HUMAN NUTRITION

Formerly The Heinz Handbook of Nutrition

Benjamin T. Burton

Willis R. Foster

Fourth Edition

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FOURTH EDITION

A Textbook of Nutrition in Health and Disease

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Originally published in 1959 as The Heinz Handbook of Nutrition, this is an authoritative and concise textbook that presents up-to-date mainstream scientific and clinical thought on all areas of nutrition, from basic phusiology and biochemistry of food intake, to therapeutic diets, to the psychology of appetite.

NOTICE

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FOREWORD

The first edition of this textbook of human nutrition was published in 1959 under the title *The Heinz Handbook of Nutrition*. It was soon chosen by the Pan American Health Organization for translation into Spanish and distribution in Latin America under the title *Nutricion Humana*. Since then it has also been translated and published in Portuguese and in Arabic to serve a still wider readership. Subsequent American editions were issued under the name *Human Nutrition* in the belief that a title of broader connotation would better serve the classroom, the medical profession, and nutrition scientists.

I feel justified in saying that I am proud that this book which my father, H. J. Heinz II, envisioned and initiated is now in its fourth edition and that it continues to bring reliable and up-to-date scientific information on nutrition in health and disease to its varied readership, be they practitioners or students.

The science of nutrition and its application are worldwide in scope. Solutions to problems of nutrition are vital to long-range improvement of public health and advancement of human welfare and, in our country in particular, to the prevention of disease. I sincerely hope that this textbook will continue to play a productive role in the achievement of these objectives.

H. J. Heinz III

United States Senate
June 1988

PREFACE

The last decades have seen major advances in the field of nutrition and a tremendous growth of its importance in human health and the prevention of disease. Concomitantly, it has become increasingly difficult to contain this growing body of knowledge in one modest volume and still do justice to all of its many diverse facets. To make an orderly and lucid presentation to the reader, the subject matter of this book is organized in five sections as follows: The first part deals with the basic physiology and biochemistry of the human body as it relates to food intake and utilization; the second part presents the various nutrients, their roles in the body, sources, metabolism, physiology, and interrelationships; the third part encompasses human nutritional requirements and nutrition under varying conditions of health, at different ages, and in periods of physiologic stress; the fourth part is devoted to nutrition in disease—the relationship between nutrition and specific diseases and the practical therapeutic and preventive aspects of special diets; the fifth part, Role of Nutrition in Modern Life, presents several essential aspects of nutrition, strongly interwoven with contemporary life and the human condition without which, we felt, this book would be incomplete.

A determined effort was made to have the contents represent the mainstream of accepted contemporary scientific and clinical opinion. Specific literature references were not cited, since we felt that the object of this book is to present concise, up-to-date, and accepted information—not to serve as a key to the existing voluminous literature. Moreover, the knowledge of nutrition and its application in medicine is progressing so rapidly that the reader interested

in a study in depth of a specific topic must use the current literature to keep abreast of all developments. To avoid needless duplication and to correlate better the subject matter, numerous cross-references are made from chapter to chapter.

This new, expanded edition has incorporated major additions of up-to-date developments in the areas of disease prevention, cancer, cardiovascular diseases, calcium, osteoporosis, obesity, anorexia nervosa and bulimia, alcoholism, total parenteral nutrition and food allergy and toxicology.

The fourth edition also introduces a new coauthor—Willis R. Foster—a physician with a background in the basic medical sciences and a strong interest in nutrition, who will lend additional strength and continuity to the undertaking. The last twenty-nine years have seen a heartening acceptance of this book, both in the United States and abroad, where it has been translated into Spanish, Portuguese, and Arabic. We hope that in the years to come this new, considerably enlarged, and revised edition will continue to further nutrition education and its clinical and public health application at home and overseas.

Benjamin T. Burton
Willis R. Foster

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UTILIZATION OF FOODS

CHAPTER 1

THE PHYSIOLOGY OF THE GASTROINTESTINAL TRACT AND DIGESTION

The term *food* embraces those substances which are taken into the body to support growth, maintain body functions, repair or replace tissues, and provide energy. As a rule we regard as foods only substances which enter the body through the alimentary tract, though, strictly speaking, oxygen fits into the definition.

The preliminary steps in the utilization of foods often involve profound physical and chemical changes which are essential to render the nutritive substances digestible and absorbable.

Mastication

In the mouth food undergoes repeated maceration through the grinding and crushing action of the teeth. Simultaneously, the food mass is being moistened and softened by saliva. Saliva acts as a lubricant and thus aids in swallowing; it also serves a chemical function since it contains ptyalin (salivary amylase), a starch-splitting enzyme, which hydrolyzes starch into dextrins and maltose. This action depends on a neutral or alkaline pH and is inhibited by an acid environment; it starts in the mouth and is brought to partial completion in the stomach and small intestine since the masticated food does not remain in the mouth long enough, nor is it alkaline or neutral for very long in the stomach.

In the mouth the moistened and macerated food comes into intimate contact with the end organs for the sense of taste, located in the tongue and palate. If agreeable, the taste sensation (really the result of the combined action of taste and smell) serves as a psychic stimulus for continued food intake. It also serves the important purpose of stimulating the flow of gastric digestive juices.

The three salivary glands are stimulated to produce the carbohydrate-cleaving enzyme amylase by a combination of mechanical, chemical, and psychologic cues. There is no known protein-splitting or lipid-splitting enzyme in saliva, although the tongue and pharyngeal walls do contain lipid-splitting enzymes (lingual lipase and pharyngeal lipase) which facilitate the hydrolysis of triglyceride fats into free fatty acids and mono- and diglycerides. This lipolytic activity is initiated in the throat upon swallowing and continues during passage of the masticated food through the esophagus and stomach.

Deglutition

After mastication has been completed, the food bolus is placed far back upon the tongue, at which point reflex swallowing contractions force the food backward and downward through the pharynx, the common air and food passage, into the upper part of the esophagus. With the initiation of deglutition the individual loses voluntary control over the fate of the ingested food until he or she is ready to expel the unusable portion of the ingesta.

Once the food bolus has reached the upper region of the esophagus, a wave of contraction propels it toward the distal end, where the cardiac sphincter, a circular ring of muscle, guards the entrance to the stomach. This may open to permit immediate entrance to the food or may await the second peristaltic wave to admit food from both waves simultaneously.

The Stomach

Three main divisions of the stomach are recognized: the upper, cardiac portion; the large rounded pouchlike main body, the fundus; and the lower outlet, the pylorus. The fundus serves to store food and is the site where the major portion of gastric juice is secreted and the largest part of gastric digestion occurs. The muscular pyloric region and its sphincter provide the mechanism for manipulation and expulsion of the gastric contents at the proper time. The semisolid food aggregates which enter the stomach accumulate in a somewhat stratified mass. That which entered first spreads out toward the periphery, while that which was swallowed later remains in the center of the mass. This arrangement of the ingesta permits the center of the mass in the fundus to remain alkaline or neutral and to continue salivary digestion for 30 min or more. In the meanwhile, gastric digestion begins in the outer layers. The acid gastric juices are gradually worked into the mass by tonic contractions. Eventually, peristaltic waves which begin at about the middle of the stomach break up the food

aggregates and sweep them toward the duodenum. These contractions vary in depth and strength; their tempo increases as digestion progresses.

The pyloric sphincter is a powerful ring of muscle located at the lower outlet of the stomach. Normally it is quiescent and relaxed, but it contracts strongly when a peristaltic wave approaches it. The sphincter opens after three or four peristaltic waves and permits the chyme, the thoroughly mixed and liquefied acid food mass, to be propelled into the duodenum. Subsequently the sphincter will remain shut until the chyme in the proximal part of the duodenum has changed from an acid to a neutral pH. In addition to resisting untimely gastric evacuation, the pyloric sphincter normally prevents any except minimal duodenal regurgitation.

Ordinarily, portions of the average mixed solid meal remain in the stomach 3 to 4½ h. In contrast to solid foods, liquids seem to take the path of least resistance and remain in the stomach for very brief periods only. Gastric peristaltic contracture is influenced by both the nature of the food and emotional mechanisms. Of the solids, fats display an inhibitory action on gastric motility and evacuation; they pass through the stomach at a slow rate. Proteins traverse the stomach somewhat more rapidly, and carbohydrates pass through it still faster. Hostility, anger, and resentment may result in contractile gastric hyperfunction; fear and depression, on the other hand, may result in gastric hypofunction and hypomotility.

Gastric Digestion

The gastric mucosa secretes hydrochloric acid, mucin, water, and a number of enzymes: (1) pepsin, which digests proteins, (2) rennin, which curdles milk, and (3) gastric lipase, which has a relatively weak lipolytic effect. The normal gastric mucosa also elaborates a substance of protein or polypeptide nature, which facilitates the absorption of vitamin B_{12} (Chap. 11).

The chief digestive action of the stomach is the splitting of proteins. This takes place in an acid medium only, at an optimum pH of 1.5, and is facilitated by the hydrochloric acid secreted by the parietal cells of the gastric mucosa. There are actually seven proteolytic fractions in gastric juice which are inactivated in an alkaline environment and are classified as pepsinogens (pepsin precursors). These fall into two immunologically distinct groups of substances and are stored in several cell types and locations in the stomach mucosa; one of them is stored in granules mainly in the acid-producing cells of the fundus. They release their active enzymes when stomach acid is secreted. The proteolytic action of gastric pepsin is limited and does not go much beyond the formation of proteoses and peptones, relatively large intermediates in the breakdown of protein molecules to their component amino acids (Chap. 7). Because patients with achlorhydria can still digest protein, as can postgastrectomy patients, pepsin is not considered a critical enzyme for the process of digestion.

Rennin splits the principal milk protein casein into soluble paracasein, which forms an insoluble curd in the presence of calcium. In addition to these

changes, the amylolytic action of the salivary enzyme ptyalin continues in the central parts of the food bolus which have not become acidified.

Gastric mucin serves as a mechanical lubricant and emollient and may protect the mucosa against the acid digestive juice through its local buffering effect.

The secretion of gastric juice is stimulated by psychic, nervous, chemical, and mechanical factors. Smelling or tasting food, as well as seeing or thinking about it, may initiate gastric secretion. Conversely, anger, fear, and excitement or repulsive sights and odors tend to inhibit the flow of gastric juice. A direct mechanical stimulation of gastric secretion is caused by the distention of the stomach musculature by the food. Chemical stimulation of the gastric mucosa has a much more pronounced effect; proteoses and peptones, meat extractives and broths evoke a copious secretion. The mechanism for this excitation involves the formation of a hormone, *gastrin*, in the pyloric mucosa in the presence of food and particularly protein breakdown products; gastrin is then absorbed into the bloodstream and carried to the cells of the fundus, where it excites secretion of gastric juice. Acid inhibits gastrin release. Peptides related to gastrin (such as pentagastrin) also stimulate gastric secretion. Histamine is a powerful stimulant and in fact may be the actual mediator of both hormonal (gastrin) and neurotransmitter (acetylcholine) stimulations. Stored in specialized (mast) cells in the mucosa, histamine acts only on the acid-secreting parietal cells via its own (H2) receptors, not responsive to the usual antihistamines. This is the basis of the recent successful uses of specific H2-receptor antagonists in the treatment of peptic ulcer (Chap. 25).

The gastric glands are also subject to humoral control originating in the duodenum. The contact of food or protein-split products with the duodenal mucosa will excite an increased flow of gastric juice. Conversely, gastric secretion is decreased when ingested fats reach the small intestine. The intestinal hormones secretin and cholecystokinin (CCK) inhibit gastrin-stimulated acid secretion, but stimulate pepsin secretion when acting alone. Inhibitors of acid and pepsin secretion include the hormones gastric inhibitory peptide (GIP), vasoactive intestinal peptide (VIP), and glucagon.

A discussion of gastric physiology would be incomplete without mention of the protective action exerted by the highly acid gastric juice in destroying or inhibiting the many and varied microorganisms which accompany normal food intake. The bacteriocidal or bacteriostatic action of the stomach secretions probably constitutes the body's first and major defense against food-borne infection; it also aids in maintaining qualitative stability in the intestinal flora distal to the stomach.

The Small Intestine

The most important digestive processes take place in the small intestine, and most of the end products of digestion are absorbed into the bloodstream here. After passing into the intestine, the chyme is subject to a variety of muscular