TROPICAL NUTRITION

NICHOLLS

SECOND EDITION

BAILLIÈRE TINDALL & COX

TROPICAL NUTRITION AND DIETETICS

By

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PREFACE TO SECOND EDITION

WHEN the first edition of this book was written in 1937 several important vitamins, including nicotinic acid and vitamin K, had not been discovered, consequently the book was in some respects out of date by the time it was published. This is the fate of all books dealing with subjects undergoing rapid development.

It appears fairly certain, however, that all the more important vitamins, sometimes called the *major vitamins*, are now known. They have been isolated or synthesized in pure form ; the effects of deficiencies of them from diets have been widely studied ; some of the parts they play in metabolic processes have been revealed ; and the amounts of them in various foodstuffs have been determined.

Several *minor vitamins* have been discovered in recent years, and doubtless others remain to be discovered. Most of them are of less importance than the major vitamins to the extent that they are very unlikely to be deficient from human diets. It is probable, however, that the absorption of some of them from the alimentary tract, or their metabolic actions within the body may be diminished in certain diseases, or that poisons or bacterial toxins may destroy them or inhibit the physiological processes of them, and these effects would have important therapeutic implications.

Much has also recently been discovered concerning a few minerals which, because they are present in exceedingly minute amounts in foodstuffs, have been called the " trace " elements. The dietary needs in animal nutrition of some of the trace elements have been proved.

The great enlargement of this edition is due to (1) the incorporation of much recent knowledge of the constituents of foodstuffs ; (2) the inclusion of details concerning foodstuffs more or less peculiar to warm climates (Chapters XII and XIII) ; (3) a description of diets suitable for hospitals, prisons and other institutions and for labourers at large ; (4) the increase in size of Chapters XVI and XVII on public health activities in relation to nutrition ; (5) the inclusion of Chapters XVIII and XX on food poisoning and insect pests of grain foods respectively.

The great progress in parasitology and the later discoveries concerning nutrition fall into two great phases which have led, and are leading, to an improvement on the health of the masses in tropical countries. And this must continue with the growing acceptance that all persons have a right to diets adequate for good growth and health, as in another sphere it has long been accepted that all children have a right to primary education.

The lowering of the death rates, especially infantile mortality, is producing such an increase in the numbers of the populations of the tropics that one may wonder what will be the nature of the end of it, for an end there must be.

It is far more desirable that the knowledge and means for better nutrition should lead to an improvement in the quality of the individuals of the masses rather than to a great increase in the density of populations.

L. N.

COLOMBO,
January, 1945.

PREFACE TO FIRST EDITION

THE subject of nutrition has come very much to the fore in temperate climates and is having far-reaching results in respect of the growth of the children and the general health of the public. The great strides made in parasitology in its numerous branches absorbed most attention in Tropical Medicine, and only extreme conditions which arise from various food deficiencies such as beriberi, scurvy, pellagra and keratomalacia received much notice until very recently.

In the last few years much nutritional work has been done in several tropical countries and this has been mainly along two lines: firstly, the study of the less cogent results of dietary deficiencies has brought to light the prevalence of many signs, symptoms, stunted growth and other effects; secondly, attention has been paid to the diets in use among general populations and large numbers of foodstuffs have been chemically analysed and biologically assayed.

The results of these investigations are recorded in many reports and papers.

The object of this book is to give, as shortly as possible, the general principles of nutrition and dietetics and to collect under one cover the salient points of this scattered information.

The book is meant primarily for medical men who work among the masses in the tropics.

L. N.

COLOMBO,
February, 1938.

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“ Where one step broken the great scale’s destroyed
From nature’s chain whatever link you strike,
Tenth or ten thousandth, breaks the chain alike.
And if each system in gradation roll
Alike essential to the amazing whole
The least confusion, but in one, not all
That system only but the whole must fall.”

ALEXANDER POPE

PRINTED IN GREAT BRITAIN

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CHAPTER I

CARBOHYDRATES, FATS AND PROTEINS

A FOOD has been defined as "any substance which when taken into the body can be assimilated into the tissues for the purposes of growth, or the repair of waste, or to produce heat or work." But most diets contain beverages and condiments which cannot be comprehended in any simple definition.

The constituents of all foods are classified into the few categories given in Table I.

TABLE I

1. Carbohydrates 2. Fats	are used mainly as fuel for work or heat.
3. Proteins	nitrogenous substances necessary for building up the body and repair of tissues.
4. Minerals	necessary for growth and all metabolic processes.
5. Vitamins	occur in small quantities and are used for many, if not all, metabolic processes.
6. Beverages and Condiments	render the food more palatable, stimulate the appetite and digestion and have other effects.
7. Indigestible residue	insoluble and indigestible matter gives a necessary bulk to the food.
8. Water.	

Although the greater amounts of carbohydrates and fats are used for the production of work and heat, yet some of them are in combination with the proteins, and in small quantities are needed for the building of the tissues. Again, although proteins are used for the building of the body and the repair of tissues they can also be used as fuel for work and heat, and may be broken up in the body for the formation of carbohydrates and fats. The minerals have many functions and some of them form crystalloid-colloid complexes with the proteins of the blood and tissues. The vitamins have been called "accessory food factors," and they are essential for healthy metabolism.

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CARBOHYDRATES

The carbohydrates comprise the sugars and starches and, being the cheapest sources of energy, constitute the greater part of the food of the populations of the world with the exception of a few pastoral and hunting tribes.

They are divided into three large groups and the names of these are derived from their general chemical formulæ :

$C_6H_{12}O_6$	Monosaccharides
$C_{12}H_{22}O_{11}$	Disaccharides
$(C_6H_{10}O_5)_x$	Polysaccharides

Monosaccharides

These simple sugars are soluble and diffuse through the walls of the alimentary tract without being acted upon by the digestive enzymes. The three commonest are glucose, fructose and galactose, and when they are consumed in larger quantities than are required for the immediate purposes of the body they are built up into the polysaccharide *glycogen*, which is stored in the liver and reconverted into glucose when required for the maintenance of the normal amount of sugar in the blood.

Glucose (*dextrose*, *grape sugar*, *starch sugar*, *corn sugar*) is of great importance in two respects—firstly, it is abundant in many fruits and other vegetable products, where it usually occurs in association with fructose and sucrose ; it may constitute 20 per cent. of the dried substance of grapes, and is present in many roots such as onions, sweet potatoes and yams ; secondly, it is the product of the action of the digestive enzymes on all starches. Glucose is oxidized to carbon dioxide in the production of energy and heat, but the action is not direct, intermediary bodies are formed.

Fructose (*fruit sugar*, *lævulose*) occurs in plant juices. It constitutes about half the sugar in honey. The body can convert it into glucose.

Galactose is formed together with glucose when the digestive enzymes act upon the dissaccharide lactose (milk sugar). The mammary gland forms galactose from glucose and then combines it with more glucose to form lactose. The galactans which occur in many plants are polymeric anhydrides of galactose.

Glucose occurs in the tissues in combination with proteins.

Disaccharides

The disaccharides are changed into monosaccharides during the process of digestion. Three of them are important constituents of foods.

Saccharose (*sucrose, beet sugar, cane sugar*) is the commonest sugar in the markets of the world and is produced in enormous quantities from canes, palm trees, beetroot and maple. It occurs in most plant juices, usually in association with other sugars. Pineapples and carrots are particularly rich in it.

Saccharose rotates the plane of polarized light to the right, but the product of its hydrolysis, an equal quantity of glucose and fructose, rotates the plane to the left, this is because, although glucose is dextrorotatory, fructose is more actively lævorotatory. This inversion gives the name *invert sugar* to the product of the hydrolysis of saccharose.

Lactose constitutes 4 to 5 per cent. of the milk of cows and 6 to 7 per cent. of human milk. It is less soluble and less sweet than market sugar, and less likely to cause digestive disturbances in infants.

Maltose occurs in germinating cereals and the products of them, such as malt. When the digestive enzymes act upon starches maltose is formed as an intermediary product in the formation of glucose.

Polysaccharides

Most of the polysaccharides are insoluble in water, but some form colloidal dispersions which are usually opalescent, and a few form solutions. Those that are available for food are broken up by the digestive enzymes into glucose.

Starch is stored in plants, specially in seeds and tubers, as a source of supply for the future requirements of growth. The dried cereal grains contain from 50 to 80 per cent. of starch. When a small piece of a grain or tuber is broken up in a little water and examined under the microscope it is seen that the starch is stored in dense granules ; if these are heated in water they rupture and the starch is dispersed. This is one of the changes brought about by cooking and enables the digestive enzymes to hydrolyse cooked starch more readily than when it is raw. One of the first actions of digestion is to break down the molecules of starch to less than a fifth of their size, and these products are soluble in water and are known as dextrins.

Glycogen is sometimes called animal starch. It forms an opalescent dispersion in cold water. It occurs in all parts of the body, and although under normal conditions the liver is richest in it, yet there are considerable amounts in the muscles, especially after periods of rest. It is rapidly used up during muscular exercise.

Celluloses. Plants are able to build up hard, resistant and insoluble polysaccharides, and these appear in wood and other structures in the form of fibres which consist mainly of cellulose. Other polysaccharides are of a softer nature and are known as hemicellulose. Some low forms of life are able to digest celluloses, but they have no nutritive value for man. They help to give bulk to the food and appear unchanged in the fæces.

FATS AND LIPOIDS

The fats and lipoids may be defined as substances which are soluble in ether, chloroform or benzene, but insoluble in water, and can be used as food by living organisms. The fats include all edible oils such as olive or coconut oil.

The fats are compounds of glycerol, which is trihydric, and fatty acids, which are monobasic, hence on hydrolysis the fats split up into three molecules of fatty acids and one of glycerol ; for example :

$$\underset{\substack{\text{palmitin}\\\text{(glycerol tripalmitate)}}}{C_3H_5(C_{16}H_{31}O_2)_3} + 3H_2O \rightarrow \underset{\text{glycerol}}{C_3H_5(OH)_3} + \underset{\text{palmitic acid}}{3C_{16}H_{32}O_2}$$

The naturally occurring fats are made up of many triglycerides, but they are not all simple triglycerides in which a glycerol molecule is combined with three molecules of a single fatty acid ; in most cases it is combined with two or three different acids ; for instance, a mixed glyceride having one molecule each of palmitic. stearic and oleic acid combined with one molecule of glycerol would be stearo-oleo-palmitin.

The fatty acids belong to a few homologous series and fall into two categories :

(1) *The Saturated Fatty Acids* have a formula $C_nH_{2n}O_2$, in which the number of hydrogen atoms is twice the number of carbon atoms. Table II gives the more important acids of this series and some of the fats in which they are found as glycerides.

TABLE II

Acids of the Series $C_nH_{2n}O_2$

Butyric acid, $CH_3(CH_2)_2COOH$.	About 6 per cent. in butter.
Caproic acid, $CH_3(CH_2)_4COOH$.	In butter and coconut oil.
Caprylic acid, $CH_3(CH_2)_6COOH$.	In butter, human fat and vegetable oils.
Capric acid, $CH_3(CH_2)_8COOH$.	In butter and coconut oil.
Lauric acid, $CH_3(CH_2)_{10}COOH$.	In butter and all palm oils.
Myristic acid, $CH_3(CH_2)_{12}COOH$.	In most animal and vegetable oils.
Palmitic acid, $CH_3(CH_2)_{14}COOH$.	,, ,, ,, ,,
Stearic acid, $CH_3(CH_2)_{16}COOH$.	,, ,, ,, ,,

The consistency of fats depends upon the molecular weights of their fatty acids. Butyric acid has a low molecular weight and the triglyceride of it is a thin oil, whereas the triglyceride of stearic acid of high molecular weight is a hard solid fat. Under ordinary temperature conditions in the tropics the last three fats of Table II are solid.

(2) *The Unsaturated Fatty Acids* are of several series and have general formulæ $C_nH_{2n-2}O_2$, $C_nH_{2n-4}O_2$, etc., in which the number of hydrogen atoms is less than double the number of carbon atoms.

Oleic acid, $C_{18}H_{34}O_2$, of the first series is the commonest unsaturated fatty acid in animal and vegetable oils. Erucic acid abundant in many vegetable oils also belongs to this series. The glycerides of the acids of the series $C_nH_{2n-4}O_2$, $C_nH_{2n-6}O_2$ and $C_nH_{2n-8}O_2$ are present in many fats. Linoleic acid, $C_{18}H_{32}O_2$, and linolenic, $C_{18}H_{30}O_2$, were first found in linseed oil, and later in butter and other fats. Sesame (gingelly) oil, a common edible oil of the tropics, contains 14 per cent. by weight of linoleic but no linolenic acid. Arachidonic acid, $C_{20}H_{32}O_2$, of the fourth series occurs in brains, liver and egg yolks.

The unsaturated fatty acids can take up iodine (or other halogen) by addition to form saturated compounds. The amount of iodine taken up by a fat is more or less characteristic of that fat, and is known as the *iodine number*, and this number roughly indicates the amount of unsaturated fatty acid in the composition of the fat. The iodine number is the number of grams of iodine which can be taken up by 100 grams of the fat. Table III gives the iodine number of various fats.

TABLE III

Vegetable Oils

Oil	*Iodine number*	*Oil*	*Iodine number*
Linseed	175–205	Olive	79–88
Soya bean	137–141	Palm	20–56
Maize	113–125	Shea butter	56
Cotton seed	108–110	"Margarine"	50
Sesame	103–108	Chinese "tallow"	30
Pea nut	83–110	Coconut	9
Castor	83–86		

Animal Fats

Fish oils	120–195	Lard	60–70
Blubber oils (whale, seal)	100–150	Butter	26–28
Marrow fat	50–80		

Most of the glycerides of the unsaturated fatty acids have much lower melting points than the glycerides of the saturated fatty acids having the same number of carbon atoms.

The fat is firmer in land animals than in those of the sea, which is well illustrated by comparing lard with whale oil.

Soft fats or oils, which are rich in unsaturated fatty acids, can be hardened to a desired consistency by hydrogenation by which they are saturated with hydrogen by the aid of a catalyst, such as powdered nickel. This process has been widely used for the production of *margarine* and lard substitutes from vegetable and whale oils. These sophisticated fats have been used in vast quantities without ill effects arising from them and therefore may be considered wholesome. (Sometimes margarines are reinforced with fat soluble vitamins A and D.)

Human Needs for Fat. Fats are deposited in the subcutaneous tissue as a protection against cold and injury, and in the abdomen as a padding and support of the viscera. Their light, compact and insoluble nature enables the storage of them to take place without the addition of water, and this can occur with no other substance. The fats are composed of the same three elements as the carbohydrates, but they are superior to them as a supply of energy because they have less oxygen in proportion to the carbon and hydrogen, and hence on complete combustion produce more energy. Any normal deposit of fat is a reserve store for the production of heat and work.

It may appear obvious from many common experiences that fats can be synthetized from carbohydrates in the animal body, such as when pigs are fattened for the market by feeding them on grain meals rich in carbohydrates and poor in fats; yet the matter was in dispute until it was settled by carefully planned experiments in which animals were fed on diets containing very little fat, showed that more fat was deposited in the body than was taken in with the diet. Other experiments have shown that carbohydrates contribute to the production of fat in milk.

Although much of the fat in the body may be formed from carbohydrates, yet fat is needed in the diet for several reasons, two of which are clearly understood. Firstly, certain essentials, such as vitamins A, D and E, can be adequately absorbed only when dissolved in fats. Secondly, there are unsaturated fatty acids, essential for healthy nutrition, which cannot be produced from carbohydrates. Burr and Burr,[1] in 1929, were the first to show that rats fed on fat-free diets became ill with staring coats, dermatitis, caudal necrosis and wasting leading to death. Later (1932) [2] they found that it was the unsaturated acids, such as linoleic and linolenic, which were essential. Their work has been amply confirmed. There is some evidence that arachidonic acid is the most important, and it may be that the two acids mentioned above are converted into it within the body. These acids act in very small amounts, one drop (0·1 gm.) of linoleic acid daily is sufficient for the growth and health of a rat. There is some evidence that these unsaturated

[1] *J. Biol. Chem.*, **82**, 345. [2] *Ibid.*, **97**, 1.

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