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Chapter 1

Principles of Healthy Nutrition

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Energy balance

What is energy balance?

Energy balance is the difference between energy intake, which can be metabolised, and total energy expenditure. It could be said that the human body's energy state is balanced when its energy expenditure is equal to its energy intake.

The human body requires energy to perform its many functions, to facilitate muscle activity and developmental demands and to correct problems that may have been caused by disease or injury. Energy needs are met by the energy obtained from the body's diet, which derives from foods either of plant or of animal origin. Food energy is released in the body through the oxidation of carbohydrates, fats, proteins (which are called macronutrients) and alcohol.

If energy intake and expenditure are not equal, the result will be either a positive energy balance, in which body energy stores (and mainly fat) are increased, or a negative energy balance, in which the body falls back on using its energy stores (fat, protein and glycogen). Consequently, the body's energy balance (along with other factors) determines to a large extent its weight and general health status.

What factors influence how much energy the human body requires?

According to the definition given by the World Health Organization (WHO), energy requirement is 'the level of energy intake that will balance energy expenditure when we have a body size and composition, and a level of physical activity consistent with long-term good health'. Energy requirements are influenced by various factors, such as the developmental stage we are in (e.g. children's or adolescents' requirements are different from those of the adults), body size, the amount and intensity of physical activity (athletes and manual workers, for instance, obviously require more energy than people doing clerical work or leading sedentary lives), gender, illness, injury, pregnancy, lactation, etc.

What is the basal metabolic rate?

The basal metabolic rate (BMR) is one of the three components that energy expenditure consists of. It is the amount of energy spent for basal metabolism, which represents voluntary and involuntary vital bodily functions, such as respiration, renal, brain and cardiovascular functions, cell and protein turnover, blood circulation, the maintenance of body temperature, etc.

BMR is commonly extrapolated to 24 hours to be more meaningful, and it is then referred to as ‘basal energy expenditure’ (BEE), expressed as kcal/24 h (kJ/24 h). Resting metabolic rate (RMR), energy expenditure under resting conditions, tends to be somewhat higher (10–20%) than under basal conditions owing to increases in energy expenditure caused by recent food intake (i.e. by the thermic effect of food) or by the delayed effect of recently completed physical activity. Thus, it is important to distinguish between BMR and RMR and between BEE and resting energy expenditure (REE) (RMR extrapolated to 24 hours). BMR is measured under a specific set of circumstances: the subject must be awake, lying comfortably in a supine position, in a state of rest, in a warm room, at least 12 hours after last food ingestion. Since these strict conditions are hard to achieve in hospital settings, energy requirements are usually expressed as RMR. Basal, resting and sleeping energy expenditures are related to body size, being most closely correlated with the size of the fat-free mass (FFM), which is the weight of the body less the weight of its fat mass. The size of the FFM generally explains about 70–80% of the variance in RMR. However, RMR is also affected by age, gender, nutritional state, inherited variations and by differences in the endocrine state, notably (but rarely) by hypo- or hyperthyroidism.

What are the other two components of energy expenditure?

The other two components of energy expenditure are (1) the energy spent on daily activities and physical exercise (which depends on the kind, the intensity and the duration of the physical activity) and (2) the energy spent in response to a variety of thermogenic stimuli (thermogenesis), which include the food we consume, certain drugs, low temperatures, muscle tension, stress and similar psychological states.

What is the thermic effect of food?

It has long been known that food consumption elicits an increase in energy expenditure, a phenomenon known as the ‘thermic effect of food’ (TEF). The intensity and duration of meal-induced TEF is determined primarily by

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the amount and composition of the food consumed, mainly owing to the metabolic costs incurred in handling and storing ingested nutrients. Activation of the sympathetic nervous system, elicited by dietary carbohydrate and by sensory stimulation, causes an additional, but modest, increase in energy expenditure. The increments in energy expenditure during digestion above baseline rates, divided by the energy content of the food consumed, vary from 5 to 10% for carbohydrate, 0 to 5% for fat, and 20 to 30% for protein. The high TEF for protein reflects the relatively high metabolic cost involved in processing the amino acids yielded by the absorption of dietary protein, for protein synthesis or for the synthesis of urea and glucose. In general, consumption of the usual mixture of nutrients is generally considered to elicit increases in energy expenditure equivalent to 10% of the food's energy content.

How is energy expressed?

All forms of energy can be converted to heat and all the energy the body uses is lost as heat. For this reason, the energy that is consumed, stored and spent is expressed as its heat equivalent. The first unit of energy employed in nutrition was the calorie [the amount of energy needed to raise the temperature of 1 gram (g) of water from 14.5 to 15.5°C]. In the context of food and nutrition, the kilocalorie (1000 calories) has been traditionally used. However, in the International System of Units, the basic energy unit is the joule (J), which corresponds to the energy used when a mass of 1 kilogram (kg) is moved through 1 m by a force of 1 newton (N). One J = 0.239 calories, so that 1 kcal is equal to 4.186 kJ.

Carbohydrates and fibre

What are carbohydrates and how are they classified?

Carbohydrates, the most prevalent organic molecules, are a valuable source of energy in the human diet. It is estimated that in Western countries more than 40% of the energy intake in an average diet comes from carbohydrates. In developing countries, this amount is even higher. Therefore, carbohydrates can be seen as an important fuel for all living beings. As their name denotes, they are synthesised from carbon dioxide and water during plant photosynthesis.

Dietary carbohydrates may be classified by molecular size into (1) sugars, which can be further subdivided into monosaccharides and disaccharides, (2) oligosaccharides, which can be further subdivided into malto-oligosaccharides and other oligosaccharides, and (3) polysaccharides, which can be further subdivided into starch and non-starch polysaccharides.

The commonest monosaccharides are glucose and fructose, which occur in fruit and vegetables. The best-known disaccharides (consisting of two sugar units) are lactose (which is found in milk), sucrose (common sugar) and maltose. Oligosaccharides, containing 3–10 sugar units, are often breakdown products of polysaccharides, which contain more than 10 sugar units. Polysaccharides differ from sugars in that they are non-sweet and less soluble in water. Examples of polysaccharides include starch and glycogen, which are the storage forms of carbohydrates in plants and animals, respectively. Finally, sugar alcohols, such as sorbitol and mannitol, are alcohol forms of glucose and fructose, respectively.

According to an older broad categorisation, carbohydrates may also be classed as (1) simple carbohydrates (known as simple sugars), which are chemically made up of one or two sugar units and are digested quickly, and (2) complex carbohydrates (or starches), which are made of three or more linked sugar units and take longer to absorb. The latter lead to a slower and more stable release of glucose in the blood and are considered healthier.

In the 1920s, according to another categorisation, carbohydrates were divided into (1) available ones (digested and absorbed in the small intestine and providing carbohydrates for metabolism) and (2) unavailable ones (carbohydrates passing to the large intestine and offering substrate for intestinal microflora). The latter were later largely replaced with the term ‘dietary fibre’, although the two terms are not entirely synonymous.

What are the main functions of carbohydrates?

As mentioned above, carbohydrates have a very crucial role in our diet as an energy source indispensable for the body, and especially for the tissues of the central nervous system, given the fact that the brain has a limited ability to use other energy sources. Carbohydrate energy content is estimated to be 3.75 kcal/g (15.7 kJ/g). Apart from that, they also serve as a structural element in bacteria, plants and animals. Moreover, they help in vitamin and mineral absorption.

Another well-known function of carbohydrates is to impart sweetness to our food. In addition to that, starch, structural polysaccharides and many oligosaccharides have various other roles. For instance, polydextrose adds texture to certain food items. Thanks to their versatility, carbohydrates are widely used in the food industry, for example as thickeners, stabilisers, emulsifiers, crystallisation inhibitors, gelling agents, etc.

What are the minimum and maximum carbohydrate amounts required by humans?

The minimum intake of dietary carbohydrate which is compatible with life can be extremely low, provided that there is an adequate intake of protein and fat amounts, in order to promote *de novo* synthesis of glucose through the hydrolysis of endogenous or dietary protein or glycerol derived from fat. Generally, it is accepted that the minimum carbohydrate amount we need on a daily basis is 100 g [380 kcal (1590 kJ)]. If this minimum requirement is not covered, the result will be the extensive breakdown of body protein, as well as significant salt and water loss.

A diet low in carbohydrates may also lead to bone mineral loss, hypercholesterolaemia, and mainly in ketogenesis and ketone-body production in the mitochondria of liver cells. Ketogenesis is the natural response of the body to a low-carbohydrate diet, owing to the exhaustion of cellular carbohydrate stores, such as glycogen and energy production through fatty acids.

For this reason, professional associations such as the British and the American Dietetic Association do not recommend low-carbohydrate diets, which usually are especially high in fat and protein. Low-carbohydrate diets restrict caloric intake by reducing the consumption of carbohydrates to 20–60 g per day (typically less than 20% of the recommended daily caloric intake).

The maximum daily amount of glucose tolerated by an average person is about 400 g. Excessive glucose intake may result in hyperglycaemia. It is generally recognised that the high consumption of sugars – and especially sucrose – has adverse effects on health as it is related to dental caries and chronic diseases, such as diabetes mellitus, obesity, heart disease, etc. Therefore, plasma concentrations of glucose must be carefully regulated.

What is the glycaemic index?

The glycaemic index (GI) is a classification proposed to quantify the relative blood glucose response to foods containing carbohydrate. It is defined as the area under the curve for the increase in blood glucose after the ingestion of a set amount of carbohydrate in an individual food (e.g. 50 g) in the two-hour post-ingestion period as compared with ingestion of the same amount of carbohydrate from a reference food (white bread or glucose) tested in the same individual, under the same conditions, using the initial blood glucose concentration as a baseline. The consumption of foods that have a low GI is beneficial for health as it contributes to good glycaemic control and to the reduction of chronic disease risk factors. Carbohydrates with a high GI cause higher insulin secretion; this is why the GI of dietary carbohydrates, along with the insulinaemic response to them, is of utmost importance for diabetes control.

What is the definition of dietary fibre?

The concept of dietary fibre has changed considerably in recent years. It is now recognised that dietary fibre encompasses a much broader range of substances than was acknowledged previously and that it has greater physiological significance than previously thought. There is no generally accepted definition of dietary fibre worldwide. However, there is a consensus that a physiologically based definition is necessary. The most recent definitions of dietary fibre emanate from the American Association of Cereal Chemists, the US Institute of Medicine, the Agence Française de Sécurité Sanitaire des

Aliments, the Codex Alimentarius Commission and the Health Council of The Netherlands. These definitions all take into account the physiological characteristics of dietary fibre, but with a varying emphasis, and are summarised in Table 1.1.

Early chemistry of non-starch polysaccharides extracted different fibre fractions by controlling the pH of solutions; in this context the terms 'soluble' and 'insoluble' fibre evolved. They provided a useful simple categorisation of dietary fibre with different physiological properties, as understood at the time. Historically, soluble fibres principally affected glucose and fat absorption, because many of them were viscous and formed gels in the small intestine (e.g. pectins and ß-glucans). In contrast, types of dietary fibre with a greater influence on bowel function were referred to as 'insoluble' (including cellulose and lignin). It is now apparent that this simple physiological distinction is inappropriate because some insoluble fibres are rapidly fermented and some soluble fibres do not affect glucose and fat absorption. As the terms 'soluble' and 'insoluble' may be misleading, in 1998 the WHO and the Food and Agricultural Organization recommended that they should no longer be used.

In general, dietary fibres consist primarily of carbohydrate polymers (non-starch polysaccharides) that are components of plant cell walls, including cellulose, hemicellulose and pectins, as well as other polysaccharides of plant or algal origin, such as gums and mucilages and oligosaccharides such as inulin. Analogous non-digestible carbohydrates that pass through the small intestine unchanged but are fermented in the large intestine should also be included, for example resistant starch, fructo-oligosaccharides, galacto-oligosaccharides, modified celluloses and synthesised carbohydrate polymers, such as polydextrose. Associated substances, principally lignin, and minor compounds including waxes, cutin, saponins, polyphenols, phytates and phytosterols, are also included, insofar as they are extracted with the polysaccharides and oligosaccharides in various fibre analytical methods. However, with the exception of lignin, these associated substances when isolated could not be described as dietary fibre. Table 1.2 summarises the most common natural sources of various components of dietary fibre.

In what way is dietary fibre beneficial for health?

Although more studies are certainly needed, it has been suggested that an insufficient consumption of dietary fibre contributes to a plethora of chronic disorders such as constipation, diverticulitis, haemorrhoids, appendicitis, varicose veins, diabetes, obesity, cardiovascular disease, cancer of the large bowel and various other cancers.

What are the recommended fibre intakes through the life cycle?

Recommendations for adult dietary fibre intake generally fall in the range of 20–35 g/day. Others have recommended dietary fibre intakes based on energy intake, 10–13 g of dietary fibre per 1000 kcal. Nutrition fact labels use

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Table 1.1 Recent definitions of dietary fibre.

American Association of Cereal Chemists (AACC, 2001)
The edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine, with complete or partial fermentation in the large intestine. Dietary fibre includes polysaccharides, oligosaccharides, lignin and associated plant substances. Dietary fibres promote beneficial physiological effects, including laxation and/or blood cholesterol attenuation and/or blood glucose attenuation.

Dietary Reference Intakes for Energy, Carbohydrates, Fibre, Fat, Protein and Amino Acids (Macronutrients), Institute of Medicine (2002)
Dietary fibre consists of non-digestible carbohydrates and lignin that are intrinsic and intact in plants.
Functional fibre consists of isolated, non-digestible carbohydrates that have beneficial physiological effects in humans.
Total fibre is the sum of dietary fibre and functional fibre.

Agence Française de Sécurité Sanitaire des Aliments (AFSSA, 2002)
Dietary fibre consists of:
- carbohydrate polymers (degree of polymerisation ≥ 3) of plant origin with lignin or other non-carbohydrate components (e.g. polyphenols, waxes, saponins, cutin, phytates, phytosterols) AND
- carbohydrate polymers (degree of polymerisation ≥ 3), processed (by physical, enzymatic or chemical means) or synthetic.

In addition, dietary fibre is neither digested nor absorbed in the small intestine. It has at least one of the following properties:
- stimulates colonic fermentation
- reduces pre-prandial cholesterol levels
- reduces postprandial blood sugar and/or insulin levels.

Codex Alimentarius Commission (CAC, 2006)
Dietary fibre means carbohydrate polymers[a] with a degree of polymerisation not lower than 3, which are neither digested nor absorbed in the small intestine. A degree of polymerisation not lower than 3 is intended to exclude mono- and disaccharides. It is not intended to reflect the average degree of polymerisation of a mixture.
Dietary fibre consists of one or more of:
- edible carbohydrate polymers naturally occurring in the food as consumed
- carbohydrate polymers, which have been obtained from food raw material by physical, enzymatic, or chemical means
- synthetic carbohydrate polymers.

Dietary fibre generally has properties that:
- decrease intestinal transit time and increase stool bulk
- are fermentable by colonic microflora
- reduce blood total and/or low-density lipoprotein cholesterol levels
- reduce postprandial blood glucose and/or insulin levels.

Health Council of the Netherlands (2006)
Dietary fibre is the collective term for substances that are not digested or absorbed in the human small intestine, and which have the chemical structure of carbohydrates, compounds analogous to carbohydrates, and lignin and related substances.

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[a] When from plant origin, dietary fibre may include fractions of lignin and/or other compounds when associated with polysaccharides in plant cell walls. Fractions of lignin and/or other compounds (e.g. proteic fractions, phenolic compounds, waxes, saponins, phytates, cutin, phytosterols) intimately associated with plant polysaccharides are included in the definition of fibre insofar as they are actually associated with the poly- or oligosaccharidic fraction of fibre.

Table 1.2 Natural sources of various components of dietary fibre.

Fibre component	Main food source
Cellulose	Vegetables, woody plants, cereal brans
Hemicellulose	Cereal grains
Lignin	Cereal brans, rice and legume hulls, woody plants
Beta-glucans	Grains (oats, barley, rye, wheat)
Pectins	Fruits, vegetables, legumes, sugar beet, potato
Gums	Legumes, seaweed, micro-organisms (guar, locust bean, carrageenan, xanthan, Arabic gum)
Inulin and oligofructose/ fructo-oligosaccharides	Chicory, Jerusalem artichoke, onions
Oligosaccharides	Human milk, grain legumes
Resistance starches:	
Type 1 (RS1)	Starch that is physically inaccessible (e.g. enclosed within intact cell structures in foods such as leguminous seeds and partly milled cereal grains and seeds).
Type 2 (RS2)	Native starch granules (e.g. in maize rich in amylose, raw potatoes, green bananas).

25 g dietary fibre per day for a 2000 kcal/day (8374 kJ/day) diet or 30 g/day for a 2500 kcal/day (10467 kJ/day) diet as goals for American intake. Attempts have been made to define recommended dietary fibre intakes for children and adolescents. Although based on limited clinical data, the recommendation for children older than 2 years is to increase dietary fibre intake to an amount equal to or greater than their age plus 5 g/day and to achieve intakes of 25–35 g/day after age 20 years. No published studies have defined desirable fibre intakes for infants and children younger than 2 years. Until there is more information about the effects of dietary fibre in the very young, a rational approach would be to introduce a variety of fruits, vegetables and easily digested cereals as solid foods are brought into the diet. Specific recommendations for older people have not been published, although a safe recommendation would encourage intakes of 10–13 g dietary fibre per 1000 kcal (4186 kJ). All recommendations need to recognise the importance of adequate fluid intake, and caution should be used when recommending fibre to those with gastrointestinal diseases, including constipation.

Fats and lipids

What are fats and what are lipids?

Lipids form a broad category comprising fats, oils, waxes and various other compounds like lipoproteins, phospholipids and cholesterol. They are all water-insoluble and very useful for living organisms. Fats are food components insoluble in water that represent a condensed source of energy. From a chemical aspect, they are fatty acids, and from a nutritional aspect, they

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include fatty acids and other lipids, such as phospholipids, sterols, such as cholesterol, and synthetic lipids. One gram of fat provides around 9 kcal (37.7 kJ) of energy.

What are the main functions of fats?

Fats, thanks to their high energy density, are used by the organism as a long-term fuel reserve. Additionally, they act as solvents in the absorption of fat-soluble vitamins and they are the precursors for hormone synthesis, while they also form an integral structural part of cell membranes, in which they play various specific roles (e.g. acting as a pulmonary surfactant, participating in cell signalling, etc.).

In what ways are essential fatty acids important?

Linoleic acid, an omega-6 polyunsaturated fatty acid, and alpha-linolenic acid, an omega-3 polyunsaturated fatty acid, are called 'essential fatty acids' because they are indispensable for our health and they cannot be synthesised by our body, so they have to be obtained through the diet. Linoleic acid is the precursor to arachidonic acid, which is the substrate for eicosanoid production in tissues, is a component of membrane structural lipids and is important in cell signalling pathways. Lack of linoleic acid may lead to various problems, such as skin rash, dermatitis and hair loss. Moreover, lack of alpha-linolenic acid results in adverse clinical symptoms, including neurological abnormalities and poor growth. Clinical and epidemiological studies have addressed the omega-6/omega-3 fatty acid ratio, focusing on the beneficial effects on risk of certain diseases associated with higher intakes of the omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). A linoleic/alpha-linolenic acid ratio of 5:1 to 10:1 has been recommended for adults.

How are dietary fatty acids classified, and which of them are known to be especially beneficial for health?

Dietary fatty acids can be classified into two large categories: saturated (with no double bonds) and unsaturated. The latter are subdivided into monounsaturated fatty acids (MUFA), which have one double bond, and polyunsaturated fatty acids (PUFA), which have more than one double bond. Animal fats tend to be richer in saturated fatty acids compared to vegetable fats.

MUFA are also known as 'omega-9 fatty acids' and the commonest of them is oleic acid. They can be found in olive oil and peanut oil and they are believed to protect against coronary heart disease and some types of cancer. MUFA are a potential fuel source for the body and are critical structural fatty acids for cell membranes and other functions. MUFA are undoubtedly required for many body functions. Nevertheless, MUFA can be biosynthesised from other fuel sources and therefore are not essential in the diet.

PUFA are further divided into the omega-3 family and the omega-6 family, both of which are known to have positive effects on human health. The primary omega-6 PUFA are:

- 18:2 linoleic acid
- 18:3 gamma-linolenic acid
- 20:3 dihomo-gamma-linolenic acid
- 20:4 arachidonic acid
- 22:4 adrenic acid
- 22:5 docosapentaenoic acid.

Sources of omega-6 PUFA are liquid vegetable oils, including soybean oil, corn oil and sunflower oil. Omega-3 PUFA tend to be highly unsaturated with one of the double bonds located at three carbon atoms from the methyl end. This group includes:

- 18:3 alpha-linolenic acid
- 20:5 eicosapentaenoic acid
- 22:5 docosapentaenoic acid
- 22:6 docosahexaenoic acid.

Plant sources of omega-3 PUFA (alpha-linolenic acid) include soybean oil, canola oil, walnuts and flaxseed. Alpha-linolenic acid is the precursor for synthesis of EPA and DHA, which are formed in varying amounts in animal tissues, especially fatty fish (e.g. trout, mackerel, herrings, salmon), but not in plant cells. EPA is the precursor of omega-3 eicosanoids, which have been shown to have beneficial effects in preventing coronary heart disease, arrhythmia and thrombosis, as well as to growth and neural development. Omega-3 fatty acids are considered good both for physical and mental health and to function preventively against heart disease and certain cancers. They also seem to have a beneficial effect on rheumatoid arthritis and atopic dermatitis.

Which fatty acids are considered 'bad' for health?

According to epidemiological and clinical studies, trans fatty acids and to a lesser extent saturated fatty acids (mainly from animal products such as meat and dairy) of the diet are positively associated with coronary heart disease, hypertension and insulin resistance. Dairy fats and meat naturally contain trans fatty acids; however, the majority of dietary trans fatty acids are derived from partially hydrogenated oils. Hydrogenation (a process used to manufacture margarine, for instance) converts PUFA to more saturated fat, thus counteracting the effectiveness of linolenic acid. Bakery foods, shortenings and fried foods, such as potato chips, French fries, etc., are rich in trans fatty acids and their consumption should be avoided.

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What are lipoproteins and what is their function in the human body?

Lipoproteins are specialised compounds whose function is to transport through blood circulation lipids to tissues where they are needed. They consist of triacylglycerols and cholesterol esters, phospholipids and free cholesterol, as well as specific proteins, called 'apoproteins', which are important for lipoprotein structure, solubility and metabolism.

Lipoprotein density depends on their lipid/protein ratio. According to the density then, lipoproteins can be divided into four classes: (1) chylomicrons, (2) very low-density lipoproteins (VLDL), (3) low-density lipoproteins (LDL) and high-density lipoproteins (HDL).

Chylomicrons, which are low-density particles formed in the gut, transport dietary lipids to the liver and elsewhere in the body. In the liver, chylomicrons are converted into VLDL, which are the least dense lipoproteins. VLDL and LDL, which are derived from VLDL metabolism, transport fat to the cells. LDL and HDL are responsible for cholesterol transport. LDL transport cholesterol to the cells, while HDL remove excess cholesterol from the cells and carry it back to the liver for breakdown and elimination (reverse cholesterol transport).

A chief dietary goal for arteriosclerotic cardiovascular disease prevention is the reduction of LDL and the increase of HDL. It has been found that a high proportion of individuals who have a myocardial infarction have low HDL.

What is cholesterol and what is its main role in the human body?

Although it is often classified as a lipid, cholesterol belongs in effect to the class of sterols and consists of carbon, hydrogen and oxygen bound in ring structures. It has a vital role as a precursor for the synthesis of bile acids, vitamin D and the steroid hormones, including cortisol, aldosterone and sex hormones. It also has a central role in cell membrane synthesis.

Cholesterol is very susceptible to oxidation. Oxidised cholesterol is involved in the lesions that are responsible for atherosclerosis; therefore, it is implicated in the pathogenesis of heart disease. The main dietary sources of cholesterol are foods of animal origin like eggs, meat and dairy products, as well as certain sea foods, such as lobster, shrimps, etc.

What is the dietary allowance for fat and to what extent should different types of fatty acids be consumed?

Fat provides more calories per gram than any other nutrient [i.e. 9 kcal/g (37.7 kJ/g)] and its addition to food or diet increases their energy density. According to the dietary reference value (DRV) for fat intake, saturated fatty acid (SFA) should provide an average of 10% of total daily energy intake, MUFA (predominately oleic acid) should contribute 12% of total daily energy intake for the population, while the intake for PUFA should not exceed 10%

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of total daily energy intake. In particular, the intake of linoleic acid (omega-6 PUFA) should provide 1% of total energy intake and the intake of linolenic acid (omega-3 PUFA) should provide at least 0.2% of total energy intake. Trans fatty acids on the other hand should not exceed 5 g/day or 2% of total daily energy intake. In conclusion, total fatty acid intake should contribute an average of 30% of total energy intake. Total fat intake, calculated by summing up the percentages of SFA, PUFA, MUFA, trans fatty acids and glycerol, should contribute up to 33% of total energy intake including alcohol or 35% of total energy intake derived from food.

According to the *Dietary Guidelines for Americans* produced by the US Department of Health and Human Services, fat intake should not exceed 35%, as higher intakes usually increase the risk of overweight and obesity and should not be less than 20% of total energy intake, as in this case there is a risk of inadequate intakes of essential fatty acids and fat-soluble vitamins and the risk of an adverse effect on high-density lipoprotein cholesterol (HDLC). Therefore, according to the *Guidelines*, total fat intake should be kept between 20 and 35% of total energy intake, mainly from MUFA and PUFA. SFA should not exceed 10% of total energy intake, dietary cholesterol should be limited to 300 mg/day and consumption of trans fatty acids should be as low as possible.

Proteins and amino acids

What are proteins and what are their main functions?

Proteins are the most complex macronutrients and the chemical building blocks composing our body. Their name derives from the Greek term *proteus*, which represents their high importance. They consist of one or more linear chains of amino acids. The size, shape and length of proteins depend on these amino acids and their interactions. In our body, there are 30,000–50,000 different proteins that are broken down and replaced at various rates (protein turnover).

Proteins are essential for life processes, as they are involved in acid–base balance, fluid regulation, immunity, growth, differentiation, gene expression, metabolism and many other functions. They also provide 4 kcal/g (16.7 kJ/g) of energy.

What are the best dietary sources of proteins?

The quality of proteins depends on the essential amino acids they consist of, as well as their digestibility, their absorptive capacity and their biological value. Proteins from animals, such as milk, eggs, meat and fish, are considered to be of higher quality than proteins derived from plant sources (e.g. legumes, grains and vegetables), because the latter lack various essential amino acids. Vegetarian diets are based on the principle of protein complementation,

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namely the consumption of plant protein sources complementing one another, for instance vegetables and legumes or bread and peanut butter.

What is the current recommended daily protein intake and what factors influence protein requirements?

The currently recommended daily protein intake is 0.8 g/kg (0.37 g/lb) body weight for adult men and women. Protein requirements are influenced by many factors, including growth, the need to replace losses and the need to respond to environmental stimuli.

Protein deficiency seldom occurs independently; more often than not, it occurs along with energy and macronutrient deficiency because of inadequate food intake. Protein energy malnutrition is the commonest type of malnutrition in developing countries. Another condition caused by the insufficient intake of proteins, calories and nutrients is marasmus, the main symptoms of which are muscle-wasting, depletion of fat, reduced growth, abnormal liver enlargement and skin problems. If protein deficiency is serious and lasts too long, it makes patients vulnerable to diseases and may even result in death.

What are amino acids and what are their functions?

Amino acids are the organic compounds that the proteins are made of. There are numerous amino acids, but only twenty of them can be found in proteins in the human body. Amino acids function as substrates for protein and nucleic acid synthesis, and are involved in protein turnover and enzyme activity regulation, nitrogen transport, oxidation-reduction reaction, etc.

How are amino acids classified?

Amino acids can be classified into essential, non-essential and conditionally essential amino acids. According to another nutritional classification amino acids are categorised into two groups: indispensable (essential) and dispensable (non-essential). The nine indispensable amino acids (Table 1.3) are those that have carbon skeletons that cannot be synthesised to meet the body's needs from simpler molecules in animals, and therefore must be provided in the diet. Dispensable amino acids can be further divided into two classes: truly dispensable and conditionally indispensable. Five of the amino acids are termed dispensable as they can be synthesised in the body from either other amino acids or other complex nitrogenous metabolites. In addition, six other amino acids, including cysteine and tyrosine, are conditionally indispensable as they are synthesised from other amino acids or their synthesis is limited under special pathophysiological conditions. This is even more of an issue in the neonate, where it has been suggested that only alanine, aspartate,

Table 1.3 Indispensable, dispensable and conditionally indispensable amino acids in the human diet.

Indispensable	Dispensable	Conditionally indispensable[a]	Precursors of conditionally indispensable
Histidine[b]	Alanine	Arginine	Glutamine/glutamate, aspartate
Isoleucine	Aspartic acid	Cysteine	Methionine, serine
Leucine	Asparagine	Glutamine	Glutamic acid/ammonia
Lysine	Glutamic acid	Glycine	Serine, choline
Methionine	Serine	Proline	Glutamate
Phenylalanine		Tyrosine	Phenylalanine
Threonine			
Tryptophan			
Valine			

[a] Conditionally indispensable is defined as requiring a dietary source when endogenous synthesis cannot meet metabolic need.
[b] Although histidine is considered indispensable, unlike the other eight indispensable amino acids, it does not fulfil the criteria used in this report of reducing protein deposition and inducing negative nitrogen balance promptly upon removal from the diet.
Source: Laidlaw SA, Kopple JD (1987) Newer concepts of the indispensable amino acids. *American Journal of Clinical Nutrition*. **46**(4): 593–605.

glutamate, serine and probably asparagine are truly dispensable. The term 'conditionally indispensable' recognises the fact that under most normal conditions the body can synthesise these amino acids to meet metabolic needs. However, there may be certain physiological circumstances: prematurity in the young infant, where there is an inadequate rate at which cysteine can be produced from methionine; the newborn, where enzymes that are involved in quite complex synthetic pathways may be present in inadequate amounts, as in the case of arginine, which results in a dietary requirement for this amino acid; or pathological states, such as severe catabolic stress in an adult, where the limited tissue capacity to produce glutamine to meet increased needs and to balance increased catabolic rates makes a dietary source of these amino acids required to achieve body nitrogen homeostasis. The small intestine's cells become important sites of the synthesis of conditionally indispensable amino acid and hence some amino acids (e.g. glutamine and arginine) become nutritionally indispensable under circumstances of intestinal metabolic dysfunction. However, the quantitative requirement levels for conditionally indispensable amino acids have not been determined and these, presumably, vary greatly according to the specific condition.

Amino acids can also be classified according to their structure into aromatic amino acids, which are precursors of neurotransmitters such as dopamine, epinephrine and serotonin, and branched-chain amino acids, which are selectively taken up by muscle cells rather than the liver. The former include phenylalanine, tryptophan and occasionally histidine, while the latter include isoleucine, leucine and valine.

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Vitamins

What are vitamins and how are they classified?

Vitamins are micronutrients necessary for the maintenance of normal metabolic functions and blood cell formation. They are not synthesised in adequate amounts in the human body, so they have to be obtained through the diet, as vitamin deficiencies may lead to various dysfunctions.

Vitamins include 13 different organic molecules, which, despite their structural and functional heterogeneity, may be classified into two main categories, as seen in Table 1.4.

Water-soluble vitamins are rapidly depleted and must be regularly replenished, while fat-soluble (lipid-soluble) vitamins are better stored in the body. Vitamins can also be divided into natural and synthetic ones. Their action and kinetics are similar.

Can vitamins become harmful to health?

Many vitamins can have serious side effects or even prove to be toxic if taken in excess; this is why megadoses must be avoided. This applies especially to the fat-soluble vitamins, as they can accumulate in the body, reaching potentially dangerous levels.

Vitamin A and D toxicity syndromes are well documented, while vitamin K may also be toxic in water-soluble form. Some examples of well-known side effects due to vitamin excess are:

- headaches (vitamin A)
- vomiting (vitamins A and D)
- nausea (vitamins D, C, nicotinamide, vitamin B_6)
- spontaneous abortions and birth defects (vitamin A)
- diarrhoea (vitamin C, pantothenic acid, choline, carnitine)
- haemolytic anaemia and kernicterus (vitamin K)
- hepatomegaly (vitamin A, niacin).

Table 1.4 Vitamin classifications.

Water-soluble vitamins	Fat-soluble vitamins
B-complex vitamins	
Thiamin (B_1)	Vitamin A
Riboflavin (B_2)	Vitamin D
Niacin (B_3)	Vitamin E
Pantothenic acid (B_5)	Vitamin K
Pyridoxine (B_6)	
Biotin	
Cobalamin (B_{12})	
Folic acid	
Ascorbic acid (C)	

Which groups of people are at greatest risk of vitamin deficiency?

Although it is preferable to follow a balanced diet that covers all the vitamin needs of the body, vitamin supplements are sometimes indicated for groups of people that may be at risk of developing certain deficiencies. Eligible candidates for vitamin supplementation may be:

- the very young, and especially premature infants
- pregnant women
- the very old
- some categories of people suffering from chronic diseases, and especially chronically undernourished patients and chronic alcoholics, who commonly develop thiamin deficiency
- injured people, given the fact that vitamins (and especially ascorbic acid) play a role in wound healing
- strict vegetarians (vegans), who may be at increased risk of developing specific vitamin deficiencies.

The importance of vitamins for health is widely publicised today, and certain vitamins (beta-carotene, vitamin E and vitamin C) are believed to be involved in the prevention of oxidative damage caused by free radicals; therefore, they have been linked to the potential prevention of cancer, atherosclerosis and heart disease. For this reason, many people, especially in Western societies, choose to supplement their diets with vitamins that they strongly believe are good for their health. It must be stressed, however, that since the antioxidant action of the above mentioned vitamins has not been fully elucidated yet and more studies are evidently needed, vitamin supplements ideally should be taken on prescription and only after careful evaluation of each individual's nutritional status. In addition, patients should be warned of the dangers of the excessive intake of vitamins, and especially vitamins A, D, E and K.

Which foods are good sources of vitamin?

Most water-soluble vitamins are generally found in the same groups of foods, namely whole grains, leafy vegetables, legumes, meat and dairy products.

Food sources of vitamin C (ascorbic acid) are fresh fruit (and especially citrus fruit) and vegetables. Vitamin B_{12} is synthesised by micro-organisms and then becomes incorporated in animal tissues. This is why vegans, who avoid animal products altogether, are at risk of developing B_{12} deficiency.

As for the food sources of fat-soluble vitamins, they generally include leafy vegetables, seed oils, meat and full-fat dairy products.

More specifically, as far as vitamin A is concerned, it should be noted that the term includes both retinol and provitamin A carotenoids. Liver, fortified margarine and full-fat milk products are good dietary sources of retinol and bright orange fruits and vegetables (e.g. carrots, pumpkins, sweet potatoes, apricots) and dark-green vegetables (e.g. peppers, spinach, broccoli) are the best sources of carotenes.

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The dietary sources of vitamin D, which are not as important as its endogenous synthesis on the skin by the sunlight, however, are oily fish, eggs, liver, full-fat dairy products and fortified milk.

Oily fish and green leafy vegetables are also rich in vitamin E. Other good sources of vitamin E are seeds, vegetable oils and beans.

The main food sources of vitamin K are nuts and seeds, as well as nut oils and seed oils.

Minerals and trace elements

What are minerals and trace elements?

Minerals and trace elements are required in only small or even trace quantities, but are nonetheless essential for normal bodily function. They exhibit a variety of roles and are often necessary for tissue structure, enzyme system function, fluid balance, cellular function and neurotransmission. The elements that are required in milligram quantities (sometimes several hundred milligrams) are called 'minerals'; those required in microgram quantities are known as 'trace elements'. Table 1.5 summarises the minerals and trace elements that are known to be essential for humans and Table 1.6 presents the reference nutrient intakes (RNIs) for adults, for some selected minerals and trace elements.

What role does calcium play in human health?

Calcium is the most abundant inorganic chemical in the human body – it accounts for 1.5–2% of our body weight – and is the main mineral of bones and teeth (approximately 90% of the calcium present in the human body can be found in bones and teeth). Bone calcium content changes with age, body size and body composition. Calcium is necessary for the regulation of neural

Table 1.5 Trace elements present in the human body.

Essential	Potentially essential
Chromium (Cr)	Aluminium (Al)
Cobalt (Co)	Arsenic (As)
Copper (Cu)	Boron (B)
Fluoride (F)	Cadmium (Cd)
Iodine (I)	Nickel (Ni)
Iron (Fe)	Silicon (Si)
Manganese (Mn)	Vanadium (V)
Molybdenum (Mo)	
Selenium (Se)	
Zinc (Zn)	

Table 1.6 Mineral RNIs for adults.

Age	Calcium mg/d	Phosphorus mg/d	Magnesium mg/d	Sodium mg/d	Potassium mg/d	Chloride mg/d	Iron mg/d	Copper mg/d	Selenium μg/d	Iodine μg/d
Males										
19–50 years	700	550	300	1600	3500	2500	8.7	1.2	75	140
50+ years	700	550	300	1600	3500	2500	8.7	1.2	75	140
Females										
19–50 years	700	550	270	1600	3500	2500	14.8	1.2	60	140
50+ years	700	550	270	1600	3500	2500	8.7	1.2	60	140

and muscular functions, the good hormonal functioning of the body, normal blood coagulation, effective digestion, etc.

The RNI for calcium is 400–1200 mg. Women's needs are higher than men's are, especially during lactation. Calcium supplements may be needed for the prevention of osteoporosis, a condition especially prevalent among older women.

Foods rich in calcium are milk and dairy products, cruciferous vegetables (e.g. broccoli, cauliflower, Brussels sprouts), mineral waters, almonds and legumes.

What is the role of phosphorus in the human body?

Phosphorus is the second most abundant inorganic compound in the body after calcium. Most of the total phosphorus present in our body can be found in the bones, along with calcium. Phosphorus also plays an important role in carbohydrate, lipid and protein metabolism.

The RNI for phosphorus intake is 550 mg. Phosphorus-rich food sources are milk, meat, poultry, fish, nuts and cereals.

How important is sodium for our health?

Sodium, along with potassium and chloride, is involved in body fluid osmolarity and plays the most decisive role in determining extracellular osmolarity. It is necessary for the good functioning of the nervous system and the muscles.

Our daily physiological requirements are small and equal to 69–460 mg/day, while the RNI for sodium for adults is 1600 mg/day (70 mmol/d) (6 g/day of salt or 2.4 g/day of sodium). These requirements can be covered from the foods we consume, without the addition of extra salt (sodium chloride), which has been associated with hypertension, renal problems, etc.

Why is iron essential?

Iron has multiple biochemical roles in the human body. It is necessary for the production of red blood cells and haemoglobin. As the major component of haemoglobin, it is necessary for the transport of oxygen to cells throughout the body. Iron also reinforces the defensive mechanisms of the body against illnesses.

The depletion of the body's iron stores leads to disorders. The most important of these is iron-deficiency anaemia, which is the commonest nutritional deficiency syndrome in the world. Consequently, our diet must contain adequate amounts of iron-containing foods, such as liver, meat, poultry, shellfish, eggs, fish, apricots, lentils, beans, etc. The RNI for men is 8.7 mg daily, while for women it is 14.8 mg daily. Daily requirements are higher during the early developmental stages, pregnancy and lactation.

It must be noted, however, that excess iron, which can be accumulated under certain conditions, is harmful as well, as it can be toxic to cells and tissues. Two pathological conditions associated with iron overload are haemosiderosis, in which too much iron is deposited in the tissues, and haemochromatosis, a rather rare, genetically predetermined disease.

Why do we need zinc and what are our daily requirements?

Zinc is necessary for a broad range of biochemical processes that are important for growth and development and zinc deficiency results in poor healing and growth retardation. The RNI for zinc is 9.5 mg for men and 7.0 mg for women daily. Its best dietary sources are whole grains, nuts, meat, fish and poultry.

What is iodine useful for?

Iodine is considered essential because it is a constituent of hormones thyroxin and triiodothyronine, which are necessary for normal physical and mental growth (i.e. maintenance of metabolic rate, thermoregulation, protein synthesis, connective tissue integrity). Its best dietary source is fish and seafood. The RNI for iodine is 140 μg daily, with no increment during lactation and pregnancy.

What is the role of chromium?

Chromium has been considered an essential trace element for the last two decades, since it was found that it is important for glucose regulation. It seems that as an insulin cofactor it contributes to insulin binding to the cell membrane, while it is also involved in maintaining normal blood glucose levels and in triglyceride level regulation. The estimated safe and adequate daily intake of chromium is 120 μg or 0.5 μmol/day for adults and 0.1 and 1.0 μg/kg/day (2 and 19 nmol/kg/day) for children and adolescents respectively. Doses larger than 200 μg are toxic and may cause concentration problems and fainting. The best chromium food sources are yeast, liver, potatoes, bran, seafood, meat and poultry.

Is fluoride essential?

Fluoride is valuable for healthy bones and teeth and it has been shown to prevent dental caries. There is little evidence that there is any physiological requirement for fluoride and therefore no RNIs have been set; however, it has been suggested that the continuous fluoridation of water supplies to achieve levels of 1 ppm (parts per million) is generally recommended. Water, therefore, is the best source of fluoride, although its content may vary from

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one area to another. Fluoride is also found in several foods, which provide about 25% of total intake. Fluoride is considered as semi-essential since, although no physiological requirement can be shown to exist, it has known beneficial effects.

Food models

What are the food models and which are the most widely used?

Food guide models are mainly teaching instruments that can be used in order to educate the general population on healthy eating and to visualise the frequency of consumption of the different food groups. They are most frequently in the form of a pyramid or a plate and are divided into sections, according to the number of food groups (e.g. fruits, cereals, fats, vegetables). The size of every section represents the frequency of food or food group consumption; although in some of the food models there are certain numeric suggestions for food consumption and for portions. In some of these models, there are suggestions for exercise, fluid consumption and alcohol.

What is the Food Guide Pyramid and how can it be used?

The Food Guide Pyramid is a practical graphic developed by the US Department of Agriculture (USDA) in 1992. It was designed to serve as a teaching instrument to offer guidance to the public concerning food choice and portion size. It divides foods into five main groups and gives the number of recommended servings for each. It is organised to facilitate the interpretation of the given information by non-experts: at the base of the pyramid we can find foods that are considered to form the basis of the diet and as we move upwards we come across groups of foods that we should consume less of, until we reach the pyramid top, where we can find foods to be used only sparingly (Table 1.7). The Food Guide Pyramid has not been revised so far, so it is officially still valid, although it no longer agrees with the *Dietary Guidelines for Americans* (Figure 1.1), which have changed already twice since the creation of the pyramid.

Concerns have been raised about the base of the pyramid, which recommends too many carbohydrates without any reference to the differences between good (complex) carbohydrates versus refined ones and sugars. In view of new scientific data, many experts also criticise the pyramid's message to avoid fat.

What is the Balance of Good Health plate?

The Balance of Good Health plate was the food model suggested and most widely used in UK, which showed the types and proportions of foods needed

Table 1.7 The Food Guide Pyramid: the main sections, the food groups and the suggested servings of the pyramid.

Fats, Oils and Sweets Use sparingly	**Vegetable Group** 3–5 servings
Milk, Yogurt and Cheese Group 2–3 servings	**Fruit Group** 2–4 servings
Meat, Poultry, Fish, Dry Beans, Eggs and Nuts Group 2–3 servings	**Bread, Cereal, Rice and Pasta Group** 6–11 servings

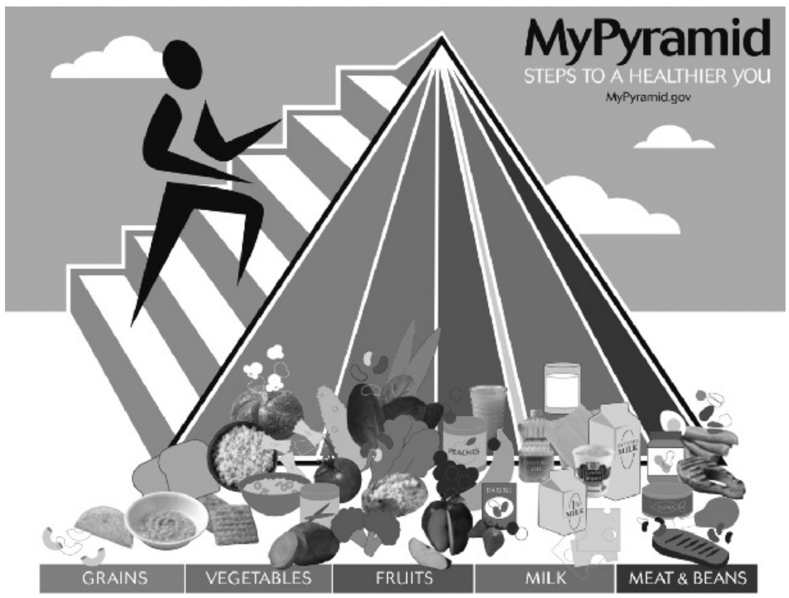

Figure 1.1 The Food Guide Pyramid. (*Source*: United States Department of Agriculture.)

for the balanced diet in a plate, in order to be more comprehensible. The Balance of Good Health plate (Figure 1.2) or the Eatwell Plate (Figure 1.3), which consists of the most recently revised version of the original Balance of Good Health plate, still represent a more pictorial way to express, in a more practical mode, the dietary recommendations for a healthy diet, for the general population.

Are there any other food models available?

There are numerous other pyramids, such as the Mediterranean Diet Pyramid (Figure 1.4), the Soul Food Pyramid, the vegetarian pyramid and many ethnic ones. A pyramid that does not limit guidance only to food choices and quantities is Willett's Healthy Eating Pyramid, a pyramid that gives emphasis

Figure 1.2 The Balance of Good Health plate. © Crown Copyright

to daily physical exercise and weight control, along with abundant consumption of whole grains, vegetables and plant oils. Most of these healthy diet models advise consuming plenty of fruit and vegetables and cutting down on sugar products and refined carbohydrates.

People should generally be encouraged to eat a balanced diet consisting of reasonable choices of all macronutrients, including fats and healthy

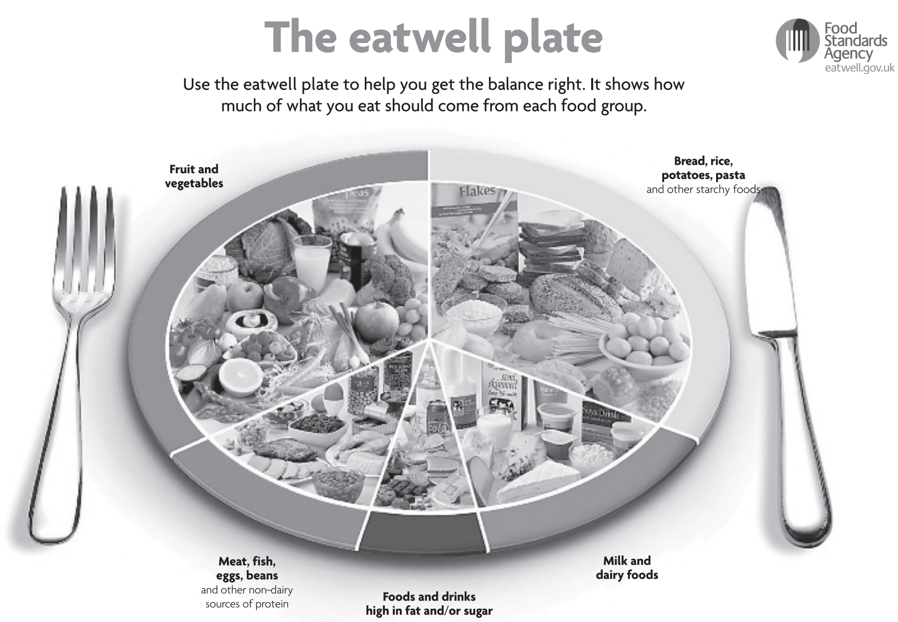

Figure 1.3 The Eatwell Plate. © Crown Copyright

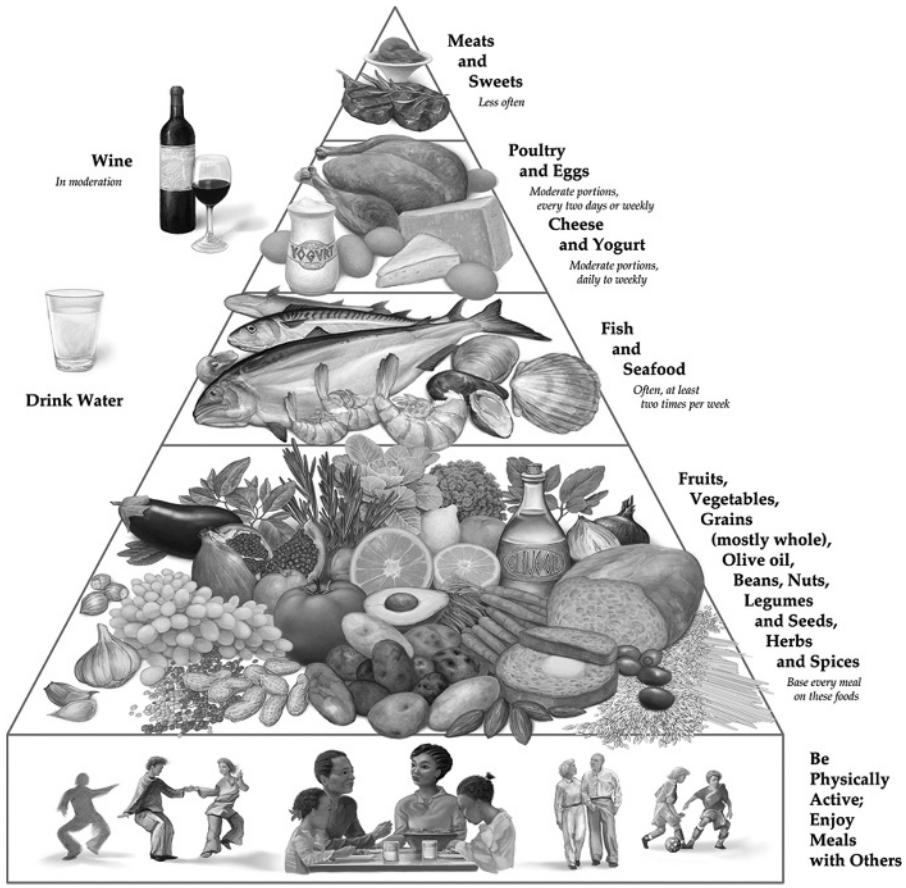

Figure 1.4 The Mediterranean Diet Pyramid. Reproduced with permission. © 2009 Oldways Preservation & Exchange Trust (www.oldwayspt.org). Illustration by George Middleton.

carbohydrates, to maintain a normal body weight and to make physical activity an integral part of their everyday life.

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