperatures tend to depress appetite and result in a preference for less concentrated foods.

Little is known about the effect of altitude per se, since dietary habits at high altitudes are likely to be influenced more by food availability than by altitude itself. It has been reported that appetite is disturbed during acclimatization to high altitudes and remains affected, but this is probably more a subjective than a physiological phenomenon. Certainly once the acclimatization is completed, persons at either high temperatures or high altitudes are physiologically almost in the same state as they would be in a temperate climate or at sea level.

2. Biological Factors: Reference has already been made to the influence of infection on the nutritional status of individuals. In one sense the endemic and epidemic prevalence of infectious agents is also a biological factor in the environment affecting the consumption of food by the host. Appetite and even tolerance to food are significantly decreased in the presence of most infections.

3. Socioeconomic Factors: Economic, political, and cultural factors all have important influences on food consumption. The relatively high cost and unavailability of so-called protective foods are major reasons for the widespread occurrence of malnutrition in the world. Political factors, such as subsidies, price controls, and low-cost distribution of food surpluses may make it easier for people to purchase food, while national policies relating to distribution and controls rising out of war, civil disturbances, and natural disasters may drastically affect individual food consumption.

Even where food is or could be made available at reasonable cost, irrational dietary habits born of ignorance and prejudices impede good nutrition. Most cultures of the tropics and subtropics have not evolved an effective way of feeding the young child after weaning so as to ensure a nutrient intake adequate for normal growth and development. Food prejudices, faddism, and quackery combined with ignorance of the principles of good nutrition are all environmental factors in the epidemiological sense which adversely affect nutritional status.

Sometimes new foods may acquire prestige value even though they are of relatively poor nutritive value and contribute little or nothing to the individual's nourishment. Through promotion of foods at exorbitant prices the consumer may be victimized by either the lowering of the over-all nutritional quality of the diet or by introduction of excessive quantities of some nutrients which lead to toxic reactions. Unsound therapeutic practices, especially in the treatment of children in technically underdeveloped areas, may exaggerate the existing stress on the nutritional status of the child, inducing severe manifestations of deficiencies. Alcoholism not only wastes money better spent for food, but substitutes the "empty" calories[40] of alcohol for food calories and thus contributes importantly to acute malnutrition in some individuals. In some Andean countries the use of coca with its high cocaine content interferes with food consumption and produces effects similar to those of alcoholism.

Summary

Consideration of the environmental factors influencing nutritional status should not be confined to the physical aspects alone. In modern epidemiological terms an appraisal of the biological and socioeconomic aspects of the environment must also be included. Obviously, each of these aspects of environment will affect the availability of food, nutritional requirements, and consumption of food, and each is interrelated and influenced by the others.

In the main, environmental factors influencing nutritional requirements are physical and stem from climatic variables, although the biological environment in which an individual lives also determines his nutritional requirements.

The availability of nutrients is determined by food production, conservation, processing, and distribution as well as population density; and these, in turn, are dependent upon geographical and climatic factors, types of foods produced, prevalence of plant and animal diseases, and cultural and economic influences.

Among the environmental factors affecting consumption, the physical are of little importance compared with cultural traditions and economic feasibility.

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