Principles of human nutrition

Michael EJ Lean

Abstract

We rely on the foods we eat to provide all the building blocks for metabolism, tissue growth and reproduction, the energy required for all functions and activities, and the 'essential' compounds that cannot be synthesized by humans. Nutritional science covers all the processes involved in achieving a healthy balance between requirements and the supply of nutrients, at the right time and in appropriate proportions, at cellular, organ, whole body and group/population levels. Nutritional status (what we eat, what we are, what we can do) should be assessed in all patients, through awareness, simple screening, and detailed evaluation when appropriate. Nutrition is only occasionally a sole cause or treatment of disease, but is frequently an important contributor to disease aetiology and management. It is commonly affected by illness and by treatments.

Keywords Food; growth development; nutritional status

Foods, nutrients and health

Taken to the simplest level, under evolutionary pressures a species has relatively few absolute requirements. Its individuals must grow to sufficient size, but not too big, to survive and function long enough to reproduce and raise the next generation into independence. A species is then likely to be successful if individuals are not damagingly stressed, and enjoy well-being.

As animals, we are not able to extract energy for activity and function out of sunlight, so we rely on both the building blocks and synthetic energy from ingested material. It is thus evident that foods, through the nutrients they contain, are vital to enable every function of which we are genetically capable — physical, mental, and social. Food is necessary for growth, tissue maintenance and repair, and of course reproduction. Inherent in this is the concept of 'health', of optimizing our capacity for physical, mental, social and genomic functions, and the absence of disease. Nutritional science covers all the processes involved in achieving a healthy balance between requirements and the supply of nutrients, at the right time and in appropriate proportions, at cellular, organ, whole body and group/population levels. It considers a range of factors that influence the digestion, absorption, metabolic transformation and functions. Food is at the core of nutrition. Health is essential for the normal growth and development of individuals, for current health and for future health (including the future adult health of fetus and child). It is a critical element in the social health of communities as well as the health (at cellular, organ and whole-person levels) of the individuals within them.

All foods, whether from animal, vegetable or mixed sources, ultimately derive from sunlight and photosynthesis to build larger molecules from CO_2 and H_2O, plus nitrogen and trace elements extracted from air, soils and water sources. This is the work of plants. Animals are obligatorily dependent on plants for nutrition, although many animals take short-cuts by consuming ready-made animal material. Foods are almost exclusively composites of many compounds that contribute to function and metabolism, known as 'nutrients'. Purified sucrose, used as table sugar, is the only food that is a single nutrient (a carbohydrate). There are otherwise no 'protein-foods' or 'carbohydrate-foods', and most fats or oils also contain small amounts of other nutrients. Small amounts are often important in nutrition.

Foods are most often consumed in combination, as 'eating occasions' or meals. The meal is the smallest unit of nutrition to which nutritional analysis is appropriate. Individual foods can be analysed in terms of nutrient composition, but this is the realm of food science rather than nutrition. Nutrients usefully contribute biologically after they are consumed, as long as they are adequately separated by digestion, digested, and absorbed. The nutrients must be 'available'. Some are partly metabolized within the bowel, or only partially absorbed, so are less than 100% available. Some foods contain non-nutrient components, such as particles of grit in stone-ground grains, that are not absorbed. Some components, such as inert metals from the soil, are absorbed but serve no function and are excreted unchanged. Some nutrients are not absorbed, but still have a function (e.g. most dietary fibre, which provides an energy source for bowel microbiota). There are more bacterial cells in the gut than there are human cells in the body, and they generate waste products, such as volatile fatty acids, which are valuable to gut health and absorbed as an energy source for humans.

Nutrients that contribute energy (calories) are known as macronutrients: fats, proteins and carbohydrates (including dietary fibre). All are composed of just carbon, oxygen, hydrogen and small amounts of nitrogen. Some of the molecules in each of these nutrient categories have other functions (Table 1). A very small number of organic molecules present in certain foods are 'essential', which means that they are necessary for biological function but cannot be synthesized by human biochemistry from other compounds. As a broad generalization, the 'essential' nutrients are ones that evolution has allowed to be un-synthesizable, because they are widely available in our evolutionary diets. These comprise the essential amino acids and fatty acids necessary to construct all the lipid and protein molecules needed in a fully functional healthy body, and the vitamins, first discovered in the early 20th century and required from foods in tiny amounts. There are technically no 'essential' dietary carbohydrate molecules, although dietary fibre is necessary for normal bowel function, and soluble dietary fibre (e.g. from legumes) has an important modifying function on metabolic processes that affect carbohydrate and lipid metabolism. The brain oxidizes almost exclusively glucose, which is usually derived from dietary carbohydrates but can theoretically come from protein and glycerol. Given time to adapt, the brain can also oxidize ketone bodies if glucose is unavailable, but sudden hypoglycaemia can be fatal. Without essential fatty acids, amino acids or vitamins in the diet, classical deficiency

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Energy contents of macronutrients

	Energy (kcal/g)
Fat	9
Protein	4
Carbohydrate	3.75
Dietary fibre	2–3

Table 1

states develop. In addition to vitamins, a relatively large number of essential trace elements, required from foods, serve as co-factors for the enzyme functions of specific proteins. An insufficiency of trace elements in the diet also leads to classical deficiency states (Figure 1 and Table 2).[1]

Vitamins and trace elements are examples of functional food components, known as 'micronutrients' (see Micronutrient deficiencies, vitamin pills and nutritional supplements on pages 66-72 of this issue). Adding them as fortified foods or as supplements will provide benefit for individuals who are deficient,

The elements of nutrition – 'building blocks'

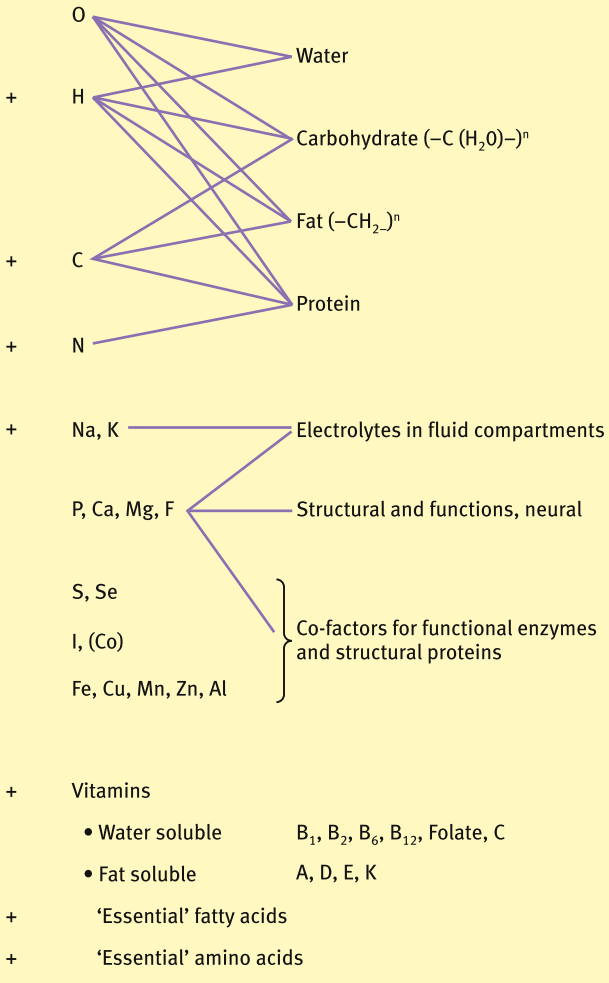

Figure 1

or replenish stores if they are low. There is no benefit from the excessive supply of micronutrients, and storage capacity does not need to be completely occupied. Moreover, excessive consumption of certain micronutrients can interfere with the absorption of others. For example, iron and zinc share a transport mechanism for absorption, and excess of one can compromise absorption of the other. Only some micronutrients are stored in the body: those that are stored can be provided intermittently, but where there is little storage capacity for a micronutrient, it must be consumed daily (Table 2).

All organic compounds from foods are ultimately either excreted intact (a minority) or metabolized and converted to fuels for oxidation. A variety of non-essential functional compounds in foods also contribute to health. These are sometimes not classified as nutrients but are ultimately metabolized and oxidized. Examples include the non-pro-vitamin A carotenoids (e.g. lutein, lycopene), the large family of phenolic compounds with antioxidant and other functions, and caffeine. Some of these act in the same way as drugs to modify cellular biochemistry; indeed, caffeine is used as a prescription drug as well as a component of coffee and other beverages. The boundary between definitions and the trade regulation of foods and drugs is sometimes ill defined.

Some foods contain toxic compounds, either as natural components of the food source, or from bacterial or other contaminants. Sodium, as salt, is required in only tiny amounts, and in the amounts usually consumed in Western diets it increases blood pressure and the risk of cardiovascular disease (CVD). Cooking or food processing can alter compounds in foods and cause them to become harmful: for example, browning of certain foods during baking forms advanced glycation end-products and carcinogenic acrylamide, barbecuing creates carcinogenic cyclic amines, and nitrite treatment to preserve meat forms carcinogenic nitrosamines.

Finally, food is not just a source of nutrients, but a source of pleasure and social cohesion. It forms the largest sector in the commercial economy and consumes budgets greater than those allocated to defence or transport. Being central to population health, foods and nutrition are important to health promotion. However, the scale of the food industry, and pursuit of profit, in a market economy, place constraints on the industry and on governments when changes are urged. Nutrition has few dramatic or rapid effects on health except through starvation. The only real nutritional emergency in clinical medicine is thiamine deficiency, most often seen in alcoholics who will develop Wernicke's encephalopathy, which can cause permanent brain damage if not treated immediately. The consequences of suboptimal diet composition for disease causation are slow to develop, difficult to attribute in individual patients and easy to ignore, but the cumulative impact of diet composition on the health of communities is very large. In seeking ways to exploit this impact, 'dietary advice' and health promotion are likely to benefit only highly literate, educated and health-aware sectors of the population. To improve the health of the most vulnerable, more socially deprived sectors, small changes in the composition of foods and meals supplied by industry and eaten regularly by large numbers of people would be effective, and everyone else's health would also improve, but current governments are reluctant to act.

When unusual toxic compounds are discovered in food groups (e.g. the recent identification of acrylamide in baked and