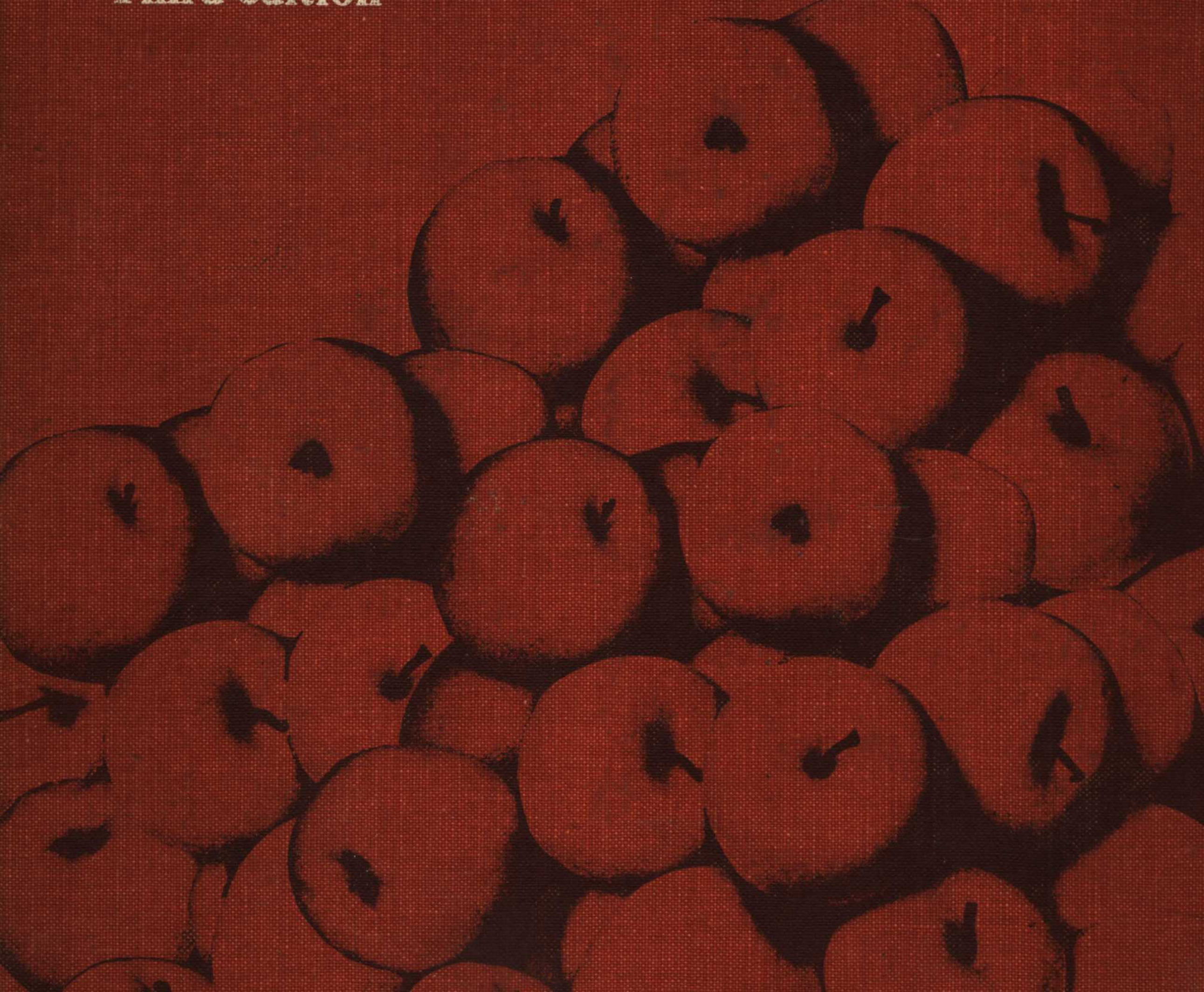
INTRODUCTORY NUTRITION

HELEN ANDREWS GUTHRIE

Third edition



INTRODUCTORY NUTRITION

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THIRD EDITION

With 125 illustrations

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PREFACE

The preface to the first edition indicated that *Introductory Nutrition* had been prepared for the new kind of student entering college, one who had graduated from high school well prepared for the serious study of elementary nutrition. Although the approach used in that edition did not presuppose formal training in physiology and biochemistry, it did take into account the experience most high school students had had in dealing with the concepts of the biological and physical sciences. It was assumed that the students using the book had the capacity and the desire to achieve some in-depth appreciation of nutritional processes. To aid the students, basic concepts from the related sciences were outlined in the first chapter, and a glossary and a list of terms and meanings of prefixes and suffixes were included in the Appendix.

Experience has shown that the scope of this book is suited to the capabilities of such a student with no college training in science. It has also become evident that the level of presentation is equally valuable and suited to the needs of the student with a more sophisticated background. The primary purpose remains one of providing an in-depth introduction to the principles of nutrition to students at all levels of competence. It has been gratifying to find that many have found that this book meets this need.

I hope that in mastering the material presented, students will become discerning consumers of nutrition information, with a comprehension of the basic principles adequate to enable them to discriminate the scientific from the pseudoscientific and fact from fallacy in the vast literature of both the lay and the scientific press. In addition to developing their own understanding of nutrition, students should be adequately prepared to interpret their knowledge of nutrition for the general public—a need that is becoming increasingly evident.

Another purpose of this book is to create awareness of the importance of nutrition in such a way that students will be motivated to apply this knowledge in establishing good eating habits. The extent to which this is achieved is more difficult to measure. It is also hoped that some students will be stimulated to continue the study of nutrition to acquire the level of competence needed to qualify them for the many challenging career opportunities in the field. The recent interest in the broad social and political implications of adequate nutrition has greatly expanded the horizons of the professional nutritionist.

An assessment of the advances in our knowledge of nutrition in the eight years that have elapsed since the first edition indicates that nutritional biochemists, cell biologists, and physiologists have made significant contributions to our knowledge of metabolic processes. Many of their findings are beyond the scope of this presentation, but I have attempted to interpret those of greatest significance in the application of nutritional principles to the practical task of feeding people. For the most part, however, I have drawn on the studies of clinical nutritonists, who have focused on the questions of metabolism and nutrient needs of the total organism. Many of them have emphasized the role of social, economic, and psychological factors, as well as physiological and biochemical factors, involved in the availability and utilization of nutrients. Again, as in the previous editions, I have chosen to mention some of the more recent nutritional concepts and theories, with full recognition that they may have to be modified or deleted in subsequent editions.

The final chapter, dealing with the questions of hunger and malnutrition as national and international concerns, reflects a growing interest in the social implication of sound nutrition. Recognition of the effect that even moderate degrees of undernutrition may have on mental as well as physical health and development points to the availability and safety of the food supply as crucial factors in national planning. At the same time, a sizable portion of the population and certain of the readers of this book are being called upon to cope with the equally complex problems of overnutrition.

To an even greater extent than was true in the earlier editions, this edition was possible only through the encouragement and cooperation of a great many individuals, including the students and colleagues whose constructive criticism led to the clarification of many points, the scientists who consented to have their work reproduced or quoted, and the persons who helped with the clerical and other time-consuming aspects of preparing a manuscript. It is impossible to recognize all those whose help was invaluable but I would like to single out Carolyn Sharbaugh, Mary Lynn Kasunic, Adria Sherman, and Frances Thompson, who helped with the preparation of the manuscript, and Dennis Cox and James Bergen, who offered constructive criticism. Again, my three children, who are now old enough to help with many tasks, and my husband have remained patient and supporting and should be given major credit for making this third edition a reality.

HELEN ANDREWS GUTHRIE

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PART I BASIC PRINCIPLES OF NUTRITION

1 OVERVIEW OF NUTRITION

The science of nutrition has been defined in many ways. Most simply it has been expressed as the science of nourishing the body properly or the analysis of the effect of food on the living organism. Yudkin chooses to define nutrition as the relationship between man and his food and implies the psychological and social as well as the physiological and biochemical aspects. Others propose defining it as a science devoted to the determination of the requirements of the body for food constituents both qualitatively and quantitatively and to the selection of food in kinds and in quantity to meet these requirements. The Council on Foods and Nutrition of the American Medical Association elaborates still further in declaring nutrition as "the science of food, the nutrients and other substances therein, their action, interaction, and balance in relation to health and disease and the processes by which the organism ingests, digests, absorbs, transports, utilizes and excretes food substances."

Regardless of the basic definition, persons studying nutrition agree that they are concerned with the changes that occur in food and the way in which the body uses it from the time food is ingested until it is eventually incorporated into the body tissues, participates in biological reactions, or is excreted from the body. This includes the study of digestion, absorption, and transportation of nutrients to the cells and their metabolism within the many types of body cells. In addition, nutritionists are becoming increasingly concerned with the factors that determine what a person chooses to eat and with monitoring the nutritive quality of the available food resources.

The nutrients in food with which nutrition is concerned are those chemical components of the food that perform one of three roles in the body: supply energy, regulate body processes, or promote the growth and repair of body tissue.

The science of nutrition is a relative youngster in the scientific community, having been recognized as a distinct discipline only in 1934 with the organization of the American Institute of Nutrition. As a science relying on the techniques of the chemist and biologist, nutrition developed only after development of these other branches of science. Nutrition, like other sciences, does not stand alone. It draws heavily on the basic findings of chemistry, biochemistry, microbiology, physiology, medicine, and, most recently, cellular biology. In turn, it also contributes to these fields of scientific investigation.

HISTORICAL BACKGROUND

Although the organized study of nutrition has been confined to the twentieth century, there is evidence of a long-standing curiosity about the subject. A few well-conceived nutritional experiments were performed earlier, but these stimulated little interest. Schneider has very aptly divided the history of nutrition into three eras: the *naturalistic era* (400 B.C.-A.D. 1750), the *chemical-analytical era* (1750-1900), and the *biological era* (1900 to present). Running concurrently with the latter from 1955 to the present can be added the *cellular* or *molecular era*, in which emphasis has been directed to the study of nutrition within the highly organized individual cells. Although no attempt will be made to discuss all the findings of each era, we will mention a few highlights to give some picture of the extent of the knowledge of nutrition in each stage.

NATURALISTIC ERA. During the naturalistic era people had many vague ideas about food, most of which revolved around taboos, magical powers, or medicinal value. Just as millions do today, early man recognized that food was essential for survival and did not discriminate about the relative value of different foods. In Biblical times, however, Daniel observed that men who ate pulse and drank water thrived better than did those who ate the king's food and drank wine. Hippocrates, the father of medicine, in his discussion of food in health and disease in 400 B.C. considered food one universal nutrient. He believed that weight loss during starvation was caused by insensible perspiration. By the sixteenth century a doctrine of diet and longevity had been well established.

In the early seventeeth century an Italian physician, Sanctorius, curious about the fate of food in the body, weighed himself before and after each meal. His only explanation of his failure to gain weight commensurate with the amount of food taken in was that there must be weight loss in insensible perspiration. It was during this period that such men as Harvey and Spallanzani, with their interest in circulation and digestion, made observations that eventually facilitated the study of nutrition. At the end of this era the first controlled nutrition experiment was carried out in 1747 by a British physician, Lind, who attempted to find a cure for scurvy by treating twelve sailors ill with the disease with six different substances. He determined that either lemon or lime juice was effective, while the others, such as oil of vitriol, seawater, and vinegar, were ineffective in curing this scorbutic condition.

CHEMICAL-ANALYTICAL ERA. The chemical-analytical era in the study of nutrition was initiated by Lavoisier in the eighteenth century, who became known as the father of nutrition. His work involved the study of respiration, oxidation, and calorimetry—all concerned with the use of food energy. His work with guinea pigs on oxygen uptake, with and without food and during work, was the first investigation that showed the relationship between heat production and oxygen use in the body. Black and Priestley, also working in the eighteenth century, contributed to the growing knowledge of respiration and energy metabolism.

Early in the nineteenth century, methods for determining carbon, hydrogen, and nitrogen in organic compounds were developed. Analyses of foods for these elements led Liebig to suggest that the nutritive value of foods was a function of its nitrogen content. He also postulated that an adequate diet must provide plastic foods (protein) and fuel foods (carbohydrate and fat). Dumas, a French chemist, tested this hypothesis during a siege of Paris in 1871. His efforts to produce a synthetic milk of carbohydrate, fat, and protein in the proportions believed to be found in cow's milk proved unsuccessful, and the infants to whom he fed it died. Dumas logically concluded that milk must contain some unknown nutritive substance.

A similar conclusion was reached in 1881 by Lunin, who found that mice fed a diet of purified casein (a protein), milk sugar (a carbohydrate), milk fat, and the inorganic ash from milk died, while those who were fed milk thrived. Between then and 1906 there were reports of twelve experiments on the use of purified diets in the feeding of animals. All led to essentially the same conclusion that the addition of "astonishingly" small amounts of natural foods was necessary to promote growth and to maintain health in the animals. Obviously, food contained more than carbohydrate, fat, protein, and mineral ash, but the nature of the other substances remained a mystery. In spite of these findings the United States Department of Agriculture steadfastly maintained until 1910 that carbohydrate, fat, and protein were the only nutrients essential in the human diet.

By 1912 it had been well established that there was an additional dietary essential be-

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sides carbohydrate, fat, protein, and mineral ash. Funk, recognizing that this dietary component was essential to life *(vita)* and believing it to be *amine,* or nitrogen containing, introduced the term *vitamine* to describe this elusive dietary factor. Two independent studies showed that there were at least two vitamins—fat-soluble vitamin A and water-soluble vitamin B. McCollum's work at the University of Wisconsin showed that some fats such as butter contained an essential growth factor, whereas others such as lard did not. Eijkman observed that a water-soluble substance in rice bran prevented beriberi, a disease common in the Orient. By 1920 when it was established that all vitamins did not contain nitrogen, the final "e" was dropped to obtain the term *vitamin,* which persists to this day.

In spite of the relatively slow communication in this period, scientists in Europe, Asia, and North America made rapid progress in identifying essential dietary components. Many times discoveries were made almost simultaneously by scientists working independently and in widely separated laboratories. The concept that diseases such as beriberi, scurvy, rickets, and pellagra, previously considered to be caused by toxic substances or to be infectious in nature, were in reality the result of an absence of nutrients needed in very small amounts did much to stimulate the attempts to identify the nature of these dietary essentials.

BIOLOGICAL ERA. The early part of the biological era was characterized by the discovery of many factors with vitamin-like properties. It soon became clear that there were several components of both fat-soluble A and water-soluble B. By 1940 four fat-soluble and eight water-soluble vitamins had been identified as essential elements of the human diet, and several others had been identified for various species of animals. The chemical structure of each had been established, many had been synthesized, and knowledge of their biological roles was accumulating rapidly. Since 1940 only two essential vitamins, folic acid and vitamin B_{12}, have been identified. The emphasis in nutrition research has changed from a search for essential dietary components to a study of the interrelationships among nutrients, their precise biological roles, and the determination of human dietary requirements. More recently, interest has been directed toward the problems of nutrition education as the result of the widening gap between our theoretical knowledge of nutrition and its application in the improvement of nutritional status.

During this same period the noncombustible component, or mineral ash, of the diet was being studied, and it too proved to be a complex mixture of elements—twenty of which have been established as dietary essentials for human beings. The essentiality of several others is still uncertain. Here again there was evidence of involved interrelationships among mineral elements; some were capable of replacing others, whereas a high intake of one could cause the excretion of another.*

CELLULAR OR MOLECULAR ERA. Since 1955 the development of the electron microscope, the ultracentrifuge, microchemical techniques, and the use of radioactive isotopes, has made it possible to study the nutritional needs and metabolism of the individual cells and even the subcellular components, or organelles, of the cell. At the present time a vast body of information is accumulating, which is leading to a more complete understanding of the intricacies of cell structure and the complex and vital role that nutrients play in the growth, development, and maintenance of the cell. Nourishment of the cell is basic to the nourishment of the collection of cells known as tissue, and this in turn is basic to the nourishment of organs of the body and ultimately of the whole complex body.

It is now well established that lack of

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*The serious student who is interested in reading some of the classic studies in nutrition is referred to a series being reprinted in *Nutrition Reviews* beginning in 1973. (Nutrition Foundation, Inc., New York.)

an essential nutrient results in a failure to form an essential enzyme or other cellular component or in an inability to use these components. This results in malfunctioning or death of the cell, which eventually shows up in a specific physical symptom of ill health.

PRESENT STATUS

We now find ourselves, a hundred years after the first studies that showed that more than carbohydrate, fat, and protein were necessary for normal growth and development, with a vast, complex, and rapidly expanding knowledge of over forty nutritional principles that must be supplied by food for normal body functioning. The absence of any one of these, regardless of the amount needed, can have a profound effect on the functioning of the whole body.

Although it is now over 25 years since the discovery of the last vitamin, nutrition remains a vital, exciting field in which new information is being accumulated at a phenomenal pace. The contributions of the nutritionist alone have been many and significant. When one integrates with these the related findings of the biochemist, the physiologist, the biologist, and the physicist, one realizes that understanding the complexity of the process of nourishing the body is a challenging frontier of science that is only beginning to be explored.

The fact that scurvy, rickets, beriberi, pellagra, and kwashiorkor, all nutritional deficiency diseases representing but a small fraction of nutritional problems, can be found in affluent and developing countries alike is stark evidence of our failure to apply what nutrition information we do have. In attempts to eliminate this paradox, nutritionists are now turning to social scientists to assist them in effecting the kinds of behavioral changes that will result in improved nutritional health.

Many new approaches to the study of nutrition are emerging. The study of the cell has stimulated interest in the role that genetics may play in influencing the nutritional needs of the organism. The interaction between nutrition and genetics in the developmental process is providing an explanation for some congenital abnormalities and metabolic defects. The role of nutrition in brain development, behavior, resistance to infection, and stress and the role of environmental factors such as pollution and the use of drugs on nutrition are but some of the newer concepts being studied.

As the biochemist becomes more concerned with the intricacies of metabolism and less and less with the total organism, the nutritionist is turning much of his attention to the integration of the theoretical knowledge from many fields of study and to the application of this to the maintenance of health and the prevention and treatment of disease. Iatrogenic nutrition, which is concerned with nutritional disease resulting from the activities of a physician in treating a patient with drugs, surgery, or therapeutic diets, represents another area of interest.

The rate at which the time, effort, and money expended on nutrition research increased after the concept of vitamins was first postulated can be judged by the number of scientific publications in the field. In 1913 there were four publications, all by Casimir Funk; by 1920 the number had risen to 73; and in 1930, 724 articles appeared. In 1974 reviews of current literature on single nutrients routinely list from 200 to 500 references. At least ten scientific journals are devoted entirely to reporting findings of nutrition research. In 1975 over 3600 papers dealing directly or indirectly with subjects of significance in nutrition will be presented at a single scientific meeting. The large number of investigators who consider nutrition their major interest is obvious from the number of members in scientific organizations devoted to nutrition and from their attendance at professional meetings. The Institute of Nutrition, whose membership is restricted to scientists who have made significant contribution to the field, has over 1500 members. The Society for Nutrition Education was formed in 1971 in recognition of the need for a forum for professionals concerned with the application of nutrition knowledge in prevention as well as cure and understanding of malnutrition.

The year 1968 saw the beginning of a surge of public interest in nutrition in the United States. This was the result of the realization that hunger and malnutrition existed in the midst of plenty. The first White House Conference on Food, Nutrition, and Health, which convened in 1969, represented a concern on the part of the federal government that the problem be identified and that steps be taken to alleviate it. Since that time a number of federally supported nutrition activities have been initiated, including nutrition programs for the elderly, comprehensive nutrient labeling of all processed food products for which any nutritional claim is made, and nutrition education in elementary schools. Other programs such as school feeding and food stamps have been expanded. At the same time a nutrition-conscious nation has manifest its concern with increased expenditures on health foods and increased reliance on alternate food patterns. The effectiveness of the activity resulting from the 1969 conference was assessed at a follow-up conference in 1974.

On an international level the importance that political leaders attach to nutrition is best illustrated by the fact that the first agency authorized within the United Nations was the Food and Agricultural Organization, commonly known as FAO. In 1944 it was charged with the responsibility of devising ways to improve the nutritional status of the world's population as one of the major pathways to peace. Since then interest in international nutrition problems has increased rapidly.

WHO (World Health Organization) allocates much of its resources toward the solution of nutrition problems, as do national groups such as the Agency for International

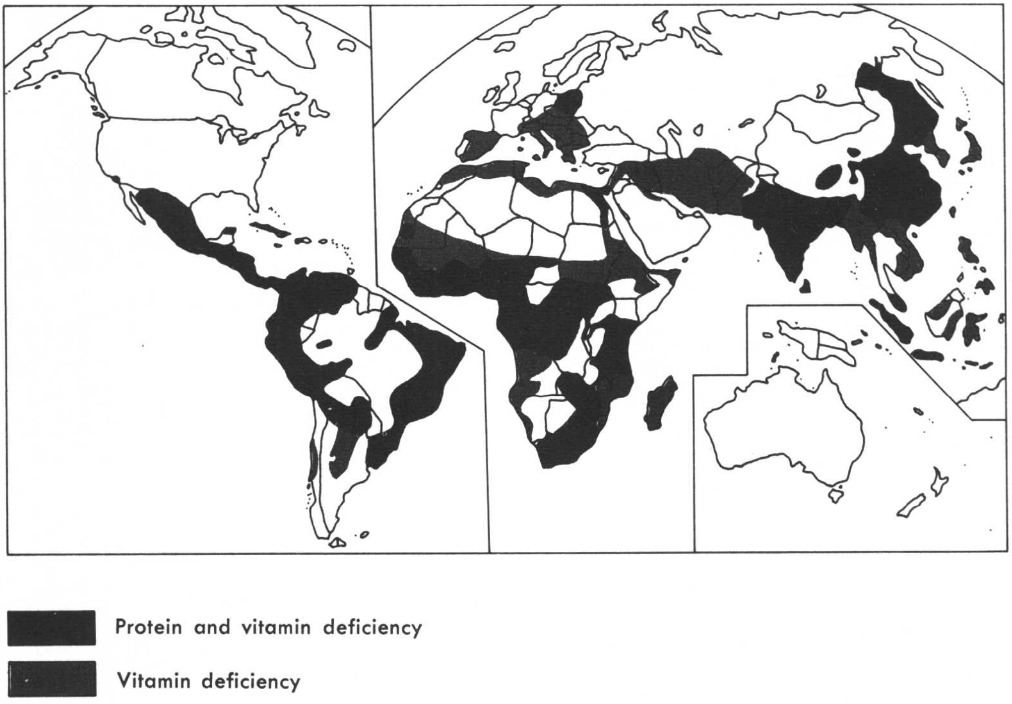

Fig. 1-1. Distribution of protein- and vitamin-deficiency diseases in the world.

Development. Innumerable privately funded organizations and foundations also work actively to contribute to solutions to nutrition problems. Numerous conferences are devoted to discussion of efforts to improve the nutritional status of the expanding populations of developing countries. The necessity of making maximum use of indigenous food products to provide a level of nutrition capable of supporting health and promoting individual productivity is an ever-present challenge to nutritionists.

In spite of these efforts, malnutrition and undernutrition existing in conjunction with a rapidly expanding population and inadequate medical care remain the most important health problems in the world today. The worldwide incidence of nutritional deficiency diseases indicates the scope of the problem (Fig. 1-1).

IMPORTANCE OF GOOD NUTRITION

Before launching on an intensive study of the individual nutrients, the student of nutrition may legitimately ask, "What evidence is there that nutrition makes a difference?" The United States Department of Agriculture (USDA) has attempted to estimate the costs of malnutrition in the United States. It suggests that appropriate nutrition intervention activities can reduce morbidity and mortality from heart disease by 25%, from respiratory and infectious diseases by 20%, from cancer by 20%, and from diabetes by 50%. The preventable costs attributable to such conditions are estimated at billions of dollars annually. Good nutrition may indeed be one of our most valuable untapped resources.

Over the years several investigators have provided evidence that good nutrition does make a difference. Although a comprehensive review of studies in this area is well beyond the scope of this text, a few examples may serve to illustrate the point.

A change from the use of poorly refined brown rice to more highly refined white rice with its improved keeping qualities occurred in the Philippines and other rice-eating countries around the turn of the century. With this change there was a marked increase in the incidence of the disease beriberi, which first was believed to be caused by a toxic substance in rice and later was attributed to unsanitary milling conditions. By 1935, however, an antiberiberi factor in rice bran had been identified, establishing that beriberi was the result of a lack of a nutrient that was apparently removed in the milling process. This nutrient became known as thiamine. Once this vitamin had been synthesized and was available commercially, the Philippine government and the Williams Waterman Fund backed a study of rice enrichment to determine the effect of adding thiamine back to the rice. People on one half of the island of Bataan ate rice enriched with thiamine, whereas those on the other half ate the unenriched milled white rice. After 9 months 90% of the population on enriched rice who had previously shown mild or definite signs of the disease were improved and the death rate had dropped by two thirds. At the end of the second year there were no deaths at all from beriberi in the enriched-rice group, indicating fairly clearly that the addition of the nutrient brought about a general improvement in the health of the population and a marked decrease in the incidence of beriberi.

In 1946 Burke, working with patients at the Boston Lying-In Hospital at Harvard, studied the relationship between the quality of the diet of the mother during pregnancy and the health of the infant at the time of birth. Of the infants born to mothers whose diet was rated good or excellent, 94% were judged in superior or good physical condition at the time of birth, and only 6% were rated in fair or poor condition. Conversely, when the diet was assessed as poor, only 8% of the infants received a superior or good rating, whereas 92% were judged in fair or poor condition. These observations are illustrated in Fig. 1-2. Since people change food habits slowly even under conditions of high motivation such as pregnancy, the dietary ratings undoubtedly reflected

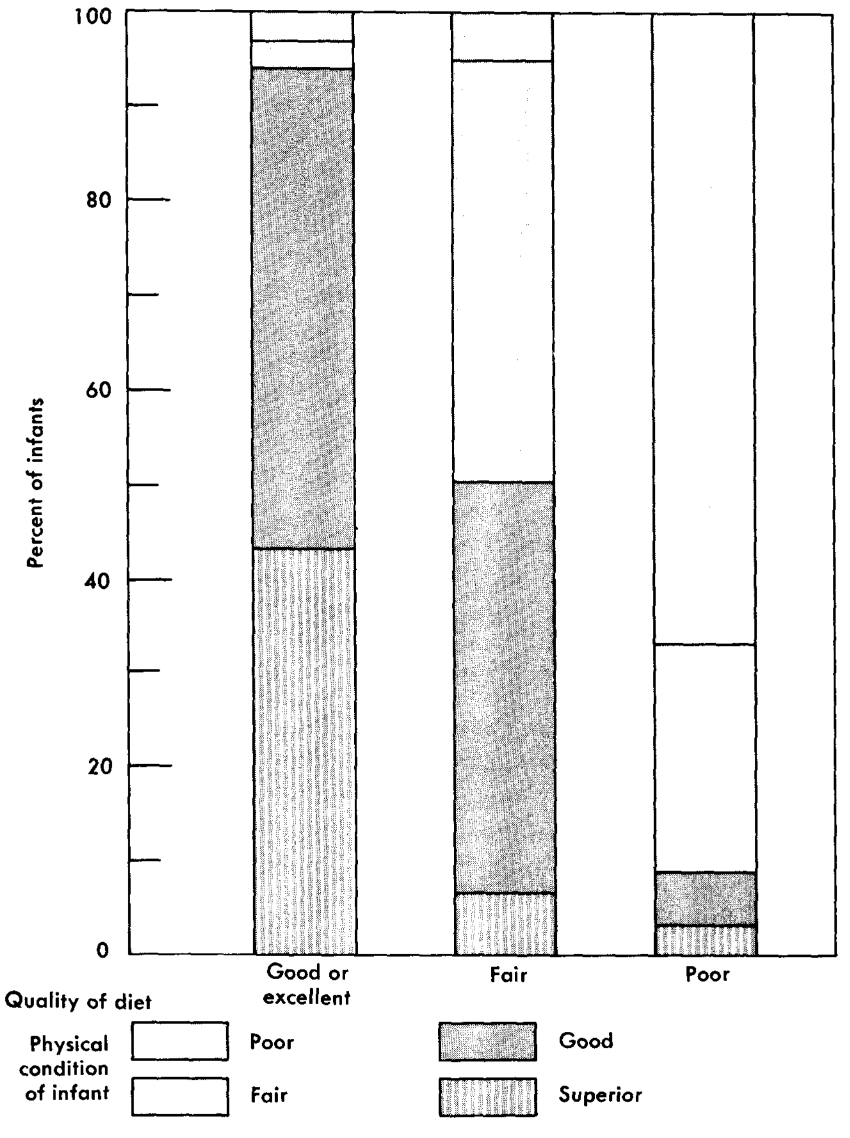

Fig. 1-2. Relationship between quality of mother's diet and condition of infant at birth. (Adapted from Burke, B. S.: J. Nutr. **38**:453, 1949.)

long-standing patterns of eating rather than those that prevailed only during pregnancy. Failure of subsequent studies to show such a clear-cut relationship may reflect an overall improvement of the diet of mothers as our knowledge of nutrition has increased.

The reduction in the incidence of simple goiter experienced in Michigan after an intensive educational campaign on the use of iodized salt is further evidence of the differences between poor and adequate nutrition in respect to one nutrient. In a thirty-year period there was a drop from 47.2% to 1.4% in the reported cases of simple goiter. Similarly, the addition of fluorine to drinking water has resulted in a 50% to 70% reduction in the incidence of tooth decay among children.

In Newfoundland a nutritional survey in 1945 revealed a high incidence of subclinical evidence of nutritional deficiency, such as rough dry skin, cracks in the corner of the lips, and soft bleeding gums. This was attributed to suboptimal intakes of the B vitamins, vitamin A, and ascorbic acid. A program of enriching flour with thiamine, riboflavin, niacin, and iron and enriching margarine with vitamin A resulted in a marked reduction in these conditions.

The change in stature of children in the United States that has occurred in the past few decades has been in part attributed to improved nutrition. There is ample evidence that children are heavier and taller than their parents. For instance, Philadelphia schoolchildren in first through fifth grades in all socioeconomic groups averaged 3 inches taller and 3 pounds heavier in 1951 than in 1925. In 1880, 5% of the male college freshmen were over 6 feet tall, whereas in 1955, 30% reached this stature. Nutrition has undoubtedly contributed to this gain, but one must also keep in mind advances in other areas of medicine that have reduced the incidence of infection and other deterrents to optimal growth at an early age. Adult heights have not shown a comparable increase. The question is now being raised as to how much of these increases in growth rate is desirable. Evidence from animal studies indicates a decrease in life-span among animals fed at a level to stimulate early and rapid growth. On the other hand, women over 5 feet 4 inches tall, possibly the better nourished members of the population, were found to have fewer complications during pregnancy and easier deliveries than did those under 5 feet tall.

HOW THE BODY USES FOOD

Food fulfills many roles for the individual. Its psychological value, its social significance, and its satiety value are more likely determinants of when, how much, and what foods are consumed than are nutritional considerations.

The role of food to which our interests will be directed primarily, however, is that of nourishing the body. Food chosen wisely provides all the nutrients essential for the normal functioning of the body. If food is not properly chosen, there will be a deficiency of one or more of the essential nutrients. An essential nutrient is defined as one that must be provided to the organism by food since it cannot be synthesized by the body at a rate sufficient to meet its needs. Nutrients essential for one species may not be essential for another.

Although we have a rapidly expanding body of information on the biological role of and the need for specific nutrients, the long-established broad classification of the function of nutrients in the body is still valid. The major functions are to supply energy, to promote growth and repair of body tissues, and to regulate body processes.

The nutrients that perform these functions may be divided into six main categories: carbohydrate, lipid, protein, minerals, vitamins, and water. A classification of the essential nutrients in each of these broad groupings follows.

CARBOHYDRATE
- Glucose

FAT OR LIPID
- Linoleic acid

PROTEIN
- Amino acids*
  - Leucine
  - Isoleucine
  - Lysine
  - Methionine
  - Phenylalanine
  - Threonine
  - Trytophan
  - Valine
  - Histidine (for infants)
- Nonessential nitrogen

MINERALS
- Calcium
- Phosphorus
- Sodium
- Potassium
- Sulfur
- Chlorine
- Magnesium
- Iron
- Selenium
- Zinc
- Manganese
- Copper
- Cobalt
- Molybdenum
- Iodine
- Chromium
- Fluorine
- Vanadium
- Tin
- Nickel
- Silicon

*Chemical formulas are shown in Appendix J.

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