Physiology and Pathology of
INFANT NUTRITION

COMPLETELY REVISED SECOND EDITION

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and SUSANNE GLASER, B.A.

This book is intended mainly for the student and the practising physician. It presents a summary of the physiological fundamentals of infant nutrition and discusses natural and artificial infant nutrition based on the extensive experience of the authors. The second half of the book which is devoted to disturbances in the nutritional processes of the infant includes detailed recommendations for diagnosis and treatment.

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Introduction

THE TOPICS of nutrition and nutritional disturbances in infancy seem no longer timely. Through improvement of living conditions of large groups of the population in many countries and through the development of social services and betterment of milk hygiene the problems of artificial infant feeding have found their solution. The constantly decreasing infant morbidity and mortality are the numerical results of this progress. The prevention and treatment of acute and chronic nutritional disturbances has led to the successful raising of artificially fed infants. The improvement of methods in treating acute diarrheal diseases which were developed in the past ten years and the possibility of successfully raising prematurely born infants contributed considerably to this decrease in infant mortality.

This desirable state of affairs has as yet not been attained in all the countries of the world. Economic, cultural and social conditions still hamper development in some places. War, famine, mass migration and concentration of large groups of the population in camps have shown how easily and rapidly seemingly established standards can again be destroyed. Unfavorable hygienic conditions of even short duration suffice to bring back to the health and life of infants all the dangers which seemed to belong to the distant past.

The progress which has been made in the last decades in the field of infant nutrition is to a great extent based on the work of previous generations of pediatricians. It is our intention to point out the connections between the older established fundamentals of pediatrics and the many new developments in this field. Our present field of work has given us ample opportunity to gather experiences in the fields of physiology and pathology of infant nutrition. Not many colleagues in other countries are still given the opportunity to experience the pathology of infant nutrition on such a large scale. It is hoped that they will also be spared this experience in the future.

This guide is intended mainly for the practicing physician and for the student. We thus felt justified in omitting literature references. The reader specially interested in any particular subject will easily find the material in the handbooks of pediatrics.

If this comprehensive presentation will also be found of use to the specialist its purpose will be fulfilled.

L. F. MEYER E. NASSAU

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CHAPTER I

Development of the Healthy Infant

THE BIRTH of a child marks the beginning of a period of growth and maturation which is hardly less spectacular than the development of the fetus from the fertilization of the ovum to the birth of a mature infant. The considerable increase in length and weight, the gain in knowledge and ability, the development of all organs and their functions are signs of rapid progress during this period of life. In none of the later periods of childhood or adulthood do we find a development of organs of an even comparable measure.

In every individual the final result of normal development is a combination of inherited and external factors. External stimuli of any kind in moderate strength cannot influence the path of development characteristic for the individual. With correct care and quantitatively and qualitatively adequate nutrition the development of the "Anlagen" takes place according to growth impulses. External stimuli can change very little and still less improve the results of growth and development which are conditioned by racial and familial factors. However, much can be done to impede, damage or destroy this development.* It must therefore be the task of the physician to protect the growing infant from all harmful influences so as not to disturb the natural development.

* The results of animal experiments, which were confirmed by observations made on women who became pregnant during or shortly following internment in one of the hunger- or concentration camps, showed that malnutrition during the first months of pregnancy results in an increased incidence of malformations in the infants. Malnutrition of the pregnant woman produces the same harmful effect upon the fetus as infections (German measles, chicken pox, grippe, etc.), insufficient oxygen supply of the fetus (caused, e.g., by an anesthetic given to the mother during pregnancy), toxemia etc. On the basis of these experiences we find it possible for the first time to avoid in part the malformations of the fetus which until now appeared to be a result of a defect in the ovum or the sperm.

During the last years some biologists have emphasized that external circumstances are of decisive significance for the pattern of development, while the genes of the gametes are of less importance. These views have so far found recognition only in a few countries, and until convincing evidence in this direction can be presented the opinion that hereditary Anlage of the gametes is the decisive factor for the future development of the child will remain in force. It must be admitted, however, that living conditions, whether good or bad, can alter the developing form. Thus an accelerated development of the child has been widely reported in the course of the last twenty years. Already at the end of the first year of life we find higher figures for weight and height measurements and an earlier onset of teething than were reported some years ago. At the end of the pre-school period we find children now one to one-and-a-half years ahead of the average data reported at earlier times. The accelerated growth is attributed to improved care and nutrition and to increased amounts of light, air and vitamins of which the infant benefits nowadays.

GROWTH

The growth impulse, a hormonal force as yet not definable, stimulates the formation of new protoplasmic tissue. The growth process maintains the living tissues by continuously replacing those which die. Throughout the growth process of the child up to the end of the growth period this force also provides for new formation and changes in the tissues which increase or alter the cell masses and cell forms. At the same time some cell groups cease to function while others are put into the operation of the organism in changed or renewed form. The time of growth is limited in every individual to a certain period of life. In the human being it terminates with the completion of growth at the end of the second decade. However, further differentiation of cells, in a positive or negative sense, and cell multiplication as replacement of destroyed tissues continue throughout life.

Quantitatively and qualitatively adequate nutrition is the necessary basis for any growth process. The new formation of viable, type-specific protoplasm ceases with hunger, as soon as food intake drops below subsistence requirements. Apart from this form of

growth impediment through complete external hunger, the growth of the infant can come to a standstill through partial external hunger, that is, through lack or insufficient intake of a single food component such as proteins, carbohydrates, water, vitamins or even fats. But even if food is offered in adequate amounts and quality, an internal hunger, caused by inadequate utilization of the ingested food, can result in growth impediment. But even in the most severe stages of hunger, whether internal or external, the growth impulse is not destroyed. With a removal of the damaging factors (sufficient food intake, addition of lacking food components, removal of the nutritional disturbances) the body not only compensates for the retarded growth but in many cases surpasses the expected limits in a relatively short time by accelerated growth. The process can be compared to a taut spring suddenly released. The terms potential, latent or dormant growth impulse could be applied to this phenomenon. During the period of arrested growth the formation of new cells in the tissues either stops (cessation of cell division) or cell division continues, although at a reduced rate, with the newly formed cells not reaching normal size, possibly as a result of lack of food (hypoplasia).

The human infant differs from all animals in the rate of growth and in the caloric requirements for this process. This difference from the entire animal world is characterized by the slow development and by the high caloric requirements needed for doubling the initial weight. Thus the time necessary for doubling the birth weight amounts to the following averages:

Rabbits	6 days
Dogs	8 days
Pigs	16 days
Cattle	47 days
Horses	60 days
Human beings	180 days

The total amount of calories needed for doubling the birthweight averages in all animals is about 4000–5000. Only in the human infant this amount is increased to about 28,000 calories. Thus the consumption of milk, the most essential food during the

period in which the weight is doubled, amounts in the human being to 50,000g per 1.5 kg weight gain, in all other mammals, however, to only 3000–10,000g for a similar weight gain. The growth quotient* in animals is around 34.4, in the human infant, however, 5.2.

What has so far been referred to as development is, however, not only a quantitative increase of a more or less complicated substance but an infinitely complex and manifold process of differentiation. There is no better way to illustrate the miracle of infant development than to compare the three stages of development through which the infant passes in the short period of one year: 1) the newborn who, in his complete helplessness, leads an almost vegetative life; 2) the infant at the age of about four to six months who has outgrown the "dumb first quarter of the year" and who, due to the development of his sensory organs, shows considerable interest in his surroundings, and 3) the one-year-old who executes purposeful movements, stands erect, walks and is capable of utilizing his senses, who speaks and understands, knows and recognizes, who can distinguish what is permitted and what is forbidden. This development and progressive differentiation can be divided into several components, some of which are clearly discernible and important for judging the child's health and will be discussed below.

Growth in Weight

Clear evidence of tissue growth is demonstrated in the ascending weight curve. With correct nutrition, adequate in quality and quantity, any weight gain represents increase of living substance. An evaluation of the body weight does not, however, permit any conclusions as to the type and value of newly formed tissue or the composition of the protoplasm in the newly built cells.

The first requirement for the transformation of food into protoplasm and cells is the presence of water in sufficient quantities. Therefore the food of the young, fast growing organism must be particularly rich in water. If measured by weight units the water

* Growth quotient $= \frac{\text{energy consumption for growth}}{\text{energy consumption for metabolism}}$

requirements are particularly large during the time of rapid growth. The percentage of water contained in the entire organism during childhood is higher than in the period after termination of growth.

Water Contents at different ages:

Fetus	97.5%
Newborn up to six months	74%
One year old	68%
Old person	60%

This water, which forms about 70% of the body weight, is found mainly within the cells (40–50%); 15% of the water is located in the interstitial tissues. The amount of water in the blood constitutes not more than 5% of the entire water reserve. These figures are of practical significance for the task of therapeutically replacing lost extracellular or intracellular fluid.

In the healthy child about one half of the water intake is eliminated by the kidneys. The water loss through insensible perspiration (skin, lungs) stands in second place, and only a small percentage of water leaves the body through the bowels (Fig. 1a). There is a close relationship between water loss through urine and through feces: if more water is eliminated through the bowels, as for instance in diarrhea, similar quantities of water are retained by the kidneys. Only if the losses through insensible perspiration are substantial do we find disturbances in this mutual relationship (Fig. 1b). If severe losses of water through lungs and skin coincide with diarrhea complete anuria may occur.

The following table indicates the intake and output of water for infants (*Butler* and *Talbot*):

	Urine	*Stool*	*Insensible Perspiration*	*Total*	*Requirements per kg Body weight*	*Total*
Infants 2–10 kg	200–500 cc	25–40 cc	75–300 cc	300–840 cc	165–100 cc	330–1000 cc

Water intake in adequate amounts has, therefore, a deciding influence on the growth process. A healthy organism eliminates excess amounts of water through the kidneys without difficulties